Annex H

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

Members: Childerhouse (Chair), Al Kiyumi, Baba, Baker, Bannister, Berggren, Birtles, Borsani, Branch, Brandao, Brownell, Jr., Burt, Butterworth, Clapham, Clark, Cooke, Danielsdottir, Diake, Ensor, Forde, Gales, Gidding, Goodman, Goto, Groch, Gunnlaugsson, Hakamada, Haug, Hedley, Hofmann, Holloway, Iñiguez, Kanda, Kasuya, Kato, Kell, Kingsley, Kock, Komatsu, Last, Lawrence, LeDuc, Lima, Lyrholm, Martin, Matsuoka, Minton, Miyashita, Moore, Mori, Morishita, Murase, Nagatomo, Nishiwaki, Okamura, Oosthuizen, Palazzo, Palka, Pastene, Polacheck, Punt, Rademeyer, Rambally, Reeves, Rennie, Ridoux, Ritter, Robbins, Rosenbaum, Sadler, Senn, Shimada, Skaug, Smith, Sohn, Thiele, Tomita, Urban, Walløe, Walters, Weinrich, Williams, Witting, Yamakage, Yamamura, Yoshida

1. CONVENOR'S OPENING REMARKS

Childerhouse welcomed participants.

2. ELECTION OF CHAIR AND APPOINTMENT OF RAPPORTEURS

Childerhouse was elected chair. Clapham undertook the duties of rapporteur.

3. ADOPTION OF AGENDA

The adopted agenda is given in Appendix 1.

4. REVIEW OF DOCUMENTS

Documents identified as containing information relevant to the subcommittee included: SC/55/SH1-21, SC/55/E11-12, IA1, SC/55/O6, 10, SD/55/SD6, For Info 5, 39.

5. SCHEDULE

Childerhouse noted that the Sub-Committee would have eight sessions in which to complete its work.

6. SOUTHERN HEMISPHERE BLUE WHALES

6.1 Abundance and trends estimation

SC/55/SH6, a Bayesian analysis of trends in Antarctic blue whales, was presented by Branch. Bayesian models fitted to three long-term sighting series spanning 1968-2001 suggested that Antarctic blue whales are increasing, at an estimated mean rate of 8.2% per annum (95% interval 1.7-15.3%). This posterior mean rate is higher than might be expected from analyses using informative priors developed from knowledge of blue whale life history (4.3% per annum, 0.6-8.0%), or from a meta-analysis of trends in other blue whale populations (3.1% per annum, 0.0-6.2%). However, it was similar to results from a meta-analysis combining recovery rates of other baleen whale populations (7.4% per annum, 2.9-12.2%). However, these rates were not incompatible because of the wide probability intervals around the estimate based on sightings alone. The estimated 1996 population size, 1800 (900-3500) was estimated to be 0.9% (0.4-1.7%) of the calculated pre-exploitation level.

SC/55/SH20, a parallel paper to SH6, presented density estimates for blue whales from the IDCR-SOWER surveys, calculated at a Management Area level (as opposed to a circumpolar level as in the past) in an attempt to detect significant evidence of a trend. Four different non-parametric tests indicate a statistically significant annual increase at the 5% level. A parametric approach allowing for densities to differ by Area yields a significantly annual increase rate estimate of 11% (s.e. 5%). A population model treating the separate Areas as containing independent stocks is fitted to these and JARPA survey data. The historic catch data used for this exercise reveal that some 90% of these catches came from Area II, III and IV, with Area II dominating. Current population levels as fractions of pristine were estimated to range from 16% (Area VI) down to 0.3% (Area IV). The authors stressed that this population modelling was intended solely as a first exploration of this issue.

Clapham questioned the validity of the estimates of increase rates in SC/55/SH20, although he recognized that this was an exploratory effort. He requested that the authors provide a range of values for demographic parameters (such as sex ratio, age at first parturition and juvenile survival) that would be required to produce the rate given in SC/55/SH20 so that the estimate could be more clearly evaluated in a biological context. Branch subsequently provided this information (Appendix 2). On this point, the Sub-Committee recommended that any future estimates of rates of increase in Southern Hemisphere baleen whale populations include this type of interpretation and context.

