

Annex H

Report of the Sub-Committee on Other Southern Hemisphere Whale Stocks (SH)

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1. INTRODUCTORY ITEMS

1.1 Opening Remarks

Zerbini welcomed participants.

1.2 Election of Chair

Zerbini was elected Chair. He noted that the sub-committee would have six sessions in which to complete its work.

1.3 Appointment of Rapporteurs

Jackson and Branch undertook the duties of rapporteuring.

1.4 Adoption of Agenda

The adopted Agenda is given in Appendix 1.

1.5 Documents Available

Documents identified as containing information relevant to the sub-committee included: SC/58/SH1-46, O4, O12, O14, Branch *et al.*, 2007a, submitted; Acevedo *et al.*, 2007, LeDuc *et al.*, 2007, Dalla Rosa *et al.*, 2008, Branch and Mikhalev, accepted).

2. IN-DEPTH ASSESSMENT OF SOUTHERN HEMISPHERE HUMPBACK WHALES

2.1 General Information

SC/60/SH4 described a non-lethal method for estimating ages of humpback whales from measurements of specific fatty acids present in their outer blubber layer. The ability to age individual humpback whales and to estimate population age distributions is critical to accurate assessments of their status and long-term viability. Outer-blubber samples were obtained from known-age whales from two distinct populations (North Atlantic, Gulf of Maine, $n=39$) and (North Pacific, Southeast Alaska, $n=17$) and analysed for their fatty acid compositions. Approximately one-half of the known-age whales from each population had "exact" ages and one-half had "minimum" ages. Multilinear fatty acid/age models were then derived for these known-age whales and used to estimate the ages of unknown-age whales. Four fatty acid-age models were developed for humpback whales, including one for the Gulf of Maine population, one for the Southeast Alaska population and an additional two that combined both populations into a single dataset and derived models based on (1) "exact" age whales and (2) "exact" plus "minimum" age whales. Each of these empirical models was based on a linear combination of fatty acid ratios (two specific fatty acid ratios per model) and each model appears to be largely independent of sex, diet and nutritional status. Results suggested that the ages of individual humpback whales could be estimated with better than decadal resolution using this approach. Moreover, it is conceivable that, when fatty acid data from additional known-age humpback whales from other populations are combined with the current data, a single updated fatty acid-age model can be derived allowing humpback whale ages to be estimated over broader areas of the world. Finally, the authors believe that in addition to humpback whales and killer whales (SC/59/SM3), this fatty acid ageing method can be extended to additional cetacean species (e.g., bowhead whales and belugas).

The sub-committee welcomed this interesting and informative work. In discussion, it was observed that no explanation for the mechanism behind the relationship between fatty acids and age has yet been identified. It was further proposed that if fatty acids from biopsy samples obtained many years previously could still be accurately measured then this could provide substantial additional information regarding animals with long re-sight and movement histories (such as those described in SC/60/O14).

SC/60/SH30 presented a review of recent data on life-history parameters influencing rates of population growth in humpback whales, including survival, age at first parturition and calving rate. Monte Carlo simulations are used to compute a distribution of rates of increase (ROI) taking into account uncertainty in biological parameters. Two approaches (A and B) for computing juvenile survival are proposed, resulting in the following estimates of ROI: Approach A: 7.1% yr⁻¹ (90% CI=5.3-8.9% yr⁻¹, 95% CI=5.0-9.3% yr⁻¹ and 99% CI=4.3-9.9% yr⁻¹), Approach B: 8.5%/year (90% CI=6.4-10.3% yr⁻¹, 95% CI=6.1-10.6% yr⁻¹, and 99% CI=5.3-11.2% yr⁻¹). It is proposed that the upper 90% CI (10.3% yr⁻¹) be established as an upper bound on possible ROI for humpback whales. This is equivalent to the 95% quantile in a one-sided distribution and therefore there is only a 5% probability that this bound is greater than the proposed value. Possible sources of positive and negative biases in the present estimates are discussed, but it is difficult to evaluate them without additional data.

In discussion, it was noted that the recommended upper bound on growth rates excludes the population increase rates for humpbacks estimated from survey data and reported in SC/60/SH31. It was also noted that most of the life history parameters used in this model are estimated from Northern Hemisphere humpbacks, which may have different life histories from their Southern Hemisphere counterparts. It was also cautioned that normally distributed adult survival rates, such as those used in the model, could have an upper tail encompassing non-plausible survival rates. In response to a

comment that right whales should not be considered 'very long-lived', it was pointed out that individuals over 65 years old were found in the North Atlantic Ocean.

The Chair noted that a similar paper on growth rates of blue whales was available (SC/60/SH8) and appointed a Working Group to discuss an upper bound on plausible rates of population increase in large whales. The terms of reference for this group were: (1) to examine the approach used to compute population growth rates in SC/60/SH8 and SC/60/SH30; (2) to discuss which choice of percentile presented in these papers is appropriate to as the upper bound. The conclusions of this group are reported in Appendix 2.

2.2 Stock structure in the feeding grounds

SC/60SH11 presents an update of a previous assessment of genetic structure of humpback whales in the Southern Ocean feeding grounds (SC/59/SH24), and their connectivity with breeding stock (BS) A, B, and C (Annex E, SC/58/Rep5) under multiple scenarios, using the Naïve and three variants of the Core-Fringe catch allocation models. This study includes 376 samples representing all major feeding grounds collected by the IDCR/SOWER program (through the 2005/2006 cruise), the SOGLOBEC program, and the Chilean Antarctic Program, and 1489 samples from BSA, BSB, and BSC (Rosenbaum *et al.*, 2008). Samples from feeding grounds were allocated to different longitudinal ranges (feeding area), according to each model, and mtDNA structure was examined using F_{ST} and Ph_{IST} fixation indices, as well as the Exact Test of Population Differentiation. In comparisons between feeding areas, all models showed significant differentiation of feeding areas associated to BSF and BSG from any other feeding areas, whereas no differentiation was detected between feeding areas associated to BSB and BSC, and between feeding areas associated to BSC and BSD. Lack of genetic structure between adjacent feeding areas associated with BSB and BSC and BSC and BSD may reflect interchange of breeding stocks on the feeding areas, as well as poorly understood migratory processes occurring between breeding and feeding stocks across the regions. In comparisons between feeding areas and BSA, BSB and BSC, under all models: 1) Feeding areas associated to BSF and BSG showed significant differentiation from BSA, BSB and BSC2). Feeding area associated to BSB showed significant differentiation from breeding sub-stocks B1, C2 and C3, but not from breeding sub-stocks B2 and C1). Feeding area associated to BSC was significantly different from BSA and BSB, but not from BSC. Also, all models found feeding area associated to BSD significantly different from BSB, whereas only the Naïve model revealed significant differentiation between feeding area associated to BSD and BSC. These data are highly consistent with the comparisons between feeding areas alone. It was found that, due to small and spatially clustered sampling, statistical significance decreases as feeding areas allocating putative populations become smaller. Because sampling in these areas is and has largely been driven by the SOWER cruise priorities, the focus has not been Southern Hemisphere humpback whales, resulting in a sub-optimal sampling strategy for testing the validity of alternative allocation models.

The sub-committee thanked the authors for the presentation of this work in response to an item in the work plan from SC59. Discussion of feeding ground stock structure in regards to catch allocation is taken further under item 2.4.2.

A working group was appointed to discuss the assessment of breeding stocks B and C. The terms of reference of this group were to review and discuss information pertaining to: (1) population structure and interchange rates across regions; (2) abundance estimates; (3) catch history and allocation; and (4) population assessment models. This group was asked to provide recommendations for new model runs, if applicable, and for future work. A summary of discussions and conclusions of the Working Group are provided below, in items 2.3 and 2.4.

2.3 Breeding Stock B

2.3.1 Distribution, movements and population structure

The sub-committee noted that currently the only known breeding area in BSB is centred on Gabon (sub-stock B1). An additional stock off South-West Africa is called sub-stock B2. The remainder of the south-west African region outside from Gabon (hitherto referred to as breeding sub-stock BX) may contain one or more additional breeding stocks. In further discussion, the sub-committee agreed that sub-stock B2 should be considered as two arbitrary sub-regions; B2 south (B2S; to the south of 16°S) and B2 north (B2N; to the north of 16°S). All available data from region B2 (genetic and photo-identification surveys and catch data) has been collected in the region B2S off the Western Cape, South Africa.

MtDNA analyses of Southern Hemisphere breeding stocks and feeding areas (reported in above, item 2.2) detected no maternal differentiation between feeding Areas associated to BSB and BSC, and between feeding areas associated to BSC and BSD (SC/60/SH11). This may reflect interchange of breeding stocks on the feeding areas, or poorly understood migratory processes occurring between breeding and feeding stocks across the regions. The feeding area associated with BSB (20°W–10°E) showed significant differentiation from breeding sub-stocks B1, C2 and C3, but not from breeding sub-stocks B2 and C1.

SC/60/SH44 presented a preliminary analysis of temporal variation in mtDNA diversity of humpback whales from Gabon (sub-stock B1) and west south Africa (region B2S). A preliminary approach was presented to test for temporal structure and population differentiation in mitochondrial DNA lineages of 1,043 humpback whales biopsied off Gabon and the west coast of South Africa. The sequence data were partitioned by season, in that for Gabon, the samples were stratified by early season (July and August) and late season (September and October). For west South Africa the samples were stratified by winter (July - October) and summer (November - February). Given these partitions, the entire winter season sample from west South Africa corresponds to the temporal sampling in Gabon. The results showed significant genetic differentiation based on haplotype frequencies (F_{ST}) for comparisons between Gabon and West South Africa using all types of seasonal partitions, showing that some population structure exists between these regions.

SC/60/SH44 also investigated sex ratios between sub-stock B1 and region B2S. In Gabon, the sex ratio is highly biased toward males, specially late in the season (2.9M:1F). This could be explained by sampling bias (in that large competitive groups are easier to detect), group structure segregation (in that not all females migrate to breeding areas each year (Chittleborough, 1965; Dawbin, 1997; Brown *et al.*, 1995) or by some geographical structure in the Gulf of Guinea breeding area where some groups of animals (like mother-calves or pregnant females) may exhibit spatial preferences. Conversely, the sex ratio on the west coast of South Africa (0.7M:1F – winter and 0.8M: 1F – summer) is much more like that of a feeding area, which is typically biased toward females (Mackintosh, 1942; Brown *et al.*, 1995). Females biopsy-sampled in early (July - August) and late season (September - October) in Gabon were also significantly different from one another based on F_{ST} statistics. The results presented seem to indicate that there is some temporal population substructure for humpback whales in B stock. However a higher degree of resolution is needed to differentiate animals from B1 and B2 regions, and clarify the population structure in this area. Analyses with multiple markers and multiple statistical approaches will be used in the future.

In discussions of region B2S (west South Africa), it was noted that there are very few observations of singing and escort activity, but that incidences of feeding has been observed, and that water temperatures are colder than those of breeding grounds in other areas (see Rasmussen *et al.*, 2007). The group concluded that this region is likely a migratory / transit corridor with some potential for feeding.

In terms of population subdivision between sub-stock B1 and region B2S, evidence for connections is provided by a small number of between-region genotypic recaptures (Pomilla *et al.*, 2006). However, available mtDNA data suggests that there is significant genetic differentiation between regions B1 and B2S (Rosenbaum *et al.*, 2006). In view of this, it was observed that there may be offshore migratory streams associated with region B1, that are not captured in region B2S photo-identification and genetic coastal sampling surveys. An oceanographic feature (the Angola / Benguela front) occurs between regions B1 and B2N and may influence interchange between these areas. The geographic borders of BSB need further consideration, especially the potential separation zones between sub-stocks B1 and B2, and between regions B2N and B2S. Currently sub-stock B1 is considered equivalent to Gabon plus possibly Cabinda, while the Angola/Benguela Current front (at about 16°S) is considered a possible environmental “delimiting factor” to humpback migration up the west coast. Whether the boundary between regions B1/B2 should be shifted south to this frontal zone, or whether the zone represents a division between regions B2N and B2S, or whether there is in reality a cline rather than a latitudinal boundary, is unclear. In view of this, the sub-committee recommended a compilation of all available information that might clarify the stock identity within BSB, to be presented at the next year’s meeting.

The group agreed that the data are consistent with sub-stock B2 containing a mixture of animals from sub-stock B1 and one or more other breeding stocks.

Sex-based differences in capture probability between regions were discussed. It was suggested that genotype capturing of males may be upwardly biased in sub-stock B1 by frequent biopsy samplings of competitive groups, which usually contain one female and multiple males. It was further noted that high captures of females in region B2S during the summer may reflect the inshore movement of cow-calf pairs on migration and the biopsy sampling of both mother and calf during an encounter which, calves having an equal probability of being male or female, would lead to >75% females sampled.

The group recommended

- (1) Analyses of photographic and genotypic recaptures and other biases between region B2S and sub-stock B1 using a subset of sampling related to catch histories; and animals that have a higher recapture rate.
- (2) Sex biases in photographic and genetic sampling are explored in order to evaluate the bias on population estimates
- (3) Analysis and inspection of genotype error rates, followed by reanalysis of abundance estimates
- (4) Collection of genetic and photo-identification data from region B2N
- (5) Perform mixture modelling to identify the proportion of animals from Antarctic feeding areas and region B2S that could be allocated to sub-stock B1 and neighbouring stocks.

2.3.2 Abundance and trends

SC/60/SH28 presented a population abundance estimate of sub-stock B1 using capture-recapture analysis of fluke photographs and genetic multi-locus genotypes for whales utilising coastal waters of Gabon between 2001 and 2006. Fluke recaptures were few and recapture probability was low. Genetic recaptures were more numerous, but recapture probabilities remained low. Small yearly photographic sample sizes for the apparent size of the population indicate low capture probabilities, resulting in poor precision. This problem may be compounded when sampling periods do not strictly overlap, or when individuals display non-random movement, introducing potential negative biases simply because animals are unavailable. Estimates generated using combined data from all sites and all years were considered unreliable due to evident closure violations, inconsistent effort and suspected within-Gabon site preferences for individual whales (not yet assessed). Photo-identification estimates of abundance are generally smaller than equivalent estimates for genotypes, which may reflect larger genotypic sample sizes but may also indicate sex bias in capture probability for flukes. Additional verification of genotypes is required to remove false negatives due to genotyping errors, a risk with a large dataset. A combination of the MARK genotypic results were proposed to define some conservative lower and upper bounds for estimates of population size. Data tested in MARK are limited to Iguela for 2001-2004 (6560; CV=0.15) and 2001-2005 (8163; CV=0.12). Genotypic results are preferred given larger sample sizes, less reliance on individual specific behaviours and more recaptures. The MARK estimates also allow for some heterogeneity in capture probability and may account for our inconsistent sampling effort. Larger estimates may be more representative for the B1 region (or even B) as a whole but the absence of sampling elsewhere makes these unreliable and caution is clearly advised if the estimates are presumed to be more representative of sub-stock B1 (or even B1/B2) as a whole.

In discussion, it was noted that both effort and survey times varied substantially between years, possibly causing heterogeneity of captures if an age/sex structured migration stream is being sampled. It was noted that the abundance estimates were sensitive both to model choice and the years surveyed. For example, photographic and genetic surveys both obtained unusually low numbers of between-year recaptures in 2004/2005 and both sets of data were highly sensitive to inclusion or exclusion of this year in the capture-recapture model. Sex ratio biases (as discussed in 2.3.1) may also downwardly bias abundance.

SC/60/SH40 presented maximum likelihood and Bayesian approaches to estimating parameters of a simple exponential growth model for the humpback whales of breeding sub-stock B1 from photo-ID and genotypic capture-recapture data for all observation sites combined and for Iguela only. The maximum likelihood estimates are generally rather imprecise, and some estimates for the annual growth rate r are demographically unrealistic. Bayesian results, for which a prior restricts its r to a demographically plausible range of [0; 0.106], are more reliable and suggest a population of size 7600 (95% Probability Interval [PI]: 6600-8800) in 2003, with r at 8.5% (95% PI: 3.7%-10.4%). These results were, however, intended primarily as illustrative of the methodologies, and to facilitate further discussion and model refinement. This would need, *inter alia*, to consider the appropriateness of aggregating data from different sites.

There was some discussion regarding rates of interchange among sites sampled in sub-stock B1 (Iguela and Mayumba). It was noted that observed resightings among sites could be used to estimate levels of site-fidelity of individuals and comparisons with expectations of sub-stock B1 abundance

under panmixia. However, some members queried whether such models would be useful given the strong likelihood of complete inter-mixing over such a small geographic area.

The sub-committee noted that it would be very interesting to see within and between-year resighting rates among sites within sub-stock B1 and recommended that this be presented at the next year's meeting. However, it was observed that there is only one year in which both sites have been surveyed, which restricts a detailed exploration of within year interchange.

2.3.3 Assessment models

SC/60/SH41 summarised updated Bayesian stock assessment results for humpback breeding sub-stock B1, which take into account recently advised capture-recapture data (SC/60/SH28). These suggest this population presently to be within the range of 65-90% of its pre-exploitation size in terms of posterior median estimates. A comparison of population assessments was provided by exploring the impact of including all sites or considering Iguela only. However, these results were preliminary and alternate options for input to these assessments were possible and needed to be discussed by the Scientific Committee.

Shortage of time prevented the full evaluation of the preliminary results in this paper. Some recommendations for the future are as follows:

- (1) The effects of 19th century whaling of humpback whales including possible sex selectivity should be investigated. The question of sub-divisions of breeding stocks still needs to be considered more carefully, and the degree to which historical catches should be sub-divided.
- (2) It was further noted that the degree to which Angolan catches need to be included in the assessments needs to be evaluated.
- (3) Choice of an informative prior on growth rate was discussed, given the absence of trend data from this region. The posterior distribution obtained from a previous population assessment of Breeding Stock A was applied. The group agreed that this posterior was an appropriate prior to use for sub-stock B1.
- (4) The group recommended not using the IDCR/SOWER abundance estimates as they did not extend far enough north to include the most of the feeding ground allocated to sub-stock B1, they may not be representative of a population trend for this sub-stock. These trend data in any case had limited impact due to the high CVs on abundance estimates.
- (5) It was also noted that integration of capture-recapture data within the population assessment model is a more statistically inclusive approach than secondarily incorporating abundance estimates from independent capture-recapture studies.
- (6) Alternative population dynamic models were briefly discussed, including models with depensation incorporated. However it was noted that the minimum past abundances estimated for sub-stock B1 are substantially larger than estimated N_{min} , suggesting that a model incorporating depensation is not likely to constitute an improvement in fit to the data over the model presented.

Since BSB and BSC share feeding grounds, future population assessments which encompass possible mixing of both stocks and allocate catch more inclusively between regions would be welcomed. The group recognised that only a limited amount of time was spent discussing breeding stock B compared to breeding stock C and agreed to review the results of preliminary assessments and any new information at next year's meeting.

2.4 Breeding Stock C

2.4.1 Distribution and population structure

The working group revisited information presented during the Southern Hemisphere Humpback Whale Comprehensive Assessment in Hobart (IWC, 2006), which divided BSC into sub-stocks C1 (further subdivided into regions C1S and C1N), C2, C3 and C4 (Fig. 1). The sub-committee agreed last year (IWC, 2008) that since sub-stock C2 is data-deficient and previous genetic work suggests that it is not significantly differentiated from sub-stock C3, both sub-stocks (C2 and C3) should be considered as one stock for the purposes of the assessment. No information was available for sub-stock C4 prior to this meeting.

The group discussed the basis for the subdivision of BSC. It was noted that mitochondrial and microsatellite DNA sequences were obtained from individuals biopsy sampled in each of the regions C1S (east South Africa and Mozambique), sub-stock C2 (Mayotte) and sub-stock C3 (Antongil Bay). Pair-wise F_{ST} comparisons between region C1S and sub-stock C3 (0.0030 / 0.0019) and region C1S and sub-stock C2 (0.0055/ 0.0048) found significant differences ($p < 0.05$) for mitochondrial and microsatellite data respectively. No genetic data were available from C1N or C4.

In discussing the genetic differentiation of stocks using F_{ST} , three points were noted:

- (1) With very large population sizes ($N > 5,000$) significant ($p < 0.05$) F_{ST} values are likely to reflect demographic independence (Waples and Gaggiotti, 2006). However, F_{ST} estimates assume genetic equilibrium among populations, which may be violated by recent exploitation. This may cause a temporary increase in estimated F_{ST} s (differentiation) between populations. Estimated migration rates arising from $F_{ST} = 0.005$ are of the order of $5-25N^{-1}yr^{-1}$ (N refers to population size), suggesting migration rates of $<1\% yr^{-1}$. This assumes a generation length of 20 years. Estimated migration would be lower for species with longer generation lengths, and vice-versa. The utility of these estimates in interpreting mark recapture estimates of abundance and amounts of interchange is dependent on assumptions about visitors versus current and ongoing gene flow.
- (2) F_{ST} values have associated confidence intervals that might include zero, in which case there is no statistically significant evidence for differentiation.

- (3) Given that each individual has a low probability of reproductive success, individuals moving between regions have a low probability of contributing genetically to those regions by producing offspring. Therefore genetic estimates of effective migrants by way of F_{ST} s might underestimate demographic exchange.

The group noted that the long-term number of effective migrants reported in Pomilla *et al.* (2006) and Rosenbaum *et al.* (2006) were not inconsistent with the reported F_{ST} values.

It was observed that, in addition to the genetic estimates, there were temporal differences in catches between sub-stocks C1 and C3, suggesting relative demographic independence between these stocks. The group agreed that these observations were compelling for the hypothesis of two stocks, but it was unclear how strong the genetic evidence was for stock structuring. For this reason, it was also agreed that the assessment should account for some degree of population overlap, which would therefore be compatible with the small sizes of the F_{ST} estimates reported.

Further discussion was held on the 'non-genetic' rationale for the divisions in the structure put forward in the workshop in Hobart (IWC, 2006), including catch histories, and oceanographic boundaries.

In response to a question regarding data available from sub-stock C4, it was noted that there are now photo-identification data available from C4 (including Isle la Réunion [2002-2007]; Mauritius [2006-2007]; and Rodrigues [2007]) which could help to inform some of the stock structure hypotheses outlined in Hobart. In this context, it was also noted that photo-identification data are available from C2 (Mayotte, Aldabra, the Seychelles and the Cormoros Islands). Photo-identification comparisons between these groups will be performed intersessionally. The sub-committee recommended that data that will contribute to a better understanding of the distribution and structure of BSC be collected.

2.4.2 Stock structure on the feeding grounds and catch allocation

Mitochondrial DNA analyses of southern hemisphere breeding stocks and feeding areas (SC/60/SH11 reported elsewhere in SC/60/Annex H) detected no maternal differentiation between feeding areas associated to BSB and BSC, and between feeding areas associated to BSC and BSD. This may reflect interchange of breeding stocks on the feeding areas, or poorly understood migratory processes occurring between breeding and feeding Stocks across the regions. The feeding area associated with BSB (20°W – 10°E) showed significant differentiation from breeding sub-stocks B1, C2 and C3, but not from sub-stocks B2 and C1. The feeding area associated with BSC was significantly different from BSA and BSB, but not from BSC. Also, all models found the feeding area associated with BSD to be significantly different from BSB, whereas only the Naïve model revealed significant differentiation between the feeding area associated with BSD and BSC.

In discussion, it was noted that previous assessments of humpback whales used the Naïve, Fringe and Overlap models (IWC, 1998) and that, for some stocks, new boundaries (named Core) were created (IWC, 2006). Changes in stock boundaries for some stocks have resulted in inconsistencies in the assignment of catches to longitudinal sectors of the Antarctic. For example, the Naïve model for BSC and BSD was originally proposed to lie between 10°E-60°E and 60°E-110°E, respectively. Boundaries for BSD were changed to a core area (80-100°E), so that a sector of 20° between 60°E and 80°E were not being considered within the Naïve model. It was also noted that there was no fringe region between the feeding areas associated with BSB and BSC. Additionally, the group discussed potential mixing across the longitudinally defined border BSB and BSC feeding grounds (at 10°E). The northerly positions of Soviet catches on the feeding grounds south of BSB may suggest some latitudinal structure near this border. The known westward limit of the sub-stock C3 feeding ground was defined by a Discovery mark linking sub-stock C3 and 10-11°E (IWC 1998).

It was also noted that two inter-oceanic genotypic matches have been made between sub-stock B1 and C3, one juvenile (Pomilla and Rosenbaum, 2005) and an adult male (Loo *et al.*, unpublished), indicating exchange between populations in western and eastern Africa. A genetic haplotype assignment test was suggested to estimate stock mixing, wherein Antarctic 'mixed' genetic data (partitioned into longitudinal sections) is fitted to 'pure' breeding stock data in sub-stocks B1, B2 and C1, C2 and C3. This could be performed in a variety of frameworks. This would improve catch allocation because the proportion of each breeding stock in the feeding grounds would be more accurately described.

The group further recommended that the haplotype assignment model be utilised to determine appropriate boundaries between adjacent feeding areas in these regions.

2.4.3 Abundance and trend estimates

SC/60/SH32 reports estimates of abundance for sub-stock C3 using identification photographs of tail flukes and multi-locus microsatellite genotypes collected in Antongil Bay from 2000-2006. Recaptures were generally sparse, and capture probability low. The primary concerns affecting accuracy of these estimates are heterogeneity of capture probability introduced by the consistent timing of capture of individuals, the small sample size relative to population size (low probability of capture), and the potential for positive bias due to using closed capture models. In addition the photographic and genetic datasets gave very different estimates for some sets of years, with genetic estimates possibly biased positively due to genotyping error. As a "lower best" estimate, the photographic Chapman's 2005-2006 estimate of 4610, CV=0.39 was recommended, because this estimate should be the least affected by closure assumption violations and is most conservative. As a "best" estimate, the Closed Capture M_t model estimate from 2004-2006 photographic data of 6737, CV=0.31 was recommended, because this model incorporates more data and therefore is likely more representative of the population, while keeping closure violation at a minimum. As a "higher best" estimate, the 4-year estimate of 2003-2007 photographic data of 7715, CV=0.24 was chosen, with the understanding that with four years of data in a closed model there could be substantial positive bias.

In discussion of the genotype data used in the capture-recapture analysis, it was noted that some animals are represented within the both the genetic and photographic datasets but to an unknown extent, suggesting photo-identification and genotype data are not independent.

For this reason, the group agreed that only abundance estimates obtained from the photographic capture-recapture data should be discussed because the genotypic data still required further error-checking. Further, the following points were made:

- (1) Photo-identification surveys cover 90% of the time that humpbacks are present and are consistent between years.
- (2) There are a very low number of photographs collected in 2002 relative to other years.
- (3) Within-bay residency time appears to be very short.

- (4) A very small part of the breeding area sub-stock C3 is being sampled. Some members felt spatial structuring within the population makes it unlikely that every whale in sub-stock C3 has the same probability of visiting Antongil Bay at some time. In this case the capture-recapture estimate for sub-stock C3 from Antongil Bay will be downwardly biased.
- (5) Differences in the sex ratio could reflect different availability patterns in different regions, a bias in capture probabilities between sexes, or both (e.g. differential availability of flukes for capture). Such a bias may cause an underestimation of abundance.

In view of the low number of samples collected in 2002 the sub-committee agreed that this year would be excluded from final analysis.

Paper SC/60/SH37 (summary below) analysed sub-stock C3 photo-ID data within the framework of an exponential model of population growth, obtaining an estimated abundance for 2003 with Bayesian posterior median of 6,475 and 95% PI = 4,987; 8,677.

An estimate of 5,965 (CV=0.17) is available from a line transect survey of region C1S (Findlay *et al.*, in press). This estimate is negatively biased as it does not cover the full range of this region (C1S).

A number of sources of trend information were available from the migration corridor to the breeding grounds for sub-stock C1 (SC/60/SH38), including:

- (1) Two sets of relative abundance estimates from shore-based surveys at Cape Vidal described in Findlay and Best (2006) for the periods of 6-22 July and 6-30 July (1988-2002).
- (2) CPUE data available from the Durban whaling ground, covering the time periods 1910-1912 (Olsen 1914), 1920-1928, 1954-1963 (Best, 2003).
- (3) Two SPUE data sets available from Durban, covering the period 1954-1975 (Aircraft) and 1969-1975 (sightings from catcher vessels) (Best 2003).

It was agreed that the 6-22 July relative abundance estimates described in Findlay and Best (2006) should be used (these estimates have less associated variance than those reported for the 6-30 July period), and along with the aircraft SPUE data (1954-1975) be included in fitting the assessment model.

No trend data were available for sub-stock C3.

Trend data from the feeding grounds in Area III were available from the IDCR/SOWER survey estimates (1978-1993; Branch 2006).

2.4.4 Estimation of interchange between breeding grounds

SC/60/SH33 reported the use of individual identification photographs of humpback whales collected from breeding stocks from the east African mainland (sub-stock C1) and Madagascar (sub-stock C3) during the years 2000 to 2006 to assess the degree of exchange and overlap between these two sub-populations. East African mainland data were contributed by whale watch tourism operations and collected during research cruises, originating from several regions in South Africa and Mozambique, but primarily the former, and effort was largely inconsistent among years. Genetic and photo-identification data were collected on the breeding area of Antongil Bay, Madagascar during yearly research seasons, and effort was consistent across years with the exception of 2002. Very few recaptures across years were made in sub-stock C1, with only 6 of 21 pairs of years containing a recapture, and only one pair with two recaptures. In sub-stock C3, recaptures across years were also limited, but more abundant than in sub-stock C1 with number of recaptures per pair of years ranging from 0 to 4. Comparison of finalised catalogues from each region revealed two recaptures between sub-stocks C1 and C3. Of these, one match involved a poor quality photo from sub-stock C1, and thus was not included in the statistical analysis of exchange. Random permutation analysis indicated that there were no statistically significant deviations in observed number of recaptures from random expectations in any individual pair of years. However an overall test combining all years resulted in highly significant differences from the random distribution, indicating both greater than expected within-region recaptures and less than expected between-region recaptures. Photographic comparisons indicate that there is clearly some exchange between the two sub-stocks, C1 and C3. However, the data indicate that the structure is neither one of a single randomly mixing population, nor one of two distinct and non-overlapping breeding stocks. The data presented here is not considered to be sufficient or adequate to estimate a parameter of interchange, due to sparse recaptures, the inconsistency of temporal and geographic effort in sub-stock C1, and the observed temporal consistency of individual recaptures in sub-stock C3.

SC/60/SH37 reported initial results of a capture-recapture analysis of humpback population sizes and increase rates for sub-stocks C1 and C2+3. Both maximum likelihood and Bayesian methodologies are developed to analyse the photo-ID and genotypic capture-recapture data available for the C1 and C3 sub-stocks of humpback whales in the western Indian Ocean. A simple exponential growth population model is assumed, and estimates of annual growth rate and abundances determined. Maximum likelihood estimates of r are generally imprecise and often the point estimates are demographically infeasible. An interchange model is developed to take account of photo-ID information on exchanges between sub-stocks C1 and C3. The results show little difference between the combined abundances estimated for the two sub-stocks with such interchange, compared to the sum of results for the two analysed in isolation. The results presented were intended to be illustrative, not definitive, having the purpose of facilitating further runs and refinements of the models during Scientific Committee discussions.

The discussion of these two papers was taken together. In light of previous discussions regarding error checking in the genotype estimates (see Section 2.4.3), the group recommended that at present genotype estimates should not be included in the assessment of sub-stocks C1 and C3 until additional error-checking has been performed on these data, together with identification of matches common to genetic and photographic data. These will be presented at next year's meeting.

The model presented in SC/60/SH37 was discussed. It was agreed that while the analysis reported in this paper represents a good first step towards determining interchange and present trends, there are a number of issues needing further examination. Illustrative runs should be undertaken as an attempt to better understand the performance of this model. On review of these results, the group recommended that the model performance would best be addressed by undertaking simulation testing to determine whether the model provided appropriate results both in circumstances where interchange was taking place in the manner assumed by the model, and also for alternative representations of the underlying interchange process (e.g. whether interchange was of a permanent transfer nature rather than the "visitor" approach assumed in SC/60/SH37).

Noting the inclusion of both capture-recapture and line transect data available for sub-stock C1 in SC/60/SH37, two points were made:

- (1) Temporal and spatial differences between the line-transect and capture-recapture estimates provided for sub-stock C1 are substantial.
- (2) Some age and sex structuring of whales both during migration and arrival at breeding grounds [see Dawbin 1966] may be inadequately captured in the framework of the capture-recapture model.

The group agreed that estimation of abundance using the sub-stock C1 capture-recapture data would lead to highly imprecise estimates.

In discussion of the single recapture between sub-stocks C1 and C3 after putting pictures through quality control (SC/60/SH33, Table 2c), it was noted that given the low number of exchanges and recaptures in sub-stock C1, estimates of exchange rate would be poor.

Appendix 3 presented preliminary analysis using a multi-state likelihood live recapture model in MARK which indicated that exchange probabilities could range from 1% to 41% (both with all photos included and poor quality photos excluded). Estimates were robust to survival, both estimated as a parameter and fixed at 0.96 or 0.98. There was not sufficient time to discuss this analysis in detail. It was noted that the inclusion of poor quality photographs introduces heterogeneity and causes exchange rate estimate to be biased low and abundance estimation to be biased high. However, some members expressed reservations about this approach, noting that the capture-recapture estimate of exchange could be obtained more directly by implementation within the framework of the population model, and thus variance is reduced. The group agreed that even though this is a preliminary analysis the lower bound estimate of interchange could be used in assessment models.

There was some discussion as to the possibility of using migration rates from coalescent analysis as an alternative index of exchange between the two populations (e.g. Rosenbaum *et al.*, 2006). It was felt that such estimates represent long-term migration rates between populations on an evolutionary time-scale which falls outside the temporal scope of an assessment. However it was also noted that the F_{ST} estimates available for this population (both from female-inherited mtDNA and bi-parentally inherited microsatellites; Rosenbaum *et al.*, 2006) are very low, suggesting either recent common ancestry or some ongoing gene flow.

The group agreed that a scenario of "50% interchange" between sub-stocks C1 and C3 should be explored. Since the group agreed that a scenario of 100% interchange is implausible in light of the seasonally comparable line transect surveys in both regions (Findlay *et al.*, 1994, in press; Best *et al.*, 1996) and the low observed interchanges they agreed to explore an upper boundary scenario wherein 50% interchange between C1 and C3 was assumed. This boundary is substantially higher than the range reported in SC/60/SH37 and described in the multi-strata model above.

The group also agreed that a reasonable lower bound for interchange was 1%, which represents the lower bound of the exchange probabilities obtained from the multi-strata recapture model. For practical purposes the lower bound on interchange in exploratory results was zero. This makes minimal difference to the Bayesian posterior estimates from the population assessment model.

2.4.5 Assessment models

For assessment purposes, sub-stock C2 and C3 are considered to represent one combined stock (IWC, 2006).

SC/60/SH38 reported updated assessments of sub-stocks C1 and C2+3 of the Southern Hemisphere humpback whales. Bayesian stock assessment results for a mixed population model containing these sub-stocks were presented. The modelling approach allowed mixing on the feeding grounds and fits to various data sources, including capture-recapture data from both sub-stocks. A baseline case suggested posterior median 2006 abundances for each sub-stock of a little more than 7,000, with sub-stock C1 at about 85% and sub-stock C2+3 at about 55% of their pristine levels. These results were intended to be illustrative only, with the variety of choices available for the various model inputs requiring further discussion by the IWC Scientific Commission.

In light of the discussions above, a number of preliminary sensitivity analyses were conducted, taking into consideration the following:

- (1) Exclude capture-recapture data from sub-stock C1.
- (2) Overlap model of catch allocation with IDCR/SOWER catches excluded.
- (3) Growth rate r shared between sub-stocks C1 and C2+C3.
- (4) 50% interchange between sub-stocks C1 and C2+C3 (accomplished by reducing sub-stock C2+C3 abundance estimate by 50% along with adding 50% of sub-stock C2+C3 breeding ground catches allocated to sub-stock C1).
- (5) Extend catches on feeding grounds from 10-60°E to 10-80°E.

After consideration of the results of the various sensitivity analyses outlined above, it was decided that a final two analyses (RUN1 and RUN2) would be run. For both analyses, the following assumptions are made:

- (1) r priors: for sub-stock C1 $r \sim U[0; 0.106]$, for sub-stock C2+3 $r \sim r$ posterior from BSA.
- (2) Historic catches: Naive catch allocation.
- (3) Feeding ground catches (10°E-60°E) are split between sub-stocks C1 and C2+3 in proportion to abundance.
- (4) Recent abundance: sub-stock C1 – use Findlay *et al.* (in press) estimate of 5965 in 2003 and sub-stock C2+3 – None for RUN1.
- (5) Trend information: sub-stock C1 – use the Cape Vidal and aircraft SPUE data only (remove fitting to the 3 CPUE time series, the Olsen series, and the IDCR/SOWER series), sub-stock C2+C3 – no trend information for breeding grounds. Feeding grounds - remove the IDCR/SOWER data for the feeding ground.