Discussion then returned to consideration of SC/55/SH6. Some members questioned the value of calculating rates of increase using non-informative priors, given that much of the resulting distribution is not plausible given knowledge of likely biological parameters for this species. Furthermore, the fact that the posterior distribution was not very different from the informative blue whale prior confirms that the data were not very informative relative to the prior on trends in blue whale abundance. It was also suggested that data from other baleen whale populations are potentially misleading because some species (e.g. balaenids) have very different life histories to blue whales.

Reilly suggested that the 1st, 2nd and 3rd circumpolar surveys for blue whales may have significant biases, and that these may have compromised the results of some of the analyses in both SH6 and SH20. It was suggested that the potential impacts of such biases should be explicitly stated in this and future analyses. However, it was also noted that work on this general problem (notably with regard to minke whale estimates of abundance) was ongoing in the In-Depth Assessments Subcommittee (see IWC 2002, Annex G, Appendix 10), and that results of those discussions could be informative with regard to blue whale work. However, such comparisons should be treated with some caution given that blue and minke whales are different in some respects, and also that the surveys from which these results were obtained were designed primarily to estimate abundance of the latter (not the former) species. In response, the Sub-Committee produced a list of factors and the direction of their influence on estimates of abundance and rates of increase in blue whales (Appendix 3). Branch additionally produced his review of the potential size of these biases and a summary of previous analysis investigating these issues (Appendix 4). Members recognized that many of these potential biases had been discussed by the Scientific Committee over the past four years, but there was insufficient time to thoroughly discuss the extent to which they might have affected the estimates given in SC/55/SH6 and SC/55/SH20.

Following considerable discussion on this topic, Branch summarised the evidence and his conclusions regarding an overall increase in Antarctic blue whales (Appendix 5). Brownell noted that while blue whales might be increasing in some areas, they did not appear to be in others, notably at South Georgia.

Overall, the Sub-committee agreed that there was evidence for an increase in blue whales in some areas of the Antarctic, but without sufficient time to explore issues of potential bias that were raised, it was not possible to accept specific estimates of abundance and trends at this time.

Butterworth drew attention to another aspect of SC/55/SH20, that the breakdown of blue whale catches given in the paper highlighted the concentration of takes from Areas II and III (South Atlantic) at South Georgia and elsewhere. Furthermore, the analysis suggested a somewhat different pattern of present distribution compared to that derived from historic data. In regard to the apparent discrepancy between the catch distribution and the current distribution (based on sightings), Ensor speculated the current distribution might reflect remnant of stocks from particular areas, which survived whaling because such areas are associated with the prevalence of poor weather. Bannister emphasized that prior to 1925 (when factory ships were introduced), the locations of blue whale catches were largely constrained by the ability to work from land stations, the most productive of which were at South Georgia. Bannister indicated that much of the relevant information was available in Mackintosh (1942 and 1965).]

In SC/55/SH18, indices of relative abundance for baleen whales on the Durban (South Africa) whaling ground were compared. This analysis covered three periods: 1920-28, 1954-protection, and 1969-75. Blue whale CPUE from 1954-58 was only 3.6% of its level in the 1920's, and by protection had fallen to only 2.8% of that level. Sighting rates from the catchers from 1969 to 1975 were significantly greater than catch rates in the last eight years of whaling, but sighting rates from spotter aircraft over the same two periods were not significantly different.

It was agreed that the information presented in SH18 was useful as ground-truthing for use in modeling assessments. The paper's author strongly recommended that a re-assessment of southern fin whale stocks be conducted. However, the Sub-Committee agreed that while further exploratory analyses on fin whales would be useful, it was probably premature to consider undertaking such an assessment because this was unlikely to be a priority at the present time.

In SC/55/SH14, results were presented from an acoustic and visual census of mysticetes, including blue whales, in the SO GLOBEC West Antarctic Pensinula region. Blue whales calls were recorded year-round by autonomous recording packages, although visual sightings of blue whales were comparatively rare. These units provide an important tool for such continuous monitoring, and the Sub-Committee recommended that this important work continue.

6.2 Population dynamics modelling

The only paper under this section was SC/55/SH17, which was presented in the Environment Sub-Committee.

6.3 Progress on sub-species identification

6.3.1 Behaviour and morphology

A short paper (SC/55/SH4) presented the first record of a blue whale from New Caledonia; the animal concerned was a juvenile male, and it was eventually attacked and eaten by sharks. Using Kato *et al.*'s method (SC/54/IA8), the authors determined the animal to be a pygmy blue whale. Matsuoka noted that this observation demonstrated the utility of Kato's method for discriminating true and pygmy blue whales according to morphological characteristics.