- (6) Capture-recapture: sub-stock C1 – use photo-ID data from SC/60/SH33 but exclude years 2000 and 2004, sub-stock C2+3 – use photo-ID data from SC/60/SH32 but exclude 2002 data (removals are due to poor temporal coverage of capture effort).
- (7) For RUN2, sub-stock C2+3 photo-ID capture-recapture data is replaced with half the value of the SC/60/SH32 abundance estimate of 6737, i.e. 3,369 for 2006, and half the breeding ground catches from sub-stock C2+3 are removed and added to the C1 sub-stock catches.

In discussion of the final runs, it was noted that in RUN1 (Table 1, Figs. 2 and 3), the probability intervals of the predicted historical population trajectories were narrower for sub-stock C1 (Fig. 2a) and wider for sub-stock C2 + C3 (Fig. 3a). This occurs because trend information from indices of abundance are available for sub-stock C1, but not for sub-stock C2+C3.

The sub-committee decided that the scenario implemented in RUN1 represents a suitable initial upper boundary on the depletion levels of sub-stocks C1 and C2+C3. However the RUN2 scenario was considered implausible due to the substantial breeding ground catch asymmetry imposed on the two stocks. It was proposed that additional scenarios were explored to investigate the depletion levels of these populations as alternative lower boundaries, but the sub-committee could not decide what would be the appropriate allocation of catches for such analysis. In view of this, the sub-committee agreed that further modelling scenarios, encompassing alternative models of stock interchange and catch allocation, should be explored intersessionally. With respect to interchange, it was suggested that the results from the open capture recapture model presented in SC/60/SH37 be compared with other types of capture-recapture population models (e.g. those implemented in MARK) in order to address differences between the estimates obtained by these models and develop alternative models of interchange within a framework that incorporates both capture recapture and population dynamics. It was also agreed that population models which assume that density dependent effects relate to abundance levels on feeding rather than breeding grounds (as conventionally assumed) should be explored.

Butterworth and Best expressed their disappointment with the decision not to proceed to add results for an initial lower boundary to those for an initial upper boundary for the assessment. In their view, the logic underlying the sub-committee's deliberations had throughout been to move to the development and report of such initial boundaries for the assessment results. The process for this had been developed and decided by the sub-committee. They had difficulty understanding why it should then not be taken to conclusion, particularly when all that was required for this was a single further model run to make the obvious correction required to adjust an error in implementing RUN2 to provide the intended lower boundary.

2.5 Other Breeding Stocks

2.5.1 *Distribution, movements and population structure*

SC/60/SH20 described the movement patterns of humpback whales between wintering and feeding grounds of the eastern south Pacific. Historic summer feeding and winter breeding grounds of the eastern South Pacific population of humpback whales are related to the west side of the Antarctic Peninsula and Ecuador and Colombia, respectively. In this study the movement of humpback whales in this ocean basin is based on analyses of photo-identification material collected in two feeding areas (the Magellan Straits and the Antarctic Peninsula) and three wintering geographic regions (Ecuador, Colombia and Panama/Costa Rica). A total of 2,945 photographs was examined, and a total of 142 whales matches was found between Antarctic Peninsula and wintering sampling areas from Ecuador to Costa Rica. In the case of the Magellan Strait the number of whales matched with wintering grounds was 14. The proportion of whales from three breeding region re-sighted in the two feeding areas were significantly different for both the Antarctic Peninsula and Magellan Strait. The significantly high proportion of re-sighted whales from Antarctic Peninsula is linked mainly with Colombia, while whales of the Magellan Strait feeding areas showed a significantly high link to Central America. A Movement Index showed humpback whales from Magellan Strait to have a preferential movement to the northernmost winter region, while the individuals that feed in the Antarctic Peninsula migrate to different wintering ground locations.

SC/60/SH27 described humpback whale migrations on feeding grounds of the eastern south Pacific. The eastern south Pacific humpback whale population (wintering primarily off Colombia and Ecuador and ranging as far north as Panama and Costa Rica), migrate south to the Magellan Strait and Antarctic Area I feeding ground during the austral summer. In recent years humpback whales have been recorded feeding in Corcovado Gulf and Northern Patagonian channels of Chile, during the summer and fall seasons. This study investigated the relationships between humpback whales of the Corcovado Gulf and those of Magellan Strait and Antarctic Peninsula. Catalogue comparisons of 1,043 individuals from the Antarctic Peninsula, 92 from the Magellan Strait and 17 from Corcovado Gulf were undertaken. No matches were found between the Magellan Strait and the Antarctic Peninsula, suggesting that both areas represent separate feeding migratory destinations. The fact that no matches were found among the Corcovado Gulf, Magellan Strait or Antarctic Peninsula, suggests that Corcovado Gulf to be an alternative summer migratory destinations for at least some of the humpback whales of eastern south Pacific population. However, these suggestions should be considered preliminary due the small sample size in the Corcovado Gulf.

SC/60/SH26 presents preliminary results of humpback whale sightings collected by Centro de Conservación Cetacea (CCC) off northwestern Isla de Chiloe. Between February and April 2006 to 2008 46 marine surveys observed 30 groups of humpbacks composed of 52 animals, including four calves. In four aerial surveys, six groups composed of seven animals were recorded. Feeding behaviour and faeces were recorded in all years. Photo-identification resulted in 22 individuals catalogued by fluke pattern (not including calves). Seven individuals (31%) were re-sighted during the same season with time between re-sightings varying from 2 to 20 days. To date, no between-year recaptures have been documented off Isla de Chiloe. Comparisons between the Antarctic Humpback Whale Catalogue and these catalogues up to 2007 found no matches. However, preliminary comparisons with the WhaleSound/ Fundación Yubarta catalogue (Colombia and Straits of Magellan) results in at least one match, in that a mother-calf pair photo-identified off northwestern Isla de Chiloé on 8 February 2008 was re-sighted in the Straits of Magellan on 18 and 23 March 2008. The low density of humpback whales off Isla de Chiloé and the first evidence of interchange between Isla de Chiloe and the straits of Magellan (approximately 700 nm) strengthen the hypothesis that the area north of Isla de Chiloe represents the northern-most limit of the humpback whale feeding ground in Chilean Patagonian fjords. While there is no evidence of exchange between the Straits of Magellan feeding ground and the Antarctic Peninsula, our new evidence of a mid-latitude feeding ground off southern Chile suggests that consideration should be given to subdividing the BSG.

In response to a query as to the extent of catalogue comparison performed, the authors explained that 92 individuals from the WhaleSound/ Fundación Yubarta catalogue (Strait of Magellan) and 22 individuals from CCC were compared and that further comparison between catalogues is ongoing. On a note of clarification, the authors observed that their recommendation of sub-division of BSG pertains to the feeding grounds associated with this region.

SC/60/SH22 reports the results of a photo-identification study of Southeastern Pacific humpback whales carried out off the coast of the Ecuadorian mainland (01°S, 80°W) between 1996 and 2007. During this 11 year period, 1,172 whales were identified. A total of 79 (6.74%) whales were resighted between years in Ecuador, and the longest span between capture and recapture was 10 years. Eighty-two individually identified humpback whales (6.99%) were resighted within the same year. The maximum period between first and last recapture within a season was 98 days, while the minimum was one day.

SC/60/SH23 describes the results of a comparison of an Ecuadorian photo-identification catalogue with catalogues from Costa Rica, Panama, Colombia, Peru and the Antarctic Peninsula and Magellan Straits. Sixty individuals were matched between Ecuador and the southern regions (56 from the Antarctic Peninsula and 4 from the Magellan Strait) while 11 individuals matched with Colombia, and 4 with Costa Rica. Minimum sighting time between breeding and feeding grounds was 176 days. One whale has a re-sight record from Colombia and Ecuador spanning 20 years.

The reports above were welcomed by the sub-committee as they address recommendations made by the Scientific Committee in previous years. In discussion, it was noted that these studies supported the hypothesis that some humpback whales from BSG are feeding in (1) the region between Corcovado Gulf and Chiloé Islands and the Magellan Strait, and (2) the Antarctic Peninsula. It was further noted that humpback whales feeding near Corcovado Gulf and Chiloé Islands have been consistently seen since 2005 (Galletti Vernazzani *et al.*, 2007; Huckle-Gaete *et al.*, 2007). The sub-committee was also informed that genetic studies suggest that diversity in the Magellan Strait is low in comparison to the Antarctic Peninsula and that there are plans to compare whales from these areas with those from Chiloé and the Corcovado Gulf in the near future.

The sub-committee particularly welcomed the initiation of collaborative catalogue comparisons among feeding regions (SC/60/SH26 and SC/60/SH27), between feeding regions and wintering grounds (SC/60/SH20), and among wintering grounds (SC/60/SH23). It was recommended that such comparisons continued.

SC/60/SH1 presented the results of a comparison of a small ($n=35$ individuals) collection of humpback whale photographs collected by Greenpeace in IWC Management Area IV with reconciled catalogues from western Australia (1,777 individuals, BSD) and eastern Australia (1965 individuals, sub-stock E1). There were no matches. However, this is not entirely surprising given the large populations concerned and the relatively small Antarctic sample. Twenty-three of the 35 humpbacks in the latter were recorded close to the Area IV/III boundary; consequently, it is possible that some of these whales are from BSC (rather than BSD).

SC/60/SH2 compared a small sample of humpback whale tail flukes ($n=11$ individuals) from the Balleny Islands (Antarctic Area V) with fluke catalogues from eastern Australia (3,120 individuals, breeding stock E1) and Oceania (725 individuals, including whales from New Caledonia, Tonga, New Zealand, the Cook Islands and French Polynesia, sub-stocks E2, E3 and BSF). Three matches were made between the Balleny Islands and eastern Australia (Hervey Bay, Byron Bay and Ballina); there were no matches to anywhere in Oceania. The former result adds to three previous photo-id matches as well as Discovery mark returns between eastern Australia and Area V, and supports the generally held belief regarding a migratory connection between sub-stock E1 and the Area V feeding grounds.

It was noted that the three matches described in this paper have also been photo-identified in the Whitsunday islands and off Eden on the south coast, and that it would be of great interest to compare humpback photo-identification catalogues from these regions with the catalogues described in this report.

SC/60/SH3 reported an investigation of the migratory movement of humpback whales past New Zealand. Discovery tags provided the first evidence of linkages between eastern Australia, New Zealand and Oceania and Antarctic Area V feeding areas and also revealed low levels of intermingling of individual humpbacks between isolated tropical breeding grounds in Western Australia, eastern Australia and Oceania. A simultaneous, near total collapse of the eastern Australian, Norfolk Island, New Zealand and Oceania stocks occurred in the early 60's as a result of commercial whaling, particularly the illegal whaling conducted by the Soviets in the Area V feeding areas. Recent abundance estimates show steady recovery of the eastern Australia stock, some recovery in the New Caledonia and Tonga stocks and little evidence of recovery at other known Oceania breeding areas and New Zealand. Previous investigations of the links between New Zealand migratory whales and Oceania found one photo-identification match with Tonga and two matches with New Caledonia but there has been no comparison with Australia. This study matched 1,315 photo-identified whales from eastern Australia with 13 whales from New Zealand and found three matches. This work has demonstrated links between New Zealand and eastern Australia and shown that whales with site fidelity to eastern Australia migrate past the South Island of New Zealand including through the Cook Strait.

SC/60/SH5 reported on a photographic match between American Samoa and the Antarctic Peninsula. Fluke photographs were obtained from 79 individuals in American Samoa (2003-2006) and compared to 1,208 individuals from feeding grounds in the Antarctic Humpback Whale Catalogue. A single individual (AHWC#2950) was successfully matched to a sighting made 3.74 years earlier at the Schollaert Channel. This is the first feeding area identified for American Samoa and the first live recapture between Oceania and the Antarctic Peninsula. The latter suggests the potential for overlap between BSF and G, at least on the feeding grounds. At no less than 9,426-km, this is also the largest mammalian migration on record, although it did not necessarily occur during a single migration. The intensity of photo-identification research in the Antarctic Peninsula likely increased the probability of detecting exchange there relative to other Antarctic areas. However, the large horizontal component of this match reinforces the need for additional data on migratory movement in the South Pacific and Southern Oceans.

SC/60/SH34 summarised the results of satellite tagging of 12 humpback whales off southern New Caledonia and six off Rarotonga in the Cook Islands. Tag longevity ranged from 4 to 52 days. The humpbacks from New Caledonia generally moved to the south or southeast, with several spending time in a previously unknown sea mount habitat named Antigonía Reef before continuing on, generally towards Norfolk Island or New Zealand. However, one female with a calf travelled the entire length of the west coast of New Caledonia and west towards the Chesterfield Reefs (a 19th century Yankee whaling ground). None of the New Caledonia whales travelled to eastern Australia, which is broadly consistent with the low rate of interchange observed from photo-identification comparisons between these two areas. The connections between New Caledonia and New Zealand, together with the relatively low numbers of whales seen in these places generally, supports the idea that whales from these two areas constitute a single population that remains small and unrecovered, and which is for the most part separate from the large, increasing stock off eastern Australia. All of the Rarotonga whales travelled west or northwest to or across the Tonga Trench, suggesting that humpbacks sweep through the Cook Islands from somewhere in eastern Oceania and move west before they initiate the southward migration to the Antarctic.

These papers (SH1-3, 5, 34) were welcomed as they addressed some of the previous recommendations of the sub-committee. In discussion, it was noted that the sex of tagged animals is of great interest given that humpback whale movements may be sex-specific. The sub-committee was informed that biopsy samples were collected from most individuals and are in the process of being analysed. At least two animals were known to be mothers and that escorts had also been tagged, suggesting that both sexes had been represented. It was noted that despite the short duration of the tags, a great deal of information regarding humpback movements in the New Caledonia region had been obtained. It was observed that the short duration of the tags was caused by the absence of key parts which had to be otherwise improvised. Noting the utility of such tags in the Oceania region, it was observed that further satellite tagging of animals in the Chesterfield Reef area would provide interesting information on the southward migratory routes of whales frequenting that area.

Some concerns were raised regarding the unknown long-term potential impacts of satellite transmitters on the animals. Currently impacts are not well understood. It was noted that a few long-term photo-identification surveys of wintering and feeding regions in Oceania with high resighting rates (e.g. New Caledonia) could provide insights into such impacts. It was also noted that report SC/60/O14 (Item 2.7 below) addresses the issue of long-term re-sightings of tagged humpback whales.

SC/60/SH13 reports on the progress of a genotype survey of 1,240 individual humpbacks identified by up to 17 microsatellite loci from BSD, sub-stocks E1, E2, E3, BSF and BSG (1,065 individuals) and Antarctic Feeding Areas IV, V and VI (175 individuals). Five genotype matches were identified between breeding and feeding areas, representing migratory connections between these seasonal habitats. The five matches showed the following connections: New Caledonia (sub-stock E2) and Area V, Tonga (sub-stock E3) and Areas VI, Tonga and Area I (n=2), and Colombia (BSG) and Area I (Antarctic Peninsula). These matches more than double the number of migratory connections previously available from *Discovery* marking and suggest that whales of Oceania range more widely in the Antarctic than the naïve model of catch allocation under consideration by the sub-committee.

In response to a query as to the probability that parents and offspring are distinguished by these data, the author noted that probabilities of mis-identifying siblings and non-siblings as unique individuals had been calculated and reported (SC/60/SH13; Table 2) and that these values were low. Another question was raised in regard to whether relaxing match criteria from 18 to 16 loci might increase the number of estimated matches. In response, it was noted that not all loci had been successfully amplified for all individuals, with 15-16 loci amplified for some individuals. However, relaxed criteria were also employed in the analysis, wherein three loci were allowed to mismatch in order to recapture false exclusions. Some soft matches attributable to allelic dropout had been identified through this approach. The author also observed that all matches were also cross-checked for similarity by reference to their mitochondrial haplotypes.

SC/60/SH15 presented mixed-stock analyses of mtDNA haplotypes for allocation of humpback whales from three Antarctic feeding areas to six low-latitude breeding grounds. These breeding grounds include New Caledonia, Tonga, Cook Islands, French Polynesia, Colombia and Western Australia. Migratory allocation was estimated using the program Statistics Program for Analysing Mixtures (SPAM) with an expanded dataset of mtDNA haplotypes from breeding grounds of the South Pacific and Western Australia ($n = 1,072$, Olavarria *et al.*, 2007) and a more limited number of samples from Antarctic feeding Areas IV, VI*, and I* ($n=144$). Assuming that the breeding grounds represent the 'pure stocks' and that each feeding area represent the 'mixed stocks' Area IV was allocated in nearly equal proportions to Western Australia (33.1%) and New Caledonia (31.0%), Area VI* whales were allocated primarily to Tonga (78.9%) and Area I* was allocated primarily to Colombia (78.3%). In this analysis, the boundaries of Area VI and Area I were modified to reflect apparent geographical groupings of samples (SC/60/SH15 Table 1); hence these Areas are denoted with an *.

The sub-committee welcomed this work. In discussion, it was observed that such assignment analyses can be sensitive to variations in population sizes between stocks and to small sample sizes in the mixed stocks. The author agreed and noted that the estimates presented have not been adjusted to take into account the size of each source population, although newer analyses that attempt to do that are underway. It was observed that the surprising allocation of New Caledonian samples to Antarctic area IV may have been driven by the absence of samples from east Australia; in this analysis New Caledonia is the next closest breeding stock to Area IV after west Australia. It was noted that since haplotypes are allocated toward the most genetically similar stock, haplotypes from New Caledonia may have acted as a proxy for the much larger breeding grounds off east Australia, a region for which there is much more evidence of connections with Area IV. It was also noted that east Australia and Antarctic Area V were excluded from this analysis as there is little genetic information presently available from these regions. Data gaps on the breeding grounds may affect allocation proportions on the feeding areas. It was suggested that adding feeding area samples from Areas II and III and testing the model sensitivity to missing components would be of interest. For example south Atlantic Areas II and III would not be expected to allocate haplotypes to the south Pacific breeding stocks.

From a technical standpoint, it was observed that the application of SPAM to a non-fisheries dataset is unusual, but that it is adequately designed to incorporate uncertainties in stock allocation. The high level of precision of these mtDNA allocation estimates was considered surprising in view of the fact that the assignment tests are usually applied to multiple polymorphic markers. It was suggested that adding multiple polymorphic markers into this analysis could increase the precision of these allocations. In order to clarify the function of the Bayesian method implemented in the model (Pella-Matsuda) the sub-committee was informed that this method was able to account for the assignment uncertainty associated with those haplotypes that are present in the mixed stocks but missing from the breeding stocks (which could be an effect of small sample size or true absence).

The sub-committee agreed that this work demonstrates a useful model framework which can be developed further in the future. The utility of this kind of analysis for the current work of the sub-committee was highlighted and the sub-committee recommended further research in this subject.

SC/60/SH21 reported on the Annual meeting of the South Pacific Whale Research Consortium met at the University of Auckland from 5-8 February, 2008 to discuss (i) the results of fieldwork and analysis conducted during 2007 and, (ii) conservation initiatives in the region. As with previous synoptic surveys dating back to the austral winter of 1999, surveys of humpback whales were conducted to collect genetic samples, individual identification photographs and song recordings in the four primary regions: New Caledonia, Tonga (Vava'u), Cook Islands and French Polynesia (Society Islands). Other regions surveyed in 2007 included Samoa, American Samoa, New Zealand, Hervey Bay, Norfolk Island and Tuvalu. Satellite tagging was conducted in the Cook Islands and New Caledonia revealing patterns of movement between breeding grounds and documenting the early stages of migration. A comparison of quality-controlled fluke photo-ID catalogues from the years 1999-2004 revealed only limited interchange between eastern Australia and Oceania (and only to New Caledonia, the closest breeding ground of Oceania) and further evidence of interchange among breeding grounds of Oceania. A large-scale comparison of microsatellite genotypes from samples collected throughout the South Pacific provided new records of

interchange between Oceania and the Antarctic and, for the first time, between French Polynesia and Colombia (BSF and BSG). Song analysis for the years 2002-2006 showed a pattern of sequential movement of unique song types from eastern Australia, east across the breeding grounds of Oceania.

The sub-committee expressed appreciation for the substantial amount of research presented for BSE and BSF and observed that results from these studies will be very helpful to upcoming assessment of these stocks.

SC/60/O12 reported on three nineteenth-century logbooks which provide evidence of possible oceanic migration routes of humpback whales in the South Atlantic. In October 1806 "plenty" of humpback whales were reported on six successive days on the eastern side of the Agulhas Bank, possibly representing a component of the southward migration of breeding stock C. In late July/early August 1831, five encounters with humpback whales occurred between about 17 and 28° 30'S along 28-29°W longitude, or some 500-1000 n. miles off the east coast of South America. In the following year no sightings were recorded by the same vessel when transiting south along longitudes of 16 – 18°30'W. The 1831 sightings possibly represent whales migrating north from feeding grounds in the Antarctic known to be visited by humpback whales from the Abrolhos Bank off Brazil. Mid-Atlantic sightings in October 1831 may represent migrants from a wintering concentration at the island of St Helena.

This work was welcomed as it provides very interesting information with regards to alternative migratory routes of humpback whales wintering in the tropical South Atlantic (possibly Brazil). In response to a question to whether these whales may be related to Walvis Ridge, it was noted that humpback whales might be in the vicinities of this region.

SC/60/SH43 reports on the results of comparisons of humpback tail fluke catalogues from Oman (Region X, within the Arabian Sea, 68 individuals) with Madagascar (sub-stock C3, 1,041 photos) and the east African mainland (sub-stock C1, 559 photos). Previous photo-identification studies have identified the Oman population to be small, while genetic analyses have previously provided evidence of the discrete nature of the Arabian population. Samples from the three regions are described and regional comparisons have been handled in the same manner as the comparison between sub-stocks C1 and C3 reported in SC/60/SH33. No matches were found in either of the comparisons, providing further evidence of a discrete population off Oman. The importance of continued and increased research effort into the status and distribution of, and threats to, the Arabian Sea population across its range (including Yemen, Oman, Iran, Pakistan and India) was stressed.

The sub-committee welcomed this report and recommended the continuation of this important study with a geographically isolated population. In discussion, a question was raised about historical observation of humpback whales east of the Bengal Sea. However, no known information seems to be available for this region.

2.5.2 Abundance and trend estimates

SC/60/SH31 describes a six week land-based survey conducted at Pt Lookout on the east coast of Australia, in June and July 2007. Over the peak four weeks of the northward migration, an average of 70.7 whales passed per 10h. This was compared with a similar metric from previous surveys at this site yielding a long-term rate of increase of 10.9% per annum (95% CI 10.5 – 11.4%), slightly higher than our previous estimate from a survey in 2004 (Noad *et al.*, 2006). This indicates that the long-term rapid increase in the size of the east Australian population of humpback whales continues without any apparent slowing. Aerial surveys were also conducted concurrently with the land-based surveys during which 249 groups of humpbacks containing an estimated 399 whales were seen from the air. Analysis confirms that only about 3% of groups pass more than 10km of the headland which is consistent with Bryden's (1985) estimates despite an approximately 15-fold increase in the population over this time. Further, the offshore distribution of whales was characterised with no significant difference being found between the patterns of distribution whether measured from land or air. Approximately 89% of groups passed within 5km of land and the mean distances offshore for both aerial and land-based surveys were less than 2.5km. This supports one of the key assumptions of the land-based counts, that they are not greatly affected by whales missed as a function of increasing distance offshore. An estimate of absolute abundance for 2007 was made by extrapolating from the 2004 absolute abundance estimate. Using the land-based correction factor for groups available but missed estimated in 2004, 2007 absolute abundance is estimated at 9,683 whales (95% CI 8,556 – 10,959).

This report was welcomed by the sub-committee. In response to a question, it was noted that the aerial surveys were conducted only in 1980/1981 and 2007. The purpose of the most recent aerial survey was to (1) investigate the offshore distribution of animals (2) compare sighting rates with the simultaneous land-based survey. In response to a query regarding the inclusion of estimates of $g(0)$ in these analyses, it was observed that the aerial surveys were carried out for the purpose of determining whale distributions rather than for estimating abundance.

It was noted that it is not yet clear whether or not the entire E1 breeding stock migrates to lower latitude wintering grounds. The sex ratio of the E1 whales sampled on migration in Hervey Bay is 2.4 males:1 female (Brown *et al.* 1995). If this sex ratio is a true measure of the population ratio then it could be argued that females only migrate (past E1) when they are going to calve. However, it was pointed out that the sex ratio could also be a function of sampling bias, since males tend to have a longer residency period than females (some residents are known from Hervey bay, consistent with this) and larger groups were sampled in the Brown *et al.* (1995) study. It was noted that there is also a strong male bias in samples from the North Atlantic breeding ground, but that females in all reproductive states are present (Robbins, 2007). This suggests that differential female migration patterns are not an explanation for unequal sex ratios there.

2.5.3 Assessment

SC/60/SH14 presents a preliminary population assessment of humpback whales breeding along the coast of east Australia (sub-stock E1) and near the islands of Oceania, South Pacific (sub-stocks E2, E3 and BSF). These breeding regions were subject to intensive exploitation by pelagic and coastal whaling operations throughout much of the 20th century and have shown apparently variable levels of recovery. While east Australia has shown high rates of population increase, breeding stocks of Oceania, including those around Fiji and those that migrate past New Zealand, virtually disappeared and have yet to show signs of strong recovery. Reconstructing the history and subsequent recovery of these populations is hampered by the difficulty of allocating historical feeding ground catch to each breeding ground population. Here we present progress on a two-stock Bayesian density-dependent logistic population model, developed to explore the influence of different catch allocations on the recovery of east Australia and Oceania. Probability distributions of carrying capacity (K), growth rate (r_{max}) and current abundance (N_{2008}) were determined for all whales breeding within east Australia (sub-stock E1) and Oceania (sub-stocks E2, E3, and BSF). Estimates of current abundance were provided by capture-recapture modelling, using individual identification photographs collected from 1999-2004. Sensitivity of the population model estimates to prior distribution choice, catch allocation (Naïve and Fringe 'maximum') and minimum past abundance (N_{min}) were investigated. Median posterior estimates of carrying capacity for east Australia

and Oceania were 26,383-31,400 and 16,022-22,957 respectively. Median recovery estimates (*N2008/K*) for the two-stock model with variable catch ranged from 27-31% (east Australia) and 20-25% (Oceania).

The sub-committee welcomed this report as it shows progress on population modelling of BSE and BSF, for which an assessment will be forthcoming. In discussion, it was noted that the levels of reported recovery in east Australia and Oceania were surprisingly similar, given the larger size and strong population increase observed for the east Australia stock. The sub-committee was informed that this may be a function of the much larger breeding and feeding ground catches attributed to the east Australia population (SC/60/SH14 Table 2 and Appendix 1). Another possible explanation for similar estimated recovery of these stocks is the fact that strong trend described for east Australia has not yet been included in the population assessment model presented. It was noted that CPUE data (e.g. from Cook Strait New Zealand) and SPUE data (e.g. Norfolk Island and Fiji) are available for this population. It was noted that while data such as catches/day tend to underestimate the rate of decline, they may be useful as a means of checking model fit. The sub-committee requested a detailed summary of these data for discussion and agreed that their utility as trends for input to the population assessment model could be explored.

Johnston and Butterworth presented an updated assessment for BSG based on a revised estimate of the abundance produced by Félix *et al.* (in press). The original estimate was 2917 in 2003, and the new estimate is 6118 in 2004. Inclusion of the new abundance estimate has a marked impact on the estimated status of the BSG. In particular, the estimated rate of increase has changed from 0.060 to 0.100, and the current status of the stock (*N2007/K*) has increased from 0.277 (95% Bayesian interval 0.185–0.391) to 0.650 (0.486–0.815) (Table 2).

2.6 Antarctic Humpback Whale Catalogue

The interim report of the Antarctic Humpback Whale Catalogue (AHWC) was presented in SC/60/SH19. During the contract period, the Antarctic Humpback Whale Catalogue (AHWC) catalogued 332 photo-identification images representing 183 individual humpback whales from Antarctic and southern hemisphere waters. These images were submitted by 37 individuals and research organisations. Photographic comparison of submitted photographs to the AHWC during the contract period yielded 48 previously known individuals. These submissions bring the total number of catalogued whales identified by fluke, right dorsal fin/flank and left dorsal fin/flank photographs to 2,858, 409 and 405 respectively. Matches made during the contract period to previously sighted individuals include resightings between Ecuador and the Antarctic Peninsula (4), Ecuador and the Antarctic Peninsula (4) and South Orkney Islands and Northwest coast of South America and the Antarctic Peninsula (1). Within-region sightings include resightings in the Antarctic Peninsula (9), Brazil (1), Ecuador (1), American Samoa (1) and Eastern Australia (1). It was noted that progress will continue to stimulate submission of opportunistic data from eco-tourism cruise ships in the Southern ocean and from research organisations and expeditions working throughout the region.

The sub-committee welcomed the presentation of this report, which contains information on a long-term project funded by IWC.

In response to a query regarding the procedure for obtaining access to high resolution copies of the IDCR/SOWER photographs, the sub-committee was informed that requests for these images should be made by a delegate to the IWC. Photographs available through the website are currently in the process of being upgraded from 72dpi to 100dpi. It was suggested that further upgrades of these photographs to 150dpi could be discussed with the IWC Secretariat.

2.7 Other

SC/60/O14 examined the resighting histories of seven humpback whales to which implantable radio tags were attached in Alaska between 1976 and 1978. All of these whales have been resighted repeatedly over time spans ranging from 17 to 32 years; five of the seven whales were still being seen more than three decades after tagging. These results suggest that the effects of the implantable tags (which were larger than some tags currently in use) were minimal.

In discussion, it was noted that the small sample size of whales tagged in this study prohibited any statistical comparison of their observed re-sight rates with re-sight rates of untagged animals. It was noted that the whales selected for tagging were local residents (although this was not known at the time) and so re-sight rates for tagged individuals was high. It was also observed that a study undertaking a comparison between tagged and untagged animals would be of interest if control animals with similar characteristics to the tagged animals could be identified.

It was noted that tagging could have an effect on the reproductive rates of tagged animals and that this kind of information was not provided for the animals described in SC/60/O14. However, some members observed that such data estimates of reproductive data from these whales could be biased upward as a consequence of inadvertent sampling of local residents. It was also noted that some satellite telemetrists may bias their efforts by targeting healthier looking animals. The sub-committee agreed that estimation of reproductive rates for tagged animals would be useful, though challenging. It was observed that for many long term studies, there are lots of available from untagged residents also, and that these biases are eliminated in comparisons between long-term residents.

The Subcommittee welcomed the result in SC/60/O14, and agreed that follow-up studies on invasive tagging were essential. The Subcommittee recommended that all tagged whales be individually identified photographically; biopsy sampling of tagged whales would provide an alternative means of individual identification (via genotyping), as well as information on sex and data for genetic and other studies. It was observed that while the relationship between tag sizes and health impacts is likely complex, the 2 x 29cm tags described in the study are similar in size to contemporary tags. The sub-committee recommended that the design and dimension of the tags deployed should be included in all reported studies using satellite tagging. The sub-committee also recommended that further studies of the short-term impacts and responses of whales to tagging be conducted.

A proposal to analyse the distribution of mtDNA lineages among southern humpback whales on the feeding and wintering grounds of BSD, BSE and BSF was presented. The objective of this study is to investigate breeding ground population structuring and the pattern of distribution and mixing of maternal lineages between these breeding and feeding grounds. In order to carry out this study, mtDNA data (such as those presented in SC/60/SH15) will be requested from the South Pacific Whale Research Consortium (SPWRC). This proposal has no budgetary implications and was endorsed by the sub-committee.

A proposal to examine multi-locus genetic assignment tests (including mitochondrial and nuclear DNA markers) was presented. The objective of this study is to investigate the relationships between Antarctic feeding grounds in Areas IV, V and VI and their associated breeding stocks. A large collection

of samples is already available from wintering grounds in the south Pacific. In order to perform this study, access to biopsy samples of humpback whales collected on the Antarctic feeding grounds during IDCR and SOWER cruises from 1999 to 2007 is requested. This proposal has no budgetary implications and was endorsed by the sub-committee.

Noting that the IDCR/SOWER tissue samples can only be sub-sampled a few times before they are depleted, it was suggested that genome amplification may aid in archiving of these data. It was also observed that Southwest Fisheries are now incurring some costs as a result of providing routine access to these samples. In response, it was noted that a major review of the whole procedure is planned in consultation with individuals from the Southern Hemisphere and Stock Definition sub-committees and that a proposal for genome amplification will be brought to the IWC next year.

3. IN-DEPTH ASSESSMENT OF SOUTHERN HEMISPHERE BLUE WHALES

3.1 New Information

3.1.1 Report of the Cape Town Workshop

Bannister reported on the one-day workshop, attended by 28 participants, held in Cape Town, South Africa, in association with the Marine Mammal Society Biennial Conference, November 2007. Aimed at the Southern Hemisphere but with examples from elsewhere, a series of 18 presentations, covering a wide range of regions and subjects, was followed by a discussion session covering six main topics: taxonomy; population identity, status and movements; breeding biology; feeding ecology/critical habitat; threats; research priorities.

Threats identified at the workshop included gillnet entanglement, ship strikes, habitat degradation, disease, military acoustics, climate change and food availability. Eleven research priority topics were recognised, viz.: long-term, repeated, population estimates; acoustic monitoring in ocean basins; genetic and morphological studies (including information from strandings and museum specimens) to delimit population boundaries; multidisciplinary shipboard surveys, particularly in areas where blue whales may once have been present/important; satellite tagging, for breeding and habitat studies, for determination of feeding home range and migration routes, to connect seasonal feeding and reproductive areas, and to identify seasonal areas of concentration; hormonal studies a) from biopsies, for investigation of reproductive status, and b) from faecal studies, for information on stress levels, for example; collaborative photo-identification and genetic studies; ecosystem approaches; fine-scale krill dynamics; studies of 'problem' populations, e.g. in the Northern Indian Ocean, and off Chile; and the need for a modelling framework, especially biological.

The workshop recognised three top priority topics, in order, as follows:

- (1) Studies of:
 - a) population distribution and identity
 - b) long-term population estimates and trends
 - c) a and b. should use a wide combination of methods, including satellite tagging, vertical photography, acoustics, photo-identification, biopsy).
- (2) Identification of the most serious threats, in specified areas, taking into account those that can be managed.
- (3) A global genetics study, increasing the existing sample size where necessary.

3.1.2 Distribution, movements and population structure

SC/60/O4 reported the new information of Southern Hemisphere blue whale sightings in the Antarctic Areas III, IV and V during 2007/08 JARPA II cruise. The research period corresponded to a total of 101 days (15 December 2007 to 24 March 2008). A total of 14,575 n. miles were systematically surveyed. A total of 49 blue whale schools comprising 92 individuals were recorded. Mean school size was 1.88 individuals and sighting rate was 0.63 individuals/ 100 nautical miles. Most sightings occurred in Area IV. Biopsy samples and photo-identification data were collected from 5 and 23 individuals, respectively.

Branch *et al.* (2007a) used a Bayesian mixture model to estimate the proportions of pygmy and Antarctic blue whales in different regions of the Southern Hemisphere and northern Indian Ocean. Female pygmy blue whales are sexually mature from 19.2m to their maximum length of 24.1m while sexually mature Antarctic blue whales are sexually mature from 23.7m to their maximum length of >30m. This fact is used in the model to estimate the proportions of each subspecies in historical catches, with an additional parameter to estimate the extent to which the length data were rounded to the nearest 5 ft interval. South of 52°S, 99.2% of catches were estimated to be Antarctic blue whales, while north of 52°S and between 35°E and 180°, 99.9% were estimated to be pygmy blue whales. Proportions are estimated separately for land stations; outside of 35°E–180°, most were estimated to be Antarctic blue whales. The lengths of sexually mature Chilean blue whales was intermediate between those of pygmy and Antarctic blue whales, and can only be explained if this population is a distinct population or subspecies. This finding is consistent with their discrete distribution, and differences in call type and genetics compared to pygmy and Antarctic blue whales.

LeDuc *et al.* (2007) described genetic estimates of subdivision among Southern Hemisphere blue whales. Mitochondrial control region sequences (400bp) and 7 microsatellites were amplified from whales in the southeast Pacific Ocean (Chile, Peru and Ecuador; $n=28$), Indian Ocean (south and west Australia, southwest Indian Ocean, (Madagascar and the Maldives; $n=36$) and the Antarctic ($n=47$). Genetic differentiation among all regions was significant for both genetic datasets. Data suggest that pygmy blue whale populations are as differentiated between the two oceans as either is from Antarctic blue whales. Microsatellite data indicate that two vagrants have been sampled between the southeast Pacific and Antarctic; one southeast Pacific blue whale ('Chilean' blue whale) in the Antarctic and one Antarctic blue whale in the Pacific. The paper indicated the need for a re-examination of blue whale taxonomy: "The non-migratory blue whales from the northern Indian Ocean (e.g. the Maldives samples) are likely reproductively isolated from the other samples from the Indian Ocean, and indeed have been considered a separate subspecies, *B.m. indica*. However this isolation is incongruent with their genetic similarity to the Australian and African samples. The present data set from the northern Indian Ocean is too limited ($n=2$) to address these issues, but hopefully will provide some impetus for additional genetic and non-genetic research."