6.3.2 Acoustics

In SC/55/SDH5, blue whale vocalizations recorded during the 2001-02 and 2002-03 IWC-SOWER circumpolar cruises were analyzed to determine the feasibility of using acoustic recordings for sub-species identification of the true blue whale and the pygmy blue whale. The research was conducted in IWC Area V, from latitude 60 degrees South to the ice edge; and between longitudes 130 to 150 degrees East (2001-02), and 150 E to 170 degrees W (2002-03). A subset of these data, including sounds recorded in the vicinity of 15 groups consisting of 42 animals as well as opportunistic recordings of an unknown number of animals during evening sonobuoy stations, was examined for the study. The results of the study suggest that the peak frequency of 27 Hz vocalizations (which has been recorded only around the Antarctic and therefore are believed to originate from true blue whales) may be used as a diagnostic feature to aid in the discrimination between the sub-species in the field. However, examination of vocalizations in relation to group size and behavior are necessary to understand the circumstances in which the 27 Hz calls were produced.

The Sub-committee agreed with the latter conclusion, and strongly recommended the necessity for linking production of this call with other (visually observed) biological/morphological features of the animals concerned in order to confirm the value of the 27 Hz vocalization as a means of sub-specific discrimination.

Another acoustics paper (SC/5/SH7) examined blue whale songs by worldwide population structure. The recorded songs were divided into nine regional types, which maintained a stable character: the authors indicated that five of the nine song types have been recorded over time spans of 30-40 years, showing no significant change in character. Many of the song types showed distinct and diagnostic differences among ocean basins or smaller areas. Song type 6 (and no other song types) was recorded around the Antarctic continent year-round and is different from song types outside the Southern Ocean. There were also Type 6 recordings in July off Peru (although these were rarely heard), and in June off western Australia, suggesting some movement to lower latitudes during the southern winter. The authors suggest that distinct differences in song provide another data set for comparison with genetic and morphological data used in defining blue whale populations. Furthermore, they recommended that when there is a lack of other data (or lack of clarity in other data sets), evidence of distinct differences in songs between areas could be used as the provisional population structure when making management decisions. They indicated that the differences in song types proposed in the paper could be used to test various phylogeographic hypotheses with other datasets on inter-area differences such as among bones, external measurements, genetics and parasites. However, the Sub-Committee noted that there remained some uncertainty regarding association of call types with true or pygmy blue whales, as evidenced by the occurrence of 27 Hz calls in locations from which pygmy blue whales are more likely to occur.

The results of SC/55/SH7 indicate some mixing of song types in certain areas, and it was not clear whether this was due to mixing of two populations (i.e. seasonal sympatry) or individuals switching song types during different parts of the migratory cycle. Overall, Sub-committee members noted that SC/55/SH7 provided some valuable information and represented a major contribution to knowledge about blue whales. In light of the potential value of these data, the Sub-committee recommended that efforts be made to continue collecting acoustic recordings of blue whales worldwide. Participants also noted that some of the results of SH7 were consistent with satellite tracking data from California, and suggested that additional satellite tagging would serve as a useful complement to acoustic investigations of this type.

In SC/55/SH9, patterns of genetic variation in Southern Hemisphere blue whales were examined using 110 samples from the southeastern Pacific Ocean, the Indian Ocean and around the Antarctic. Each of these strata were found to be distinctly different from the others, in both mitochondrial and nuclear DNA. The differentiation between the geographic ranges of the nominal subspecies (true blue whales in the Antarctic versus pygmy blue whales in the Pacific and Indian Oceans) was not markedly greater than between the populations of pygmy blue whales. In spite of the high level of statistical differentiation, there were no diagnostic differences that would allow confident identification to subspecies of any particular genetic sample of unknown provenance. However, the degree and pattern of differentiation and potential mixing was consistent with the acoustic (SC/55/SH7) and morphological data (SC/54/IA8). In discussion LeDuc noted that higher-resolution analysis comparing the genetic data with details of other types of datasets (such as those on acoustics and morphology) might yield more useful diagnostic differences.