Branch *et al.* (submitted) explored the production of ovarian corpora in blue whales. Blue whales accumulate permanent ovarian corpora each time they ovulate or become pregnant. As they grow older and longer, the number of ovarian corpora increases. The relationship between length and ovarian corpora count therefore is quite different for pygmy blue whales and Antarctic blue whales. This fact was used to estimate the proportion of pygmy blue

whales in the Antarctic region, by applying a Bayesian mixture model to data from 1,378 pygmy blue whales and 3,844 Antarctic-region blue whales. Only 0.1% (95% credibility interval 0.0–0.4%) of the Antarctic-region blue whales were estimated to be pygmy blue whales. Over a period of four decades, despite substantial depletion of Antarctic blue whales, the proportion of pygmy blue whales in the Antarctic did not increase, suggesting that pygmy blue whales did not shift southwards to take advantage of the more vacant Southern Ocean habitat.

SC/60/SH29 presented a study on photo-identification of Antarctic blue whales. Over 21,000 identification photographs were collected during 19 IWC IDCR/SOWER cruises conducted from 1987-1988 to 2007-2008. Archiving and analysis of these photographs has been undertaken at the Southwest Fisheries Science Center (SWFSC) to aid in the assessment of Southern Hemisphere blue whales. Photographs were obtained from all six IWC Management Areas and represent a minimum of 311 whales. Film images from earlier cruises have been digitised to facilitate archiving, analysis and the creation of a photo-ID catalogue. 95% of the currently available photographs have been examined, yielding 203 photo-identified individuals. Photographs from five cruises in Area III have been cross-referenced to identify re-sighted individuals, locations and re-sighting rates for that region. Four whales were re-sighted in Area III in multiple years, including one whale with a 12-year sighting interval. The within season re-sighting rates for 2005-2006 and 2006-2007 were 11% and 17%, respectively. Two whales were photo-identified in 2007-2008 in Area IV, but did not match three whales identified from Area IV during a previous cruise.

The absence of photos from Area V was questioned. The Sub-Committee was informed that pictures obtained by the IDCR/SOWER cruises in this region have been sent to the IWC Secretariat by Japan. It was recommended that attempts be made to locate these photographs for inclusion in the blue whale catalogue. The SC also recommended that blue whale photographs collected by the Institute of Cetacean Research be incorporated into the catalogue. Japanese scientists recognised the importance of photo-identifications of blue whales and agreed to add photographs collected on the JARPA surveys to the blue whale catalogue when they have been archived and examined by Japanese scientists. The subcommittee recommended that analyses of the blue whale photographs taken on JARPA cruises be conducted by Japanese scientists and presented at the next IWC meeting. Once presented, the blue whale photographs can then be added to the catalogue of photographs held by IWC/Olson, and the joint catalogue analysed.

In response to a question on further analysis and data collection for the catalogue, it was noted that this was a work in progress and the sub-committee recommended that archiving continues and that the resulting analysis is presented to the Scientific Committee next year.

SC/60/SH24 present information on the conservation status of blue whales off Isla de Chiloe collected since 2004 through six aerial surveys on board Chilean Navy, 55 marine surveys and 146 days of land-based observations. In 2008, land-based observers recorded an average of 23 whales per day. Seventeen photo-identification surveys resulted in the documentation of 172 blue whale groups (270 whales). The number of whales encountered does not include animals resighted on the same day. 2008 was the first year that the number of pairs was higher than the number of single whales and the first year that a calf was recorded. Faeces, feeding and social behaviour also were recorded. From 2004 to 2008, a total of 250 individual blue whales have been photo-identified. Approximately 23% of all catalogued individuals have been resighted within the same season and 30% have been resighted between years. Recaptures of photo-identified individuals from other areas in northern and southern regions of the country support the hypothesis that the feeding ground off southern Chile is extensive and dynamic. The overall annual return rate and SPUE highlight the importance of the waters off northwestern Isla de Chiloe and northern Los Lagos as a feeding area for this population. The high frequency of large vessels in the area north of Los Lagos with a high number of blue whales is reason to be concerned about the possible increase of vessel collisions. There is a significant positive correlation between the proportion of skinny whales and sea surface temperature, which raises concerns on potential impacts from global warming and El Niño phenomena.

In discussion it was noted that the relationship between SST and skinny whales is based on only three years of data and may not hold up when more years are analysed.

In response to a question regarding comparison of the catalogue from Chile with other regions, the sub-committee was informed that no matches were found in an initial comparison of pictures from 2004/2005 with the eastern tropical Pacific (ETP) catalogue. Further comparison of the full Chilean catalogue (2004- 2007) with the ETP and the Antarctic is currently under way. In addition, a web-based system for blue whale photo ID matching is also being developed. A question was raised over what information was available to support the conclusions that Isla Chiloe and northern Los Lagos correspond to a feeding area for blue whales. In response, it was noted that faeces have been collected and feeding behaviour has been observed in the region. In response to a question about the use of photo-identification and genotypic data to compute abundance estimates from this population, it was noted that estimates will be provided in the near future. The sub-committee recommended that abundance estimates should be provided for next year's meeting.

SC/60/SH46 describes the movement, behaviour and use of space of humpback, blue and sei whales on the coast of Chile (southward from Chiloe Island and Corcovado Gulf) through shore-based observations using a theodolite. The data were analysed in order to determine the whale's location, distance from the coast, movement patterns and swimming speed. During the 2008 field season an apparent increase in the number of observations of baleen whales was observed in the Corcovado Gulf, notably an increase in blue whale sightings, the presence of sei whales and a reduction in humpback whale observation in the research area. The results suggest that blue and humpback whale species feeding ranges overlap to some extent within an area of 1542km². The presence of blue, humpback and sei whales feeding in the same area could be explained by the differential use of available prey, thus overlapping on solely one edge of the *n*-dimensional niche e.g. krill, possibly avoiding competition in this way.

In discussion, a question was raised about the sample size of the calibration study of species identification from land and boat briefly mentioned in the paper, given the great distances to the sightings shown in SC/60/SH46 Fig. 11. The authors noted that this study was preliminary and that detailed information will be provided in the future. Concern was expressed in regard to (1) assigning behavioural categories and (2) following the same individual at such distances. It was noted that whales were followed by a boat to determine species identification and general behaviour, and that boats were within sight of the land observation point on most occasions. The Sub-committee recommended that a full report of the boat-based data and calibrations should be presented at next year's meeting.

3.1.3 Acoustics

SC/60/SH45 presented findings from opportunistic acoustic recordings of Chilean blue whales in the Corcovado Gulf, southern Chile. A total of 206 individual calls were identified, of which 24 were short-duration (<2s) high-frequency calls (average 418Hz, range 396-442 Hz), 37 were short-duration

(<2s) lower frequency calls (average 351Hz, range 305-366 Hz). These are of a higher frequency than previously reported blue whale calls worldwide. The other 144 calls were long-duration (3-24s) and between 19-98Hz, similar to previously reported vocalisations for this species. These results support the hypothesis that Chilean blue whales belong to a separate subspecific grouping and suggest that acoustic recordings could be used in field identification of the subspecies.

In discussion, it was observed that most blue whale acoustic studies have not sampled the high frequency part of the call making comparisons of this and other acoustic studies difficult. The authors were asked whether the low frequency calls recorded in Corcovado Gulf were similar to those of other blue whales. In response, it was noted that calls are similar in nature and duration to other blue whales and the authors agreed that their use of a wide-range frequency monitor may have captured sounds not normally captured in acoustic studies of the species. It was also noted that this study is preliminary and strong conclusions cannot be made at this stage as to evidence of differences between Chilean blue whales and Antarctic blue whales.

3.1.4 Biological information

Branch and Mikhalev (*in press*) presented an analysis of ovarian corpora data recovered from the original logbooks recorded during illegal Soviet catches in the Southern Hemisphere and northern Indian Ocean. The data recovered included 1,272 catches north of 52°S assumed to be pygmy blue whales and 153 south of 56°S assumed to be Antarctic blue whales. Three likely Antarctic blue whales were reported north of 52°S. The number of whales shorter than 70 ft (21.3m) examined by Soviet whalers was 32 times greater than the number examined by the Japanese whalers, therefore the Soviet data allows for more precise estimates of length at sexual maturity to be made. The length at which 50% and 95% of females (L_{50} and L_{95}) become sexually mature was estimated using a Bayesian logistic model. For pygmy blue whales, grouping all data, L_{50} was 19.2m (95% credibility interval 19.1–19.3m) and L_{95} was 20.5m (95% interval 20.4–20.7m), and this was much shorter than Antarctic L_{50} (23.4m, 95% interval 22.9–23.9m). The median L_{50} was 0.5–0.6m shorter for pygmy blue whales in the northern Indian Ocean than in the south-west Indian Ocean or south-east Indian Ocean; although this difference is statistically significant, it is not large enough to provide support for the idea that northern Indian Ocean blue whales are a separate subspecies, *B. m. indica*.

SC/60/SH6 Biological parameters are estimated for pygmy blue whales based on new biological data from Soviet whaling, and re-analyses of existing published data from Japanese whaling. Separate length-at-age curves for males and females are generated in a Bayesian framework from a von Bertalanffy growth equation. Female age at sexual maturity is estimated to be about 10 yr (95% credibility interval 9–11yr). The inter-ovulation interval is estimated to be 2.6yr (95% CI 2.2–3.0), and this is argued to be close to the inter-birth interval. Natural mortality, based on age frequencies, is 0.06 yr⁻¹ (95% CI=0.05–0.07), with some inconsistent variability between sexes and data sources. Taken together these estimates suggest that in the early 1960s the potential rate of population change for pygmy blue whales in the Indian Ocean was less than 2% yr⁻¹.

In discussion of Branch and Mikhalev (*in press*) and SC/60/SH6, it was noted that there could be a confounding effect of catch selectivity (particularly with respect to age and distribution) or exploitation rates in light of the relatively large estimates of natural mortality presented. In response, it was noted that there were no spatial differences in the lengths of catches and that pygmy blue whale exploitation was recent (1959-1969) and probably would not have impacted the equilibrium natural mortality estimate presented in SC/60/SH6 given the life span of the species. In addition, no difference in whale ages was found over the duration of this whaling period, in particular there was not an increase in the catches of young animals over time. It was further noted that pygmy blue whales have a low lifetime corpora production rate which is consistent with the biological observations presented. In addition, the catches under discussion (Soviet) are known to have been indiscriminate with regards to age and sex.

It was further observed that zeroes in the data may bias the regression analysis shown in Figure 1 of SC/60/SH6. In response to a question regarding whether incorporating data on juvenile survival rates would be informative, the Subcommittee was informed that there are currently no juvenile survival rate data available for blue whales and that adult survival rates calculated in the SC/60/SH6 are non-calf survival rates.

SC/60/SH8 computed maximum plausible rates of increase are estimated for Antarctic blue whales based on biological parameters. The literature was reviewed to obtain likely distributions for each relevant biological parameter: adult survival $S \sim N(0.963, 0.02^2)$, calf survival $S_j \sim N(0.84, 0.15^2)$, annual pregnancy rate $p \sim U(0.33; 0.5)$, age at first parturition $l_p \sim N(10, 2^2)$, and the proportion of births that are female $q_f \sim N(0.473, 0.001^2)$. Lower and upper bounds were also placed on S , S_j and l_p ; most important of these is the restriction that $S_j < S$. A basic equation that relates values of these parameters to an estimated rate of increase was used to convert these biological parameters into a distribution for the instantaneous annual rate of increase, which was $\sim N(0.040, 0.019^2)$ with an upper 99th percentile of 0.082, assumed to be the maximum rate of increase. This corresponds to annual rates of increase $\sim N(0.041, 0.019^2)$ and 0.085 respectively. Rates of increase from JARPA (0.074 yr⁻¹) and IDCR/SOWER (0.082 yr⁻¹) surveys are close to this upper bound and have confidence intervals that exceed the maximum.

In response to a question about possible transient effects of whaling mortality, it was noted that these effects made very little difference in the estimation of rates of increase for humpback whales with age-structured models. Paper SC/60/SH8 was discussed in a small working group (see item 2.1 above) from which conclusions are presented in Appendix 2.

SC/60/SH25 reported different types of skin lesions identified from blue whale photographs taken off the northwestern coast of Isla Grande de Chiloé, Chile, in 2006 and 2007. The main lesions were: (1) cookie-cutter sharks and (2) blister like or vesicular lesions.

3.1.5 Abundance and trend estimates

SC/60/SH10 presented minimum bottleneck abundance is estimated for Antarctic blue whales based on the observation that each mtDNA haplotype in the population at the present time must have been represented by at least one female at the time of the bottleneck. The methodology used is similar to that in Jackson *et al.* (2008), and used mtDNA data from LeDuc *et al.* (2007), who found 26 haplotypes among 47 Antarctic samples. Conservative correction factors are applied to convert these 26 haplotypes to a minimum abundance estimate. Correcting for low sample size in the current population increases the likely current haplotype richness to at least 51, to which multiplicative factors are added as follows: 1.29 to correct for haplotypes missed because of short mtDNA sequences, 2.11 for the sex ratio in the bottleneck population, 1.50 for overlapping generations in the bottleneck population,

and 1.03 for haplotypes that were lost after the bottleneck. The resulting minimum bottleneck abundance is 214, which can be used as a lower bound for population size of Antarctic blue whales.

In response to a question, the sub-committee was informed that the genetic samples used from LeDuc *et al.* (2007) represented different individuals. The possibility that whaling might affect lineage survival differentially across age classes was raised. It was recognised that this effect could apply but the current simulation was individually based so individual survival varied greatly. It was suggested that running only lineages with the highest survivorship may be informative. In response, it was observed that the majority of lineages had only one surviving animal after exploitation and that the approach in SC/60/SH10 was essentially intended to be conservative.

In response to another query regarding the method of sampling for missing haplotypes it was recommended that the authors discuss this issue with Pastene, who has looked into this with other balaenopterids. The authors agreed.

It was observed that accounting for sequence length is not necessarily a conservative correction factor. In response, it was explained that the correction was provided by New Zealand southern right whales, which have very low genetic diversity. In light of the concerns regarding the correction for sequence length, it was recommended that this correction be explored further, either by examining data for longer sequences of other species such as humpback or minke whales, or preferably by rerunning the genetic analyses for Antarctic blue whales to 1000 base pairs to directly improve this estimate. However, it was noted that changes to the correction factor would interact with estimates of the discovery curve for haplotypes in the population as a whole.

SC/60/SH16 presents a capture-recapture estimate of pygmy blue whale abundance from western Australia (Perth Canyon). Photographs collected over 2000-2005 (dorsal fins and lateral bodies) were used to identify 208 individuals. 23 individuals were re-sighted once and 2 individuals were re-sighted more than twice between years. An open population model (POPAN) and a closed model with individual heterogeneity yielded abundances of 791 (95% CI: 569 - 1,147) and 1019 (95% CI: 712 - 1,754). Because of the low re-sight rates between other sighting locations at Geographe Bay (west Australia, 200km south of Perth Canyon (125 sightings)) and the Bonney Upwelling (southern Australia) the possibility of substructure within the population was discussed. If substructure exists then the population estimate from Perth Canyon is likely to underestimate of the total abundance of pygmy blue whales in the region. The authors propose that the coordinated matching of photographs between sites throughout Australia and the Indian Ocean will improve the population estimate and the understanding of structure within and among pygmy blue whales populations. Geographe Bay may contain a component of Antarctic blue whales which may also influence the accuracy of population estimates. The subspecific composition of this population has yet to be determined.

The sub-committee welcomed this work and recommended that it continue.

It was noted that satellite-tagging can provide some data regarding blue whale movements around the Perth Canyon and Geographe Bay region. Blue whales recently tagged in the Perth Canyon spread widely (including a movement to immediately west of Geographe Bay) and appeared to be feeding on the shelf break.

The ability to distinguish between pygmy blue whales and Antarctic blue whales at Geographe Bay and the Perth Canyon was questioned. It was stated that available genetic and acoustic data coupled with the seasonality of the observations (LeDuc *et al.* 2007; McDonald *et al.* 2006; Branch *et al.* 2007b) strongly suggest the blue whales observed within the Perth Canyon (January to April) are pygmy blue whales. Acoustic and catch data also suggest that a very high proportion of blue whales observed in Geographe Bay (October to December) are pygmy blue whales, however, genetic data are not yet available to confirm the subspecific identity of these whales.

3.1.6 Catch data

SC/60/SH9 describes a worldwide catch series for five regional groupings of blue whales during the modern whaling period, 1868–1978. There were only a handful of catches before this period, and none afterwards. The data come from the IWC individual catch database and the IWC annual summary catch database, and are corrected for Soviet misreporting of catches from the late 1950s to the early 1970s. No adjustment is made for struck and lost whales or those lost after being caught and flagged, except for a small fraction of the total that were reported to the IWC. Catch series for the North Pacific, North Atlantic and South-east Pacific are presented, but no attempt has been made to apportion catches in these three regions where the species was not recorded. Greatest emphasis is placed on obtaining updated catch series for Antarctic blue whales and pygmy blue whales, and catches of unspecified species were apportioned to blue whales in regions where they occur (South-west Pacific, South Atlantic, Indian Ocean, and Southern Ocean). Catches were divided between Antarctic and pygmy blue whales based on recent studies of length frequencies and the relationship between length and ovarian corpora. Total worldwide catches of blue whales were 382,595, of which 90.4% were Antarctic blue whales ($n = 345,775$), 3.4% were pygmy blue whales ($n = 13,022$), 1.4% were from the South-east Pacific ($n = 5,383$), 2.1% were from the North Pacific ($n = 7,973$) and 2.7% from the North Atlantic ($n = 10,442$). A correction factor for whales struck and lost (mean=1.006, 95% CI = 1.001-1.031) was provided considering the total number of whales (118) lost in the IWC database.

3.2 Assessment

3.2.1 Antarctic blue whale

SC/60/SH7 uses Bayesian modelling to assess the current status of Antarctic blue whales: an exponential model is used to assess recent trends in abundance, and a logistic model to estimate pre-exploitation abundance and population trajectories. The input data included absolute abundance estimates from the IDCR/SOWER surveys, abundance estimates for Area IV and V assumed to be an index of abundance, and sighting rates from JSV data south of 60°S and between November and February. Additionally, the upper limit of the rate of increase is limited to 0.085 yr⁻¹ based on biology, and abundance is required to be greater than 214 in all years based on an analysis of mitochondrial DNA. The population is estimated to have declined from 256,000 (95% credibility interval 235,000–307,000) to a low of 395 (235–804), which was 0.15% (0.10–0.28%) of pre-exploitation levels. Whaling mortality was greater than sustainable levels in every year from 1926 to 1971 except during World War II. The population low point was reached in 1971 or 1972 when the introduction of international observers halted catches of Antarctic blue whales by Soviet fleets. Since then the population is estimated to have been increasing with probability 0.998, at an annual rate of 6.4% yr⁻¹ (2.4–8.4%). Despite this increase, the most recent abundance estimate of 2,280 based on surveys with a mid-point of 1997 is only 0.9% (0.7–1.0%) of pre-exploitation levels. Population trajectories of the base case model are illustrated in Fig. 4.

The following sensitivity scenarios were explored using the exponential model with the purpose of investigating the effect of assumptions on model outputs:

- (1) **R wide.** The prior for the rate of increase was changed from $U[-0.3; 0.085]$ to $U[-0.3; 0.3]$ to test the impact of changing the upper bound of 0.085 on this parameter derived from a biologically plausible distribution for rates of increase (SC/60/SH8).
- (2) **Zero minimum.** The minimum abundance in any year was bounded by zero instead of the 214 obtained from an analysis of mtDNA haplotypes (SC/60/SH10).
- (3) **R wide and zero minimum.** The prior for the rate of increase was set to $U[-0.3; 0.3]$ and the minimum abundance was bounded by zero.
- (4) **R biological.** The prior for the rate of increase was changed from $U[-0.3; 0.085]$ to $N(0.041; 0.019^2)$, with bounds of $[-0.3; 0.3]$, reflecting the distribution of plausible biological rates of increase (Branch, 2008b).
- (5) **R other whales.** The prior for the rate of increase was changed from $U[-0.3; 0.085]$ to $N(0.067; 0.04^2)$, with bounds of $[-0.3; 0.3]$, corresponding to the distribution obtained from a Bayesian hierarchical meta-analysis of rates of increase in other formerly depleted mysticete populations (Branch *et al.*, 2004).
- (6) **No JSV.** The JSV data (Japanese Scouting Vessels) were excluded from the assessment.
- (7) **No JARPA.** The JARPA data (Japanese Whale Research Program Under Special Permit in the Antarctic) were excluded from the assessment.
- (8) **Only IDCR.** Both JSV and JARPA data were excluded from the assessment.
- (9) **Increase IDCR/SOWER.** The IDCR/SOWER absolute abundance estimates were increased by 30%, the upper limit of the suggested bias in the current abundance estimates due to whales missed on the trackline, north of 60°S and in the pack ice (Branch 2008).

Results, summarised in Table 3, indicated that over the range of sensitivity tests examined, very similar median and 95% credibility intervals were obtained compared to the base case. The rate of increase was consistently estimated to be 5.3–7.6%, with a high probability that the population is increasing (≥ 0.988). Lowest median abundance was estimated to have been 306–481 in 1971 or 1972, followed by an increasing trend to a median of 1,595–1,915 in 1997.

In discussion, the possibility of performing assessments on a more regional basis than circumpolar was raised. The sub-committee was informed that this had been previously considered as it was believed that different histories of exploitation might have led to varying levels in depletion in the IWC Management Areas. In response, the sub-committee was informed that abundance estimates are not informative enough to conduct assessments at a finer spatial scale than the Antarctic as a whole, and that assuming shared r parameters across Areas (e.g. Area II), as in a previous analysis (Rademeyer *et al.* 2003), would not allow for the investigation of different levels of regional recovery.

Compared to the previous assessment (Branch *et al.*, 2004), this revised assessment indicates a higher pre-exploitation abundance, slightly lower estimated rate of increase, and similar depletion levels, and has generally narrower 95% credibility intervals around the parameters of interest.

The sub-committee agreed on the following estimates of the status of Antarctic blue whales (with 95% credibility intervals in brackets): pre-exploitation abundance of 256,000 (235,000–307,000) decreasing to a minimum abundance of 395 (235–804), which was 0.0015 (0.0010–0.0028) of the original abundance, followed by a significant rate of increase (with probability 0.998) of 6.4% (2.4–8.4%) per annum, leading to the most recent survey abundance estimate in 1997 of 2,280 (from Branch, 2008), which is 0.009 (0.007–0.010) of the original abundance.

The sub-committee expressed its appreciation for the considerable work done by Branch in undertaking this assessment and other blue whale analyses discussed by the sub-committee.

4. OTHER

SC/60/SH35 was not presented due to lack of time.

5. WORK PLAN AND BUDGET CONSIDERATIONS

5.1 Humpback whales

Considering discussions on item 2 regarding the research required to advance with the assessment of Southern Hemisphere humpback whales, the sub-committee agreed that the completion of the assessments of BSB and BSC is a matter of highest priority and decided on the following work plan:

- (1) Organisation of an intersessional workshop to develop methodologies appropriate for modelling the complexities in mixing and sub-structure associated with BSB and BSC, and BSD, BSE and BSF. This item has financial implications for the sub-committee. A proposal for this workshop is presented in Appendix 4. This proposal will address the following aspects:
 - a. Mixing of these stocks / sub-stocks on the feeding grounds.
 - b. Allocation of past catches on the feeding grounds between stock/sub-stocks, using genetic data to estimate the proportions of such stocks /sub-stocks in different longitudinal regions at high latitudes.
 - c. Disaggregation of population models by sex to take account of information indicating other than 50:50 sex ratios in data for catches or information relating to abundance.
 - d. Estimation of exchange rates between sub-stocks on or near breeding grounds using capture-recapture data.
 - e. Review of results from internal simulation testing of models to estimate exchange rates, and finalisation of such tests to provide a basis to select appropriate models and subsequent consideration of the results at the 2009 Scientific Committee meeting.

- f. Clear specifications of the various categories of input data needed to implement such models.
- (2) Continue the development of humpback whale assessment models (Johnston). This item has financial implications to the sub-committee. A proposal to conduct this work is presented in Appendix 5.
 - (3) Revise the genotyping error in data available for sub-stocks C1, C3, B1 and B2 (i.e. assess allelic dropout rates in order to improve estimates of interchange and abundance among the BSB and BSC, with reference to the recommendations laid out in SC/60/SD1 - Rosenbaum).
 - (4) Obtain information on sex ratios from stocks C1 and C3, investigate possible sources of sampling bias in capture and obtain sex-specific abundance estimates for potential inclusion in age-structured population dynamics models (Rosenbaum).
 - (5) Collection of genetic and photo-ID material from region B2N (currently no data available) in order that the southern border of breeding stock B1 can be identified (Findlay and Best).

A further item with financial implications for the sub-committee is the Antarctic Humpback Whale Catalogue, with a budget of £6,600.

5.2 Blue whales

5.2.1 Antarctic blue whales

The sub-committee agreed that the analysis for Antarctic blue whales when combined at a circumpolar level, was complete, and the priority of Antarctic blue whales to the subcommittee could be lowered for next year.

The sub-committee recommended that the previous area-specific analyses (Rademeyer *et al.*, 2003) be examined by Branch, Butterworth and Rademeyer and their conclusions presented at next year's meeting, with a view to seeing whether it was worth conducting separate assessments for each IWC Management Area in future (post SC61) meetings.

The sub-committee recommended analysing the blue whale photographs taken during the JARPA surveys for next year (Pastene) with a view to adding those to the larger catalogue maintained by Olson once those analyses had been conducted.

5.2.2 Pygmy blue whales

The sub-committee recognised that to undertake assessments it is necessary to have acceptable abundance estimates. Therefore, the subcommittee recommended that abundance estimates be developed. Two areas of special interest are Western Australia and the coast of Chile.

The sub-committee recommended that the estimates of natural mortality for pygmy blue whales (based on age data from whales caught throughout the entire Indian Ocean) be analysed with a simple age-structured model that would include estimating separate selectivities for the Japanese and Soviet fleets operating in the region. This work was to be undertaken by Branch and Butterworth with no funding implications.

The subcommittee recommended that a photographic catalogue be developed which included all photographs of blue whales in the Southern Hemisphere including Australia, Chile, Indonesia, the northern Indian Ocean (Maldives) and the Antarctic to test for resightings between these disparate areas. This item has financial implications for the sub-committee. A funding proposal to conduct this work is presented in Appendix 6.

The sub-committee agreed with the proposed work plan.

Intersessional E-mail groups will be as follows:

Group	Terms of Reference	Membership
Southern Hemisphere Humpback Whales Breeding Stocks B and C (Working Group).	Advance the assessment of humpback whale breeding stocks B and C	Zerbini (Convenor), Best, Butterworth, Cerchio, Collins, Donovan, Findlay, Jackson, Johnston, Loo, Rosenbaum, Weinrich
Intersessional Workshop on Assessment Methodology to take account of Mixing/Interchange between Southern Hemisphere Humpback Populations (Steering Group).	The Terms of Reference of the workshop are to progress and desirably agree the following aspects of the methodology needed for the assessment of the B and C, and the D, E and F breeding stocks in combination: (1) Mixing of these stocks/sub-stocks on the feeding grounds, (2) allocation of past catches on the feeding grounds between stock/sub-stocks, using genetic data to estimate the proportions of such stocks/sub-stocks in different longitudinal regions at high latitudes, (3) disaggregation of population models by sex to take account of information indicating other than 50:50 sex ratios in data for catches or information relating to abundance, (4) estimation of exchange rates between sub-stocks on or near breeding grounds using capture-recapture data, (5) review results from initial simulation testing of models put forward to estimate exchange rates and finalise further simulation tests to allow selection of appropriate models and (6) clearly specify the various categories of input data needed to implement such models.	Zerbini (Convenor), Baker, Butterworth, Donovan, Double, Hammond, Jackson, Punt, Rosenbaum, Wade and Weinrich

6. ADOPTION OF THE REPORT

The report was adopted on 10 June 2008 at 11:00. The Chair expressed its appreciation to all participants for all their hard work, in particular to the rapporteurs. The sub-committee thanked the Chair and rapporteurs for the successful completion of the report.

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Table 1. Humpback whale population dynamics model without exchange between sub-stocks on their breeding grounds (RUN1; posterior medians with 5th and 95th percentiles in parenthesis). Model includes fitting to photo-ID capture-recapture data for both sub-stocks (see text). Results assume $r^{C2+3} \sim \text{post BS A}$ and $r^{C1} \sim U[0, 0.106]$.

	Sub-stock C1	Sub-stock C2+3
r prior	U[0, 0.106]	post BS A
Historic catch	Feeding grounds split proportional to abundance	Feeding grounds split proportional to abundance
Recent abundance	5965 (2003)	None
Trend information	Cape Vidal and SPUE only	None
Capture-recapture data	photo-ID data (excluding 2000 and 2004)	photo-ID data (excluding 2002)
r	0.093 [0.073; 0.104]	0.048 [0.012; 0.088]
K	8,363 [8,066; 9,227]	11,015 [9,225; 16,681]
N_{min}	341 [254; 673]	2,142 [784; 5,535]
N_{2006}	7,433 [6,492; 8,084]	8,599 [6,587; 11,333]
N_{min}/K	0.041 [0.031; 0.073]	0.194 [0.082; 0.341]
N_{2006}/K	0.890 [0.728; 0.968]	0.783 [0.464; 1.000]
N_{2020}/K	0.996 [0.971; 0.999]	0.945 [0.547; 1.000]
N_{2041}/K	1.000 [1.000; 1.000]	0.996 [0.670; 1.000]

Table 2. Humpback whale breeding stock G model parameter estimates. Posterior medians with the 5th and 95th percentiles (in parentheses) are reported. An N_{min} constraint > 108 is imposed.

	Previous assessment	Updated assessment
r prior	$r \sim U[0, 0.106]$	$r \sim U[0, 0.106]$
Historic catch	Fringe	Fringe
Recent abundance	Felix <i>et al.</i> (2006) 2917 in 2003	Felix <i>et al.</i> (in press) 6118 in 2004
Trend information	IDCR/SOWER	IDCR/SOWER
r	0.060 [0.023; 0.088]	0.100 [0.061; 0.106]
K	11,677 [10,697; 13,889]	10,402 [10,262; 11,673]
N_{min}	390 [150; 1,232]	234 [149; 838]
N_{2006}	3,452 [2,454; 4,682]	6,847 [5,243; 8,632]
N_{min}/K	0.033 [0.014; 0.089]	0.020 [0.013; 0.069]
N_{2006}/K	0.277 [0.185; 0.391]	0.650 [0.486; 0.815]
N_{2020}/K	0.593 [0.290; 0.849]	0.979 [0.872; 0.994]
N_{2040}/K	0.950 [0.458; 0.997]	1.00 [0.994; 1.000]

Table 3. Antarctic blue whale assessment: results of sensitivity tests for the rate of increase, probability that the population is increasing (P), minimum abundance (N_{min}), and abundance in 1997 (N_{1997} , the mid-year of the most recent IDCR/SOWER survey estimate). Results are posterior medians with 95% credibility intervals in brackets where appropriate, and are based on the exponential model starting in 1965 that is presented in SC/60/SH7.

Scenario	Rate of increase	P increase	N_{min}	N_{1997}
Base case	0.064 (0.024; 0.084)	0.998	378 (236; 795)	1,739 (1,022; 2,832)
r wide	0.068 (0.026; 0.103)	0.999	348 (227; 780)	1,856 (1,056; 3,332)
Zero minimum	0.064 (0.022; 0.084)	0.999	374 (217; 803)	1,699 (1,003; 2,785)
r wide zero minimum	0.076 (0.030; 0.127)	0.999	306 (127; 712)	1,915 (1,048; 3,450)
r biological	0.053 (0.024; 0.082)	0.998	438 (250; 810)	1,597 (992; 2,674)
r other whales	0.069 (0.030; 0.101)	1.000	351 (227; 707)	1,853 (1,083; 3,186)
No JSV	0.063 (0.023; 0.084)	0.999	385 (236; 804)	1,746 (1,019; 2,869)
No JARPA	0.059 (0.008; 0.083)	0.988	426 (245; 1,005)	1,732 (973; 2,843)
Only IDCR	0.059 (0.009; 0.083)	0.991	435 (246; 989)	1,720 (962; 2,874)
Increase IDCR/SOWER	0.064 (0.025; 0.084)	0.999	481 (273; 986)	2,226 (1,308; 3,630)

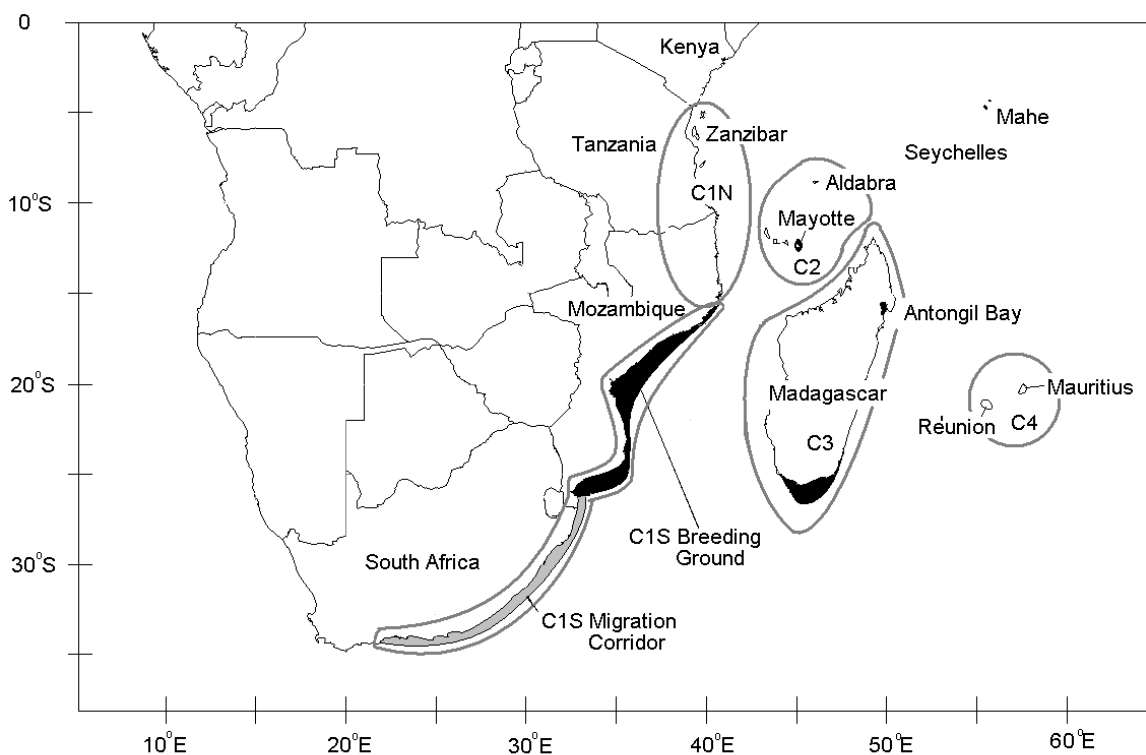


Figure 1. Sub-stock division Southern Hemisphere breeding stock C, as proposed in IWC (2006).

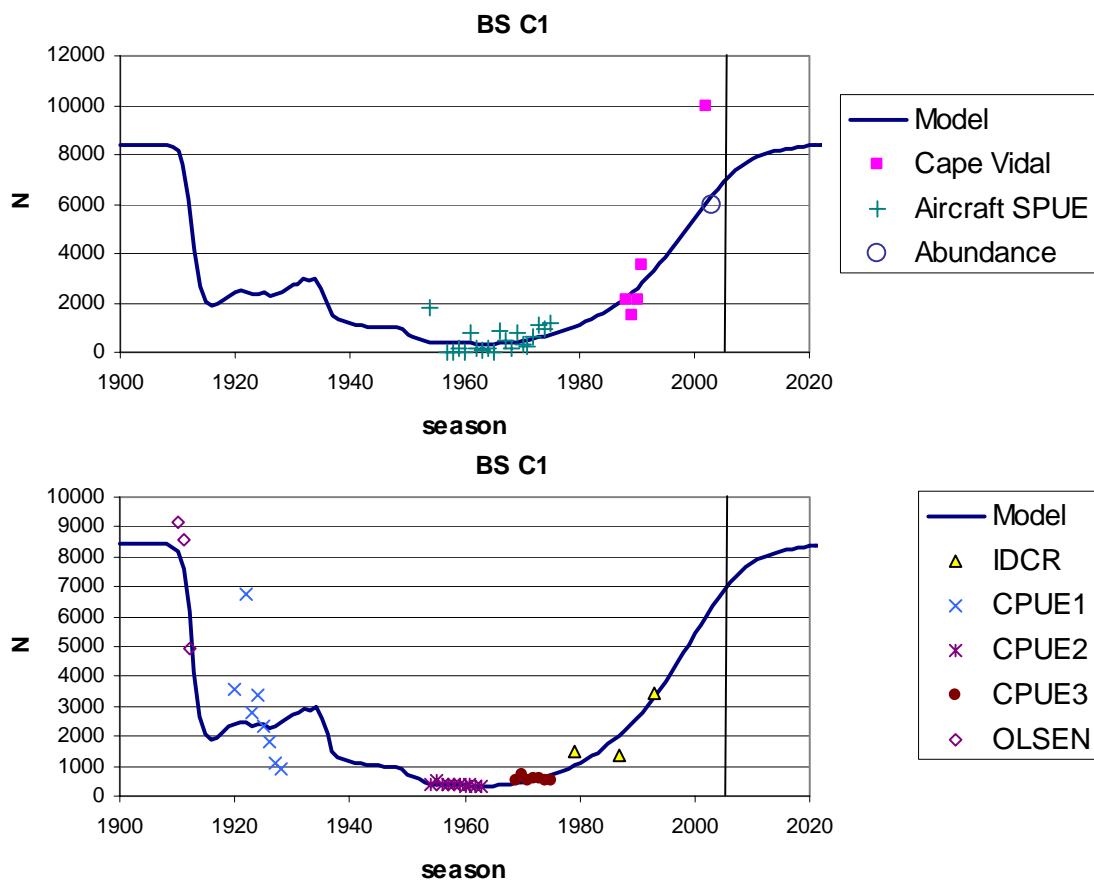


Figure 2a: Humpback whale population dynamics model without exchange between sub-stocks on their breeding grounds (RUN1) fitted to sub-stock C1 Cape Vidal and SPUE trend information, where the population trajectory shown is the Bayesian posterior median. The vertical line shows 2006. The lower plot compares this population trajectory with the Olsen's, CPUE1, CPUE2, CPUE3 and IDCRC trend information which is not used to fit the model. Further information on all these series is provided in SC/60/SH38; Best ascribes the lack of fit to the CPUE1 series to a movement offshore by the whalers during this period to focus on other species.