Bannister noted that recommendations had been made previously to obtain historical material from animals of known subspecies. He asked to what extent they were now considered were useful. LeDuc responded that the utility of such specimens depended on the nature of the material and the method of preservation, but that often such samples yielded only fragmentary DNA. The Sub-Committee recommended that additional effort to obtain biopsy samples of blue whales, together with length measurements for potential assignment of sampled animals to sub-species, should be a priority in future work.

Finally, the question of the relative utility of sloughed skin, biopsies and other sources of DNA (including samples fixed in formalin) for blue whale genetic analysis was raised; a review of this issue is given in Appendix 6.

6.4 SOWER - blue whale component

SC/55/IA1 summarized blue whale sightings from the 2002-2003 SOWER cruise. Eight groups of 24 animals were encountered, only in the south of the research area. Most of the sightings were in close proximity to the ice edge. Sounds attributed to blue whales were recorded in the vicinity of seven of the groups. Participants expressed their regret concerning the small amount of effort that had been devoted to blue whales during 2002-03; Matsuoka responded that this had been due in part to logistical and weather constraints. The Sub-Committee acknowledged this, but recommended that future SOWER cruises allocate additional time for work on this species. During 3.41 hours of research, biopsy samples were obtained from four individuals, 3 animals were videotaped, photo-id images were obtained from 9 individuals, and dive times were recorded for a solitary animal.

6.5 Other

In SC/55/O6, results were presented from the 2002/03 JARPA survey conducted in Area V and western Area VI. Four blue whales in two groups were sighted in the western part of Area VI; five whales in three groups were observed in the eastern part of Area V. No blue whales were observed in the western part of Area V. Sightings of blue whales were limited to the eastern edge of the East-North stratum and center of the east stratum of Area V. Three whales were photo-identified, and sonobuoy recordings were made around two other whales; no biopsy samples were obtained.

SC/55/E12 discussed ecosystem studies being conducted in a southern Australian blue whale (putatively pygmy blues) feeding ground in the Bonney Upwelling region. These studies include broad- and fine-scale surveys for distribution and ecology, as well as acoustic monitoring, satellite tracking and population assessment.

Bannister drew attention to a comprehensive study of blue whales, probably pygmy blue whales, being carried out off the Western Australian coast. It is a continuation and expansion of an earlier study centred on the Perth Canyon, Western Australia, reported in SC/55/Progrep Australia, where aerial surveys were conducted over the period February 1999-May 2002. Encounter rates were generally low (maximum sightings per flight 14, in 12 pods), with peak abundance in the period Jan-March and few sightings at other times. The extended programme involves aerial surveys over a wider area but sighting numbers have so far been very low, with most in the Perth Canyon area; however, encounter rates for 2003 in that area have been higher, with up to 28 sightings (possibly including some repeats) on one flight. Acoustic and oceanographic studies are also being conducted, as well as intensive vessel work involving photo-identification and biopsy sampling.

Clark gave a report from a IWC-SOWER working group on blue whale acoustics which met in August 2002 (Appendix 8). The acoustic data currently do not contradict the hypothesis that high-latitude animals (presumably true blue whales) have distinct acoustic signatures from those in the mid-southern latitudes (presumably pygmy blue whales). Clark reported that the working group report identified a limited number of song types occurring in different regions of the world, and that song types have remained constant over periods of decades. He noted that all blue whale recordings from the SOWER cruises have been archived in the Cornell University Library of Natural Sounds, and are available through the IWC Secretariat with access governed by SC guidelines. The Sub-Committee noted that the recommendations from this working group have been considered by the SOWER planning group and will be considered under the In-Depth Assessments Sub-Committee. In response to a question, Clark noted that there were to date no positive identifications of pygmy blue whale sounds in waters south of 60 degrees south, but cautioned that associations between specific vocalization characteristics and pygmy blue whales remained uncertain.

6.6 Workplan

The Sub-Committee again noted that there was insufficient time to complete an in-depth assessment of blue whales. Therefore, the sub-committee recommended that the assessment of blue whales start in 2006. However, to ensure that the necessary materials are available for the review, the sub-committee identified the following as important tasks to be addressed before 2006:

(1) Sub-species identification

(a) Obtain genetic samples and morphological data from vocalising blue whales

(b) Continue sub-species differentiation by genetic markers

(c) Continuation of archiving and preliminary analysis of acoustic data at Cornell University

(d) Archiving and preliminary analysis of genetic data at the Southwest Fisheries Science Center (La Jolla, California)

(e) Identify and collection of genetic samples from known true and pygmy blue whales for use as a reference collection

(2) Abundance estimation methodology and trend

(a) Compile a list of potential sources of bias and factors which may influence estimates and assign plausibility

(b) Compile a summary of the current knowledge regarding Southern Hemisphere blue whales, by population or management area; identify major gaps in knowledge; and establish priorities for research to fill these gaps (Inter-sessional EWG)

(c) Estimation of sources of variation over and above sampling variance

(d)Extrapolation north of 60º based on JSV data

(e)Improve extrapolation methods used to estimate abundance between 60º and the northern boundary of IDCR/SOWER surveys

(f) Investigate other methods of detecting trend over time(e.g. use of GLMs with year and Area factors)

(g) Investigate the use of detection functions other than the hazard rate form, including the possibility of incorporating environmental covariates

(h) Attempt to evaluate g(0)

(i) Consideration of alternative approaches to take account of spatial distribution suggested during in previous meetings

(3) Prepare historic catch data for use in assessment, including requesting all catch data available from Japanese and Chilean Governments

(4) Prepare for stock assessment

(5) Consider the feasibility of satellite-tagging Antarctic blue whales to establish location of breeding ground

(6) Undertake analysis of IDCR/SOWER identification photographs

7. SOUTHERN HEMISPHERE HUMPBACK WHALES

7.1 Report from intersessional group

Bannister summarized the report of the intersessional working group on Southern Hemisphere humpback whales (Appendix 7). The terms of reference of this group were: (i) to summarize current knowledge by population or management area; (ii) to identify major gaps in knowledge; and (iii) to establish research priorities to fill the gaps. Bannister noted that, in light of the working groups review, some further subdivision of certain breeding stocks has been suggested, notably the F ground which may require subdivision into two elements (Cooks Islands and French Polyesnia). Breeding grounds are reasonably well known for most groups except for the F ground. Migrations routes are quite well known for four groups (B, C, D and E(i)), while feeding grounds are well-defined for only one group (D, eastern Indian Ocean) and either poorly defined or not defined at all for the remainder. There are moderately good estimates of abundance for four groups (A, C, D and E(ii)1), but only poor estimates, or none at all, for the others. Moderately good estimates of trends exist for only the D and E groups, and only poor estimates, or none at all, for the remainder. Most catch histories are more or less complete with the exception of the central Pacific (BS E (ii) 2 – F), where the coverage is generally poor.

The Sub-Committee thanked Bannister and the working group for their hard work in producing this useful review, and recommended that the working group continue its work inter-sessionally and provide updated information, as available, next year. This review should include also the Arabian Sea population of humpback whales. Baker noted that the review indicated that there may be more sub-division in Southern Hemisphere humpback whales than had been realized, and suggested that some populations may even have been extirpated. He suggested that assessment models used to date may not have sufficiently accounted for this, and that attempts to undertake historical reconstructions may very difficult. Brownell said that it may be possible to improve allocations of illegal Soviet catch data, which has been a major factor in such reconstructions; he noted that an intersessional group will meet in Cambridge to pursue this question. The Sub-Committee agreed, and recommended that this work be given high priority over the next year.

7.2 New estimates of abundance and rates of increase, and new stock structure information

In SC/55/SH1, a humpback whale abundance estimate in the Brazilian coastal breeding grounds was reported. Between 7th and 16th September 2002, an aerial survey was conducted with track lines running from the northern margin of Bahia State to the southern margin of Espirito Santo State. Seventy-five parallel were established and flown from the coast to the 500m isobath. Total effort was 2030.47 nm. A total of 176 on-effort sightings were made, and group sizes ranged from one to five individuals (mean 1.53). An estimate of abundance of 2663 (CV=0.13) was obtained, assuming that g(0)=1. In discussion, it was agreed that this value for g(0) was probably unrealistic, and that future analyses should attempt to address this.

SC/55/SH10 gave information on the distribution, abundance and trend in density of humpback whales in Antarctic Areas IV and V (south of 60 degrees S) between the 1988/89 and 2001/02 austral seasons. The DISTANCE analysis program was used to estimate abundance. The main concentration of humpback whales was observed between 90 and 110 degrees E in both the northern and southern strata. Abundance in Areas IV and V were estimated as 29,856 (CV=0.27) in 2001/02 and 4,251 (CV=0.48) in 2000/01, respectively. Annual rates of increase for humpback whales were estimated as 12.5% (CV=0.58) and 10.3% (CV=0.59) in Areas IV and V, respectively.