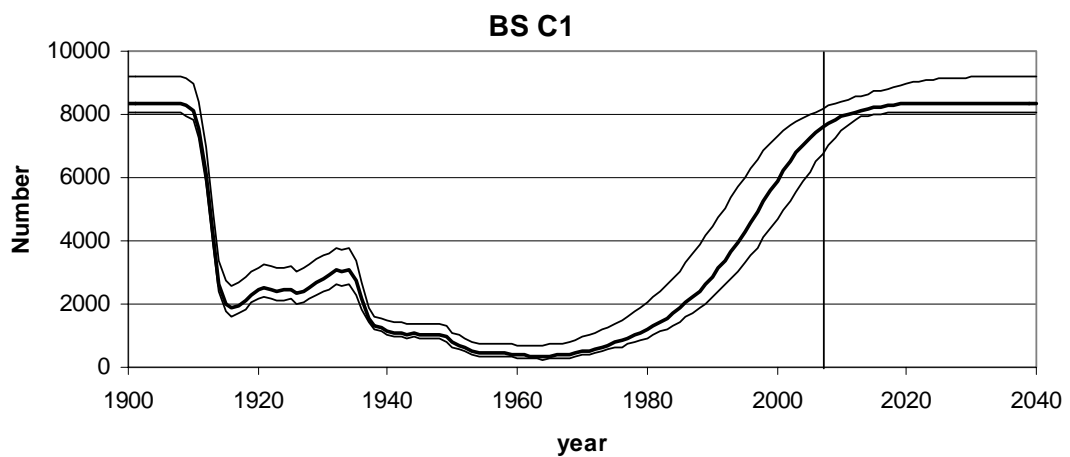


Figure 2b: Humpback whale population dynamics model without exchange between sub-stocks on their breeding grounds (RUN1). Sub-stock C1 population trajectories, showing the median and 95% probability envelopes. The vertical line shows 2006.

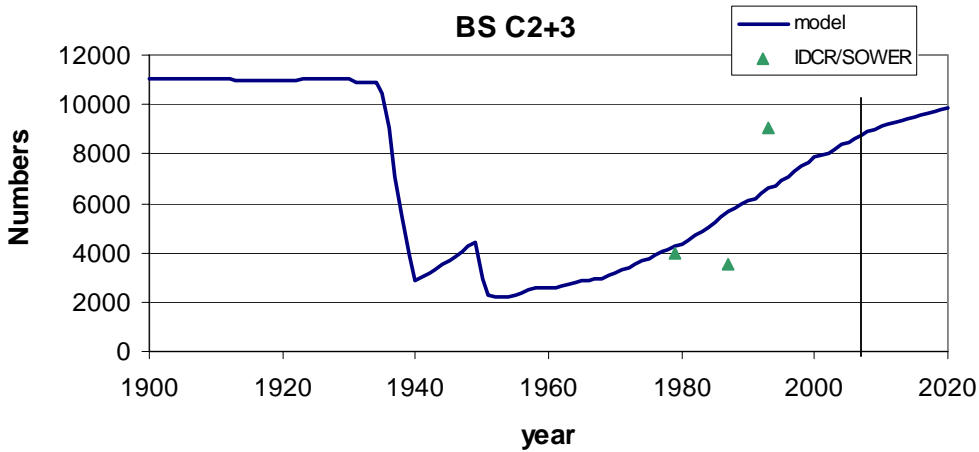


Figure 3a: Humpback whale population dynamics model without exchange between sub-stocks on their breeding grounds (RUN1). Results for the sub-stock C2+3 population. The trajectory shown is the posterior median. Note that the model is fitted directly to annual capture-recapture data (see text); the IDCR/SOWER data shown below are not taken into account in this fitting process. The vertical line shows 2006.

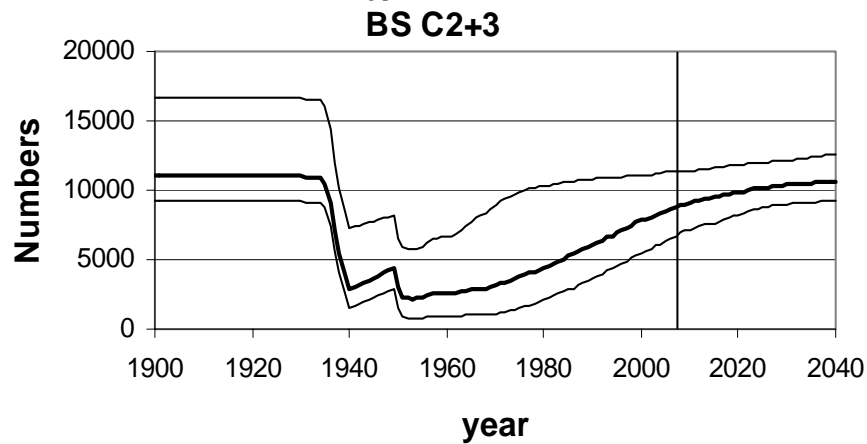
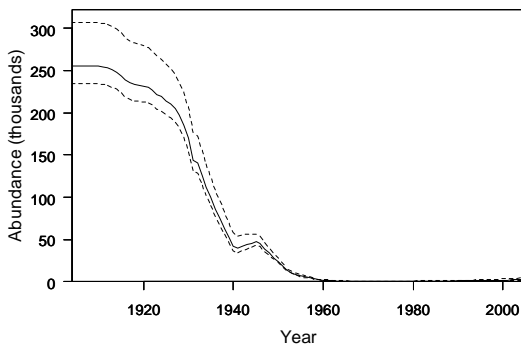
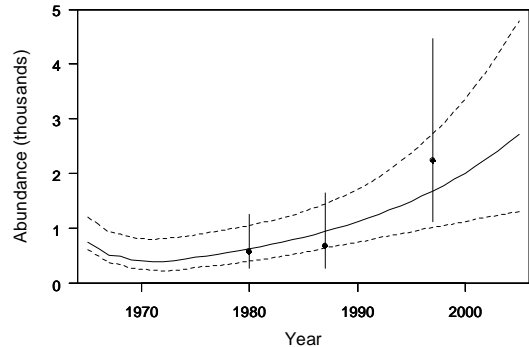


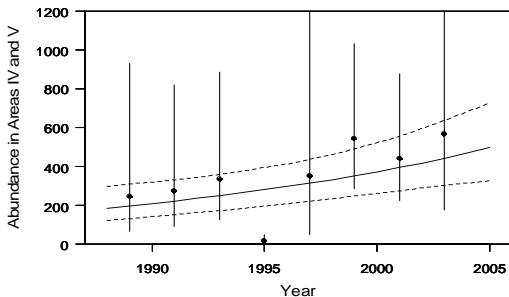
Figure 3b: Humpback whale population dynamics model without exchange between sub-stocks on their breeding grounds results for the sub-stock C2+3 population trajectories showing the median and 95% probability envelopes. The vertical line shows 2006.



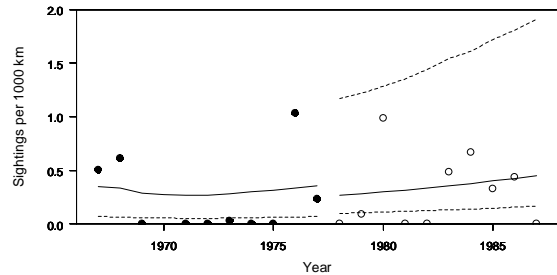
A – Population trajectory of Antarctic blue whales from 1904 to 2005 based on the logistic model. Solid line is posterior median, dashed lines are posterior 95% intervals.



B – Logistic model fit to the IDCR/SOWER circumpolar abundance estimates (close-up of the trajectory given in A after 1965).



C – Logistic model fit to the JARPA abundance estimates combined for Area IV (70°E–130°E) and Area V (130°E–170°W). Upper confidence intervals for the 1997/98 and 2003/04 estimates exceed the graph dimensions.



D – Logistic model fit (solid lines are the medians, dashed lines are the 95% credibility intervals) to the JSV sighting rates from the early period (filled circles) and late period (open circles). The upper credibility interval for the early period is 20–29 per 1000 km and is outside the scale of the figure.

Figure 4. Population trajectories of Antarctic blue whales.

Appendix 1

AGENDA

1. Introductory Items
 - 1.1. Opening Remarks
 - 1.2. Election of Chair
 - 1.3. Appointment of rapporteurs
 - 1.4. Adoption of the agenda
 - 1.5. Review of documents
2. Assessment of Southern Hemisphere Humpback Whales
 - 2.1. General information
 - 2.2. Stock structure in the feeding grounds
 - 2.3. Breeding Stocks B
 - 2.3.1. Distribution, movements and population structure
 - 2.3.2. Abundance and trends
 - 2.3.3. Assessment models
 - 2.4. Breeding Stock C
 - 2.4.1. Distribution, movements and population structure
 - 2.4.2. Abundance and trend estimates
 - 2.4.3. Assessment
 - 2.5. Other Breeding Stocks
 - 2.5.1. Distribution, movements and population structure
 - 2.5.2. Abundance and trend estimates
 - 2.5.3. Assessment
 - 2.6. Antarctic Humpback Whale Catalogue
 - 2.7. Other
3. Assessment of Southern Hemisphere Blue Whales
 - 3.1. New Information
 - 3.1.1. Report of the Cape Town Workshop
 - 3.1.2. Distribution, movements and population structure
 - 3.1.3. Acoustics
 - 3.1.4. Biological information
 - 3.1.5. Abundance and trend estimates
 - 3.1.6. Catch data
 - 3.1.7. Other
 - 3.2. Assessment
 - 3.2.1. Antarctic Blue Whales
4. Other
5. Work Plan and Budget Considerations
6. Adoption of the Report

Appendix 2

REPORT OF THE WORKING GROUP TO ADDRESS MAXIMUM GROWTH RATES IN BLUE AND HUMPBACK WHALES

Trevor A. Branch, Doug Butterworth, Phillip J. Clapham, Jennifer A. Jackson, Paul R. Wade, Alexandre N. Zerbini

Terms of Reference

The terms of reference for the working group were:

- (1) to examine the approach used to compute maximum population growth rates;
- (2) to discuss whether the choice of percentile was appropriate.

Discussion

Branch (SC/60/SH8) and Zerbini *et al.* (SC/60/SH30) used a similar modelling approach to estimate a distribution of growth rates for blue and humpback whales based on life history data for these species. While the methods were comparable, Branch was using the life history data to provide an informative prior on mean growth rates for blue whales, while Zerbini *et al.* were looking for a maximum bound. For this reason, the latter authors used more extreme estimates of life history (as opposed to an average). Branch suggested that the upper 99th percentile on the growth rates distribution should correspond to the upper bound in prior distributions used for assessment models. This choice excluded only 0.5% of the most extreme (higher) rates. In contrast, Zerbini *et al.* suggested the 90th percentile for humpbacks, which excluded 5% of the most extreme values.

Survival rates

In discussion, the group noted that survival has a strong influence on plausible rates. Both reports used the constraint $S_j < S$ (S_j refers to juvenile survival, S to adult survival). S_j is expected to be substantially lower than S for both species but there are few data available to inform these parameters. There are wide variances on the available estimates for S . It was suggested that high survival rates are used (0.97, 0.98, 0.99) in order to explore model sensitivity. Alternatively the highest survival rate encompassed by the upper confidence boundary in the available S estimates may provide an appropriate value for the model. However, concerns were raised regarding how S_j should be constrained relative to this high value in the model.

Zerbini proposed that an examination of all available information regarding S_j and S for cetaceans and other long-lived mammals could provide additional information on average ratios and potentially inform these models. The group agreed that this was a sensible approach.

Estimation of pregnancy and calving rates

There was some discussion regarding whether current estimated calving rates were too conservative. However, it was observed that neonatal mortality rates in the North Pacific may be high, specifically that a number of mothers on wintering grounds without calves may have calved and lost neonates before they were observed. This would result in the current estimates of calving rates being biased downward. An enquiry was raised as to the possibility of cows becoming pregnant immediately after losing calves. One year inter-birth intervals are known to occur, but the average calving interval is > 2 yr in the Northern Hemisphere.

Maximum plausible rates and known trends, modelling and percentiles

SC/60/SH30 observes that the maximum plausible rate of increase for humpbacks (one-sided 95th percentile) is 10.3%. This value is below the lower confidence boundaries (10.65/year) of the estimated population increase in eastern Australia (SC/60/SH31) although the variance on this trend estimate is narrow and various aspects of the data (influence of initial years, corroboration of different counts etc.) have been explored.

The group agreed that this observed trend may be valid, though two points were noted;

- 1) Other biological factors may be influencing the trend estimation, such as immigration from other populations (Clapham and Zerbini, 2006).
- 2) Sample variance and empirical variance may not have been appropriately accounted for in higher trend estimates such as the one presented in SC/60/SH31. This should be further investigated.

Additionally it was observed that the majority of life history estimates for humpbacks that were available were from Northern Hemisphere stocks, where estimates of population growth rates are lower than have been estimated for the Southern Hemisphere. Obtaining life history estimates for southern hemisphere stocks would be valuable to understanding the observed population growth rates. An explanation for the discrepancy between the observed population growth rates and the maximum rate calculated from life history data could simply be a difference between Southern and Northern Hemisphere humpbacks. Constructing a hypothetical life history that would allow for the observed growth rates could generate hypotheses that could be tested with the collection of additional data.

The group agreed that the modelling approach used by Branch and Zerbini *et al.* was useful but should be further explored (e.g. in a Bayesian framework) in order to identify the various combinations of life history parameters which would allow for higher population growth (such as that described in SC/60/SH31).

While the choice of any particular percentile as a delimiter is somewhat arbitrary, the group agreed that for the time being the 99th percentile could be used as a common delimiter to determine the boundary of the maximum plausible rate of increase for modelling purposes, though concerns regarding the biological implausibility of such rates were noted. This corresponds to eliminating the upper 1% of the estimated distribution and equates to 8.5% / year for blue whales and 11% / year for humpbacks. The group agreed that Branch would use the approach of Zerbini *et al.* to explore the maximum plausible growth rates for blue whales e.g. looking at maximum life history parameter values and that these values should be used as upper bounds in prior distributions in assessment models. Any rate close to this boundary might be plausible, but it should be emphasised that such rates require extreme values for all life history parameters.

The group also discussed an alternative approach, previously described in Brandão *et al.* (2000), which takes the maximum possible fixed value of each life history parameter in order to provide a maximum point estimate of rates instead of placing a distribution on each parameter. It was noted that this approach does not take uncertainties in parameter estimation into consideration.

REFERENCES

- Brandão, A., Butterworth, D.S. and Brown, D.R. 2000. Maximum possible humpback whale increase rates as a function of biological parameter values. *J. Cetacean Res. Manage.* (Supplement) 2:192-193.
- Clapham P.J. and Zerbini A. 2006. Is social aggregation driving high rates of increase in some Southern Hemisphere humpback whale populations? Paper SC/58/SH3 presented to the IWC Scientific Committee, May 2006 (unpublished). 12pp. [Available from the office of this Journal].

Appendix 3

INTERCHANGE BETWEEN BREEDING STOCKS C1 AND C3 AS ASSESSED BY LIVE CAPTURE MULTI-STRATA MODEL IMPLEMENTED IN PROGRAM MARK

Salvatore Cerchio

The following analysis was conducted using data from SC/60/SH33, humpback whale capture-recapture data using tail flukes identification photographs from sub-stocks C1 and C3 in the western Indian Ocean. The purpose of SH33 was to assess interchange of individuals between these sub-stocks. In this report it was concluded that mixing between C1 and C3 sub-stocks was not random, nor were the two regions entirely demographically isolated. However, it was also concluded that the recapture data was inadequate for estimation of a parameter of interchange. Despite these recommendations by the authors, it was recommended by the SH Subcommittee Working Group to Assess Humpback Whale breeding stocks B and C that such an analysis could be informative to the recovery assessment, and hence the following analysis was conducted and presented in session. The data was submitted to various models formulated in the Program MARK Live Capture Multi-Strata model (White et al. 2001), assumptions and structure of which are detailed below from the software's documentation following the tables of results.

Only data from years 2003, 2005 and 2006 were used in this assessment, as these were the only with appreciable numbers of samples (see SC/60/SH33 for details of sample). Tables 1 and 2 present model results using photographic data after filtering for quality (see SC/60/SH33 for procedure). Model evaluation results (Table 1) are presented for 12 model variations, and parameter estimation results (Table 2) are listed for all models that reported a Delta AICc less than 2.0. Note that when interchange probability (Psi) is estimated as a constant parameter for both directions of interchange, it is robust to model variations at approximately 0.072 (0.01, 0.38). When Psi is estimated as a regionally dependent parameter, the value changes, but it is again robust to model variation. In this latter case, since there was only 1 recapture in a single capture-recapture direction (C1 -> C3) the estimate increases to approximately 0.12 (0.01, 0.58), whereas the opposite direction (C3->C1) is estimated as 0. Since this is both unrealistic and the observed direction of recapture was entirely subject to stochasticity, the modelling of Psi as a constant parameter is preferable until better data with more recaptures is obtained.