Bannister commented that the estimate of abundance for Area IV from SC/55/SH10 was much larger than estimates from surveys off western Australia, and that while mixing between Areas IV and V might explain some of this difference it was unlikely to account for most of it. Clapham noted that the reported rates of increase in SC/55/SH10, notably that for Area IV, were unrealistically high, which also cast doubt on the abundance estimate for this region. Weinrich noted that a single large point estimate for Area V (1998/99) appeared to drive the model that resulted in the high growth rate, and suggested reanalysis excluding that data point. It was also noted that there were several aspects of the line-transect methodology underlying the surveys that required further investigation, including why strip-width had changed between years and whether high encounter rates in some areas were driving much of the results. In light of these doubts, the Sub-Committee agreed to treat the estimates of abundance and rate of increase in SH10 with considerable caution. Weinrich also noted that extrapolation of surveys into the area of 70-80 degrees East in Area IV, which appears from other years to be a relatively low-use area but which were not surveyed in 1998-99, may have compromised the reliability of the estimates of abundance and rate of increase.

The Sub-Committee returned to consideration of SC/55/SH18, the analyses of indices of abundance for baleen whales off Durban, South Africa. Humpback whale abundance declined markedly during the 1920's, and further after 1954, reaching an estimated 13.5% of its 1920-22 level at protection. In addition as substantial catches were taken out of this stock before 1920, this must be an under-estimate of the degree of depletion. Sighting rates from the spotter aircraft from 1969-1975 were higher than in the last seven years of humpback whaling, indicating some increase of this stock under protection.

Clapham presented SC/55/SH2, the annual report of the South Pacific Whale Research Consortium. This included updated information on inter-area matching for photographically identified individual humpback whales from the South Pacific, including New Caledonia, New Zealand, Tonga, Niue, the Cook Islands and French Polynesia. Comparisons were also made between the Oceania catalogue and photographs from Byron Bay in eastern Australia, as well as from Fiji and the Antarctic Peninsula. New matches made included: Tonga 2002 to Cook Islands 2000; Tonga 2002 to New Caledonia 2000; Cook Islands 2002 to Tonga 2000; and Cook Islands 2002 to Tonga 1999. Overall, the results of this new matching confirmed recently published data by Consortium members (Garrigue *et al.* 2002), which indicated that there are relatively low rates of exchange among the different areas, suggesting that the major areas represent largely distinct sub-populations. Updates were also presented on genetic analyses using Consortium data (see SC/55/SH8 and 11, below).

In SC/55/SH11, maternal gene flow among six regional breeding grounds in the South Pacific region was analyzed. These included Western Australia (recognized by IWC as the “D” breeding stock”), New Caledonia (Eii1 sub-stock), Tonga (Eii1 sub-stock), Cook Islands (F stock), French Polynesia (F stock), and the Pacific coast of Colombia (G stock). Mitochondrial DNA control region sequences (n=1069, 447 bp) identified 138 haplotypes defined by 85 polymorphic sites. An analysis of molecular variance showed significant differentiation at both the haplotype or nucelotide level between all the studied breeding areas (with the exception of Tonga and the Cooks at the nucleotide level). This suggests that the Cook Islands and French Polynesia should be considered separate stocks, not the single F stock as previously combined, and confirms a previous suggestion by Poole that French Polynesia represents a distinct breeding ground unknown in the whaling literature. The analyses also indicate that New Caledonia and Tonga should be considered separate stocks (Eii1 and Eii2), as suggested by recent photo-id work from these areas. A Boundary Rank analysis agreed with the results of the AMOVA in suggesting that the existing E and F divisions do not full reflect true population structure in the western South Pacific. The authors concluded that the extensive data set used in SC/55/SH11 could be used for an improved allocation of feeding grounds to breeding grounds, and a proposal had been submitted to IWC to use IDCR/SOWER samples in this manner. Kato noted that many humpback whale samples from these cruises have already been sent to H. Rosenbaum.

Again, the question of the relative utility of sloughed skin, biopsies and other sources of DNA (including samples fixed in formalin) for genetic analysis was raised; a review of this issue is given in Appendix 6.

In SC/55/SH8, the abundance and reproductive autonomy of humpback whales from the New Caledonia wintering grounds were investigated using capture-recapture models and paternity inference based on nuclear genotyping, mtDNA sequencing and photo-id data. The analyses included records of 213 individuals (exclduing 16 calves used in paternity inference) identified by genotype at 9 loci, and 210 identified by fluke photographs collected from 1995 to 2001. A genotype-based estimate of abundance (643, cv=0.18) was slightly larger than the estimate from photo-id (574, CV=0.18). A genotype-based sex-specific estimate of abundance gave comparable numbers of males (382, CV=0.22) and females (239, CV=0.29). The likely paternity of 5 calves from 16 cow/calf pairs was assigned to five individual males from the total sample of 133 non-calf males. The assigned paternities provided an alternate “gametic recapture” estimate of male abundance. This estimate (382, CV=0.30) was almost identical to the sex-specific estimate, and this close agreement provided strong evidence that this humpback whale wintering ground represents an autonomous population unit that is relatively closed to demographic and reproductive interchange.

In SC/55/SH16, the distribution of humpback whales wintering in French Polynesia was investigated during the 1997-2002 period from dedicated small boat surveys. Visual and acoustics surveys took place in the Society Islands, Austral Islands, Marquesas and Tuamoto archipelago. The surveys, and other data, suggest that humpbacks are widely distributed throughout the Society Islands, with most areas not currently studied; relatively few whales are present in the Marquesas.

SC/55/SH19 presented preliminary results from the 2002/03 field season of a study of migrating humpback whales on the western coast of South Africa. The highest peaks of abundance were recorded in October/November and January. Tracks on 165 whales did not suggest that a migration was actively taking place during these abundance peaks. Rather, the high incidence of non-migrating whales together with observations of feeding and faecal production in October-January, suggests that suspension of migration due to prey availability is a common phenomenon in this region.

Last year, the Sub-Committee strongly urged that a paper be produced reviewing rates of increase for eastern Australian humpback whales; this paper was made available this year (SC/55/SH21), although the authors were not able to be present. Nonetheless, the Sub-Committee noted its appreciation for the submission. Shore-based surveys have been conducted at Point Lookout in 1981, 1982, 1986, 1987 and then in 1991, 1993, 1996 and 2000, thus providing a nearly two-decade time series. Results from some of these surveys have been presented to the SC previously (SC/49/SH35), and the present paper updated rates of increase by incorporating data from 2000. Analytical methods based on those used for California gray whale census data were used to model the count data, to obtain a time-series of relative estimates of abundance, and generalized linear models were used to estimate rates of increase. Annual rates of increase were estimated at: 10.08% (s.e. unavailable) for 1981-2000; 8.52% (s.e.-0.05) for 1986-2000; and 8.54% (s.e.=0.05) for 1991-2000. These rates are lower than those reported in SC/49/SH35, although it was noted that rates are not directly comparable because of model differences. The authors suggested that biases in the estimates of relative abundance (and thus rates of increase) were likely to be small, and concluded that the rate of 8.54% (s.e.=0.05) for the period 1991-2000 was likely to represent the most reliable estimate for the current rate of increase in this population. Several members raised questions regarding these analyses which could not be clarified at the meeting; Childerhouse agreed to communicate these issues to the authors and report their responses next year. In the meantime, and pending the outcome of these discussions, the Sub-Committee agreed not to endorse the estimates given in SH21.

In SC/55/O10, Minton summarized work on the apparently non-migratory population of humpback whales off Oman. This work has involved surveys in the Gulf of Masirah and the Dhofar/Hallaniyat Islands region, and includes photo-identification studies. Over the period 2000 and 2003 the percentage of new individuals has decreased, indicating a relatively high degree of residency in this population, as well as fidelity to specific areas. Preliminary estimates of abundance yielded small population sizes, although the authors commented that these figures should be treated with great caution in light of the small sample sizes and the likely violation of mark-recapture assumptions. Nonetheless, it appeared likely that the population of humpback whales off Oman was small (in the hundreds), perhaps indicating that the population has yet to recover from illegal Soviet whaling in the 1960's (Mikhalev 1997). In response to a question regarding photo-id comparisons with Southern Hemisphere locations, Minton responded that the Omani catalogue had been compared with collections from Mayotte and Madagascar (Rosenbaum and colleagues), with no matches made to date. In addition, she noted that songs recorded off Oman and Madagascar were different, although detailed comparisons had not yet been made. Minton indicated that additional matching to other areas (including South Africa) was planned. The Sub-Committee commended Minton for the report on this work, and acknowledged the value of this research to an understanding of this unique and apparently small population. The Sub-Committee recommended that this research continue, and looked forward to hearing the results of future work. Recognizing that the Arabian Sea is not in the Southern Hemisphere, the Sub-Committee nonetheless agreed to include consideration of whale populations from this region in its future work (see above).