Tables 3 and 4 explore the use of all photographic data including poor photographs. In doing so an additional inter-region recapture was included. It is noted that addition of poor quality photographs increases the probability of a false negative in the data, and thus increases the potential for bias. Since this bias will disproportionately affect inter-region recaptures (numbering 2) over intra-regional recaptures (numbering 7 for sub-stock C1, and 40 for sub-stock C3), the resultant bias on the interchange probability will be negative. Therefore the resulting estimates of interchange probability can be considered conservative. Since the addition of the single interregional recapture doubles the sample, the Psi point estimate increases slightly with comparable CI to approximately 0.13 (0.03, 0.41), when estimating Psi as a constant parameter. All estimates presented in this exercise should be considered with some caution given the sampling and data concerns discussed in detail in SC/60/SH33.

REFERENCES

More details on the theory of the multi-strata model are available at the WWW site http://www.cnr.colostate.edu/class_info/fw883/multistrata.pdf.

Table 1. Results of Program MARK multi-strata model assessment for estimation of interchange between C1 and C3, using data from years 2003, 2005 and 2006 and quality filtered photographic IDs. Model notation (column 1) is explained in last three columns.

Model	AICc	Delta AICc	AICc Weights	Model Likelihood	Num. Par	Deviance	Survival (S)	Capture (p)	Exchange (pi)
{S=0.96,pXY,pi}	122.490	0.000	0.180	1.000	3	7.704	Fix at 0.96	Reg	Constant
{S=0.98,pXY,pi}	122.539	0.049	0.176	0.976	3	7.753	Fix at 0.98	Reg	Constant
{S=0.96,pXtYt,pi}	122.853	0.363	0.150	0.834	5	3.996	Fix at 0.96	Reg & Time	Constant
{S=0.98,pXtYt,pi}	122.893	0.403	0.147	0.818	5	4.036	Fix at 0.98	Reg & Time	Constant
{S=0.96,pXY,piXY}	123.863	1.373	0.091	0.503	4	7.045	Fix at 0.96	Reg	Reg
{S=0.98,pXY,piXY}	123.919	1.429	0.088	0.489	4	7.102	Fix at 0.98	Reg	Reg
{S,pXY,pi}	124.367	1.877	0.070	0.391	4	7.549	Constant	Reg	Constant
{S,pXY,piXY}	125.691	3.201	0.036	0.202	5	6.834	Constant	Reg	Reg
{S,pXtYt,piXY}	126.262	3.772	0.027	0.152	7	3.303	Constant	Reg & Time	Reg
{SXY,pXY,piXY}	126.967	4.477	0.019	0.107	6	6.064	Reg	Reg	Reg
{S,pXY,piXtYt}	128.827	6.337	0.008	0.042	7	5.868	Constant	Reg	Reg & Time
{S,pXtYt,piXtYt}	129.055	6.565	0.007	0.038	9	1.962	Constant	Reg & Time	Reg & Time

Table 2. Parameter estimates from multi-strata models evaluated in Table 1. S = survival, p = probability of capture, Psi = probability of exchange, EAM = East African Mainland (C1), MAD = Madagascar (C3).

{S=0.96,pXY,pi}					
Index	Label	Estimate	SE	LCI	UCI
1	S	0.96	0	0.96	0.96
2	p MAD	0.024812	0.0082039	0.012922	0.047122
3	p EAM	0.0059112	0.004172	0.001477	0.023353
4	Psi	0.0721162	0.0706298	0.009724	0.380876

{S=0.98,pXY,pi}					
Index	Label	Estimate	SE	LCI	UCI
1	S	0.98	0	0.98	0.98
2	P MAD	0.0238409	0.0078809	0.01242	0.045282
3	p EAM	0.0056795	0.0040083	0.001419	0.022444
4	Psi	0.072144	0.0706498	0.009729	0.380939

{S=0.96,pXtYt,pi}					
Index	Label	Estimate	SE	LCI	UCI
1	S	0.96	0	0.96	0.96
2	p MAD	0.0086463	0.0086165	0.001215	0.058875
3	p MAD	0.0323681	0.011304	0.016221	0.063549
4	p EAM	0	0	0	0
5	p EAM	0.0086225	0.0060776	0.002154	0.033856
6	Psi	0.0722345	0.0706988	0.009751	0.381031

{S=0.98,pXtYt,pi}					
Index	Label	Estimate	SE	LCI	UCI
1	S	0.98	0	0.98	0.98
2	p MAD	0.008298	0.0082694	0.001166	0.056582
3	p MAD	0.0311238	0.0108701	0.015601	0.061132
4	p EAM	0	0	0	0
5	p EAM	0.0082909	0.0058439	0.002072	0.032572
6	Psi	0.0722626	0.0707185	0.009757	0.381091

{S=0.96,pXY,piXY}					
Index	Label	Estimate	SE	LCI	UCI
1	S	0.96	0	0.96	0.96
2	p Y:MAD	0.0218098	0.0076756	0.010895	0.043183
3	p X:EAM	0.0069349	0.0050362	0.001663	0.028446
4	Psi Y to X	0	0.0000001	-1E-07	1E-07
5	Psi X to Y	0.1119315	0.1222661	0.011185	0.584106

{S=0.98,pXY,piXY}					
Index	Label	Estimate	SE	LCI	UCI
1	S	0.98	0	0.98	0.98
2	p Y:MAD	0.0209495	0.007373	0.010467	0.041491
3	p X:EAM	0.0066659	0.0048414	0.001598	0.027359
4	Psi Y to X	0	0	0	0
5	Psi X to Y	0.1116403	0.1220461	0.01114	0.583672

{S,pXY,pi}					
Index	Label	Estimate	SE	LCI	UCI
1	S	0.8343175	0.2985636	0.068064	0.997128
2	p MAD	0.0322854	0.0236306	0.007519	0.128098
3	p EAM	0.0076988	0.0074222	0.001154	0.049514
4	Psi	0.0719419	0.0705084	0.009688	0.380511

Table 3. Results of Program MARK multi-strata model assessment for estimation of interchange between C1 and C3, using data from years 2003, 2005 and 2006 and all photographic IDs. Model notation (column 1) is explained in last three columns.

Model	AICc	Delta AICc	AICc Weights	Model Likelihood	Num. Par	Deviance	Survival (S)	Capture (p)	Exchange (pi)
{S=0.96,pXtYt,pi}	138.1728	0	0.16744	1	5	5.676069	Fix at 0.96	Reg & Time	Constant
{S=0.98,pXtYt,pi}	138.185	0.0122	0.16642	0.9939	5	5.688217	Fix at 0.98	Reg & Time	Constant
{S=0.96,pXY,pi}	138.6295	0.4567	0.13326	0.7959	3	10.19011	Fix at 0.96	Reg	Constant
{S=0.98,pXY,pi}	138.6473	0.4745	0.13208	0.7888	3	10.20787	Fix at 0.98	Reg	Constant
{S=0.96,pXY,piXY}	139.3589	1.1861	0.09253	0.5526	4	8.894075	Fix at 0.96	Reg	Reg
{S=0.98,pXY,piXY}	139.389	1.2162	0.09115	0.5444	4	8.924168	Fix at 0.98	Reg	Reg
{S,pXtYt,piXtYt}	140.1072	1.9344	0.06365	0.3801	8	1.475777	Constant	Reg & Time	Reg & Time
{S,pXY,pi}	140.6411	2.4683	0.04874	0.2911	4	10.17627	Constant	Reg	Constant
{S,pXtYt,piXY}	141.0777	2.9049	0.03918	0.234	7	4.497743	Constant	Reg & Time	Reg
{S,pXY,piXY}	141.3425	3.1697	0.03432	0.205	5	8.845771	Constant	Reg	Reg
{S,pXY,piXtYt}	142.6533	4.4805	0.01782	0.1064	7	6.073263	Constant	Reg	Reg & Time
{SXY,pXY,piXY}	143.2236	5.0508	0.0134	0.08	6	8.688462	Reg	Reg	Reg

Table 4. Parameter estimates from multi-strata models evaluated in Table 3. S = survival, p = probability of capture, Psi = probability of exchange, EAM = East African Mainland (C1), MAD = Madagascar (C3).

{S=0.96,pXtYt,pi}					
Index	Label	Estimate	SE	LCI	UCI
1	S	0.96	0	0.96	0.96
2	p MAD	0.006797	0.006781	0.000955	0.04672
3	p MAD	0.029917	0.009877	0.015581	0.056683
4	p EAM	0	0	0	0
5	p EAM	0.007027	0.004958	0.001755	0.027699
6	Psi	0.130973	0.089292	0.03137	0.412234

{S=0.96,pXY,pi}					
Index	Label	Estimate	SE	LCI	UCI
1	S	0.96	0	0.96	0.96
2	p MAD	0.022329	0.007021	0.012013	0.041135
3	p EAM	0.004747	0.003353	0.001185	0.018807
4	Psi	0.130816	0.089316	0.031268	0.412379

{S=0.98,pXY,pi}					
Index	Label	Estimate	SE	LCI	UCI
1	S	0.98	0	0.98	0.98
2	p MAD	0.021444	0.006742	0.01154	0.039509
3	p EAM	0.004558	0.003219	0.001139	0.018064
4	Psi	0.130851	0.089325	0.031284	0.412405

{S=0.96,pXY,piXY}					
Index	Label	Estimate	SE	LCI	UCI
1	S	0.96	0	0.96	0.96
2	p Y:MAD	0.017616	0.006184	0.008823	0.034864
3	p X:EAM	0.006634	0.005073	0.001475	0.029312
4	Psi Y to X	0	0	-1E-07	1E-07
5	Psi X to Y	0.221312	0.183806	0.033944	0.696872

{S=0.98,pXY,piXY}					
Index	Label	Estimate	SE	LCI	UCI
1	S	0.98	0	0.98	0.98
2	p Y:MAD	0.016904	0.005938	0.008464	0.033476
3	p X:EAM	0.006379	0.004883	0.001417	0.028236
4	Psi Y to X	0	0	0	0
5	Psi X to Y	0.221144	0.18406	0.03378	0.697517

Appendix 4

COMPREHENSIVE ASSESSMENT OF SOUTHERN HEMISPHERE HUMPBACK WHALES: PROPOSAL FOR AN INTERSESSIONAL WORKSHOP ON ASSESSMENT METHODOLOGY TO TAKE ACCOUNT OF MIXING/INTERCHANGE BETWEEN SOUTHERN HEMISPHERE HUMPBACK POPULATIONS

It has become evident that advances in the "isolated stock" methodology that has been used to assess breeding stocks A and G of the Southern Hemisphere humpback whales are necessary to handle the complexities of mixing and sub-stock structure associated with breeding stocks B and C, and D, E and F.

An intersessional workshop is proposed whose intent would be the development of such methodology to allow its ready application to data for these regions during the 2009 meeting of the Scientific Committee. Without this prior consolidation of methodology, it will not be possible within the time available at the annual meeting of the Scientific Committee to make the progress needed on agreeing both methodology and application to secure reasonable advance in the Comprehensive assessment of humpback whales in the Southern Hemisphere.

Objective

To advance the Comprehensive Assessment of Southern Hemisphere humpback whales by the development of assessment methodology incorporating stock mixing and interchange processes to allow its ready application to data for these regions during the 2009 meeting of the Scientific Committee

Terms of Reference

The Terms of Reference of the workshop are to progress and desirably agree the following aspects of the methodology needed for the assessment of the B and C, and the D, E and F breeding stocks in combination:

- 1) Mixing of these stocks/sub-stocks on the feeding grounds.
- 2) Allocation of past catches on the feeding grounds between stock/sub-stocks, using genetic data to estimate the proportions of such stocks/sub-stocks in different longitudinal regions at high latitudes.
- 3) Disaggregation of population models by sex to take account of information indicating other than 50:50 sex ratios in data for catches or information relating to abundance.
- 4) Estimation of exchange rates between sub-stocks on or near breeding grounds using capture-recapture data.
- 5) Review results from initial simulation testing of models put forward to estimate exchange rates (see 4) above) and finalise further simulation tests to allow selection of appropriate models for this purpose on the basis of test results to be reported at the 2009 Scientific Committee meeting.
- 6) Clearly specify the various categories of input data needed to implement such models.

The Steering Committee proposed for the event is Zerbini (Convenor), Baker, Butterworth, Donovan, Double, Hammond, Jackson, Punt, Rosenbaum, Wade and Weinrich. The Steering Committee will select the participants for the workshop, focusing on scientists able to contribute to the methodological issues to be addressed, but also including some scientists familiar with the assessment-related data available. Depending on circumstances, a day may be appended to the workshop for discussion on the data required for the assessment of breeding stocks B and C.

Essential prerequisites for the Workshop are:

- a) proposals for methods to address 1) to 4) above; and
- b) a report of results of initial simulation testing of methods for estimating exchange rates (see 5) above).

Budget

10,000 pounds is required to cover travel and subsistence costs of 6-7 invited participants at a 5-day workshop, of venue still to be determined.

Appendix 5

SHORT TITLE

Assessment models for Southern Hemisphere humpback whales

RELEVANT AGENDA ITEM (NO. AND TITLE)

10.2 Southern Hemisphere Humpback Whale

BRIEF DESCRIPTION OF PROJECT AND WHY IT IS NECESSARY TO YOUR SUB-COMMITTEE

Further development of assessment models which take account of mixing/interchange between stocks/sub-stocks have been identified as a core need to complete the Comprehensive Assessment of the B and C and the D, E and F groupings of breeding stocks for Southern Hemisphere humpbacks whales, together with simulation testing of the robustness of the associated estimation procedures under alternative models of plausible underlying processes. This project will pursue these general aims, commencing with a simple simulation study of the estimator of exchange rates from capture-recapture data put forward in SC/60/SH37, and extending this to models of a dispersive rather than "visitor" mixing process. This work will first be targeted at the planned intersessional workshop on assessment methodology for these populations, and thereafter at application of approaches developed at that workshop to humpback breeding stocks B and C for report to the 2009 meeting of the Scientific Committee.

TIMETABLE

- a) Initial report of work conducted to the intersessional workshop on humpback assessment methodology
- b) Final report to the 2009 meeting of the IWC Scientific Committee.

RESEARCHERS' NAME

Dr S. Johnston (Holloway) through University of Cape Town

ESTIMATED TOTAL COST WITH BREAKDOWN AS NEEDED (E.G. SALARY, EQUIPMENT)

£2000 (salary contribution)

Appendix 6

SOUTHERN HEMISPHERE BLUE WHALE PHOTO-IDENTIFICATION MATCHING PROJECT

GENERAL AIM:

This project will establish a central web-based system by which southern hemisphere blue whale photo-identification (ID) matching can take place. The system will be developed so that photo ID and associated regional and institutional data will be accessible to users for uploading, updating, and managing their data within a data-base with advanced and multiple search capabilities for matching. The design will allow authorised researchers to access and search the data bank individually for matching identification. Matching will be conducted through this platform by researchers from three southern hemisphere regions. Given the large number of researchers involved, this will be facilitated through one coordinator within each region. The project will result in a report of comparisons and resulting matches made across the three regions. Although the catalogue has been established primarily for the Southern Hemisphere, researchers with new projects in the region are welcome to join.

Project Objectives:

- (1) Establish a central web-based system (by modification of software already developed specifically for blue whales at Mingan Island Studies (Richard Sears and Christian Ramp) with search capabilities for matching of southern hemisphere blue whales.
- (2) Make the electronic format photos accessible through user logins for researchers to conduct a preliminary search of matching photos, which would make it possible for an interested party to contact the researchers "owning" the photo for further information.
- (3) Develop and standardise protocols for data management and searching.
- (4) Integrate photo-id banks from all collaborating institutions into the web-based central database.
- (5) Conduct matching across databases intra and inter-annually, test consistency of matching, and make documentation of resulting matches available to IWC.
- (6) Investigate further image matching techniques.

Rationale:

Very little is known about the migration of blue whales, population sizes, whether the currently defined populations (McDonald 2007) are defined correctly, and the level of interchange of these populations. The answers to these kind of questions can be facilitated to a great extent through obtaining photos of whales, and comparing them to different locations and times to quantify the resight rate of individuals. There are sizable and growing archives of photos taken for this purpose among researchers in the southern hemisphere (Table 1), of which only limited comparisons have been made. This project intends to allow a comparison of blue whale photos among a noteworthy list of researchers working in the southern hemisphere. The facilitation of cross regional matching will result in a considerably better understanding of the basic questions relating to blue whale populations in the southern hemisphere.

CONTACTS BY REGION:

GULF OF CALIFORNIA/EASTERN TROPICAL PACIFIC/SOUTH AMERICA

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Paula Olson, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive
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INDONESIA/AUSTRALIAN/NEW ZEALAND

Chandra Salgado Kent & Rob McCauley: Centre for Marine Science and Technology (CMST), Curtin University, GPO Box U 1987, Perth WA 6845, phone 08 9266 7380.

SECURITY AND DATABASE ACCESS:

Authorised researchers will be allocated a login and password to search a web-based database for matches. The web-based database will consist of all photos, but will only include the contact information of the "owner" of the photo, and region of location. It will then be up to the researcher to contact the "owners" to decide on exchange of information and further collaboration, beyond making this information available for reporting to IWC. Due consideration will be given to incorporating the IWC data availability agreement into the protocol to enable maximum benefit to the work of the IWC Scientific Committee whilst protecting the rights of the data holder.

TIMETABLE

The project will begin as soon as approval is obtained, with the aim of beginning the database development in work in July-Aug of 2008. The timetable for activities is listed in Table 2.

Table 2: Timetable of activities. Personnel are: BG – Barbara Galletti; CR – Christian Ramp; PO – Paula Olson; DG – Diane Gendron; DP – Daniel Palacios; CB – Christopher Burton; CJ – Curt Jenner; MJ – Micheline Jenner; MM – Margie Morrice; PG – Peter Gill; BK – Benjamin Kahn; JC – John Calambokidis; CC – Carole Carlson; TG – Tim Gerodette; NG – Nicholas Gales; MD - Michael Double; CSK – Chandra Salgado Kent; RM – Robert McCauley; RB – Robert Brownell; RH - Rodrigo Hucce; PE – Paul Ensor.

Date	Event	Overseeing Personnel
July/Aug 2008	work begins – establish committed working space & research assistant, acquire software	BG, CR
Sep 2008 – Mar 2009	Develop a secure web-based platform with user login capabilities.	BG
Jan - Mar	Develop criteria for photo inclusion (to ensure quality) and protocols for accurate matching	All collaborators (CC, TG, BG, JC, PO, MJ, CJ, CB, DG, DP, PG, MM, BK, CSK, RM, RH, CR, NG, MD, RB, PE)
Apr	Testing of matching protocol	BG, CSK/RM, PO
Jun – Sep 2009	Upload data banks, and integrate them into central system, and searching by researchers.	CC, TG, BG, PO, MJ, CJ, CB, DG, DP, PG, MM, BK, JC, MD, NG, RH, RB, PE (BG, CSK, PO to coordinate regions)
Nov – Dec 2009	Provide summary report of resulting matches to IWC.	BG, CSK/RM, PO