In SC/55/SH13, photo-id data from the Chilean Antarctic catalogue of Antarctic Peninsula humpback whales for the period 1995-99 were reported. A total of 157 individuals were identified, with only eleven whales resighted within season and only two across years. This suggests that either the population is large or that there is considerable movement within the wider region. Additional matching to the Antarctic Humpback Whale Catalogue revealed a further 27 re-sightings. No matches have been made with photo collections from the western South Pacific breeding areas.

SC/55/SH12 explored the migratory relationship between humpback whales in the Magellan Strait and the Antarctic Peninsula (AP) using photo-id and mtDNA data. No matches were found in a comparison of 12 Magellan Strait and 157 AP photos. The mtDNA analysis of 12 Magellan Strait bopsies showed found three haplotypes, two of which were shared with AP humpbacks; no further conclusions were possible given the small sample size. The Sub-Committee agreed that this work was important in terms of understanding the distribution and structure of humpback whale populations in this region, and recommended that these studies continue.

The acoustic monitoring from the West Antarctic Peninsula previously reported (SC/55/SH14) also detected humpback whales. The Sub-Committee reiterated the potential value of this monitoring tool, and noted the importance of assessing whether humpback whales are present in this feeding area in winter, since this had implications for interpretation of differences in estimates of abundance from the feeding and breeding grounds (see discussion above on SC/55/SH10).

7.3 Further population dynamics modelling

There were no papers under this item.

7.4 Antarctic Humpback Whale Catalogue

In SC/55/SH15, the status of the IWC-funded Antarctic Humpback Whale Catalogue curated by the College of the Atlantic was summarized. Photographs from this region date back to 1987. During the last year, 695 images representing 352 individual humpback whales were added to the Catalogue, bringing the total number of individuals represented to 1693. The Sub-Committee recommended that IWC continue to fund this effort.

7.5 Other

In SC/55/For Info 39, Matsuoka reported the relationship between large whale distributions and the southern boundary of the Antarctic Circumpolar Current (ACC) using JARPA-1997/98 survey data. Longitudinal distributions of humpback, southern right, large male sperm and southern bottlenose whales were concentrated between 80°E and 110°E during austral summer in the Antarctic (south of 60°S). Results of XCTD (eXpendable CTD) analyses in this area revealed a large meander of the southern boundary of the ACC that seemed to be moving north along the continental rise to 61° S, and then down to 63° S between 80° E and 120° E. This region appeared to be a high-productivity area formed by large-scale up-welling with nutrient-laden bottom waters due to the effect of the southern Kerguelen Plateau. High-density areas of humpback whales were observed along the large meander of the southern boundary of the ACC between 80° E and 110° E. Southern right, large male sperm and southern bottlenose whales were also concentrated in this longitudinal section, although they were distributed on the Antarctic continental slope. Several whale species, especially humpback, southern right, large male sperm and southern bottlenose whales used this section as a primary feeding area, although they appeared to be segregated from each other in their feeding habits. The Sub-Committee thanked Matsuoka, and welcomed his provision of this information on humpback whale distribution. An abundance estimate of humpback whales from this cruise was reported in SC/55/SH10 as 11,739 (CV=0.45).

Clapham presented SC/55/SH3, an update on humpback whale research in Fiji. He recalled Paton's analysis (presented last year) of survey data from Bill Dawbin, who conducted surveys at Fiji in the winters of 1956-58, and noted that Paton had been to Fiji in 2002 in an attempt to reconstruct Dawbin's methods; Paton also conducted some preliminary surveys in an effort to produce data that were directly comparable to Dawbin's. It was clear that the population of humpback whales in the area remains small, which is in sharp contrast to numbers reported from the 1950's survey. This suggested that the population had still not recovered from whaling, notably from the large illegal Soviet catches in Antarctic feeding areas in 1959-61, or shortly after Dawbin's work in Fiji. Baker noted that this might represent an example of the extirpation of a local population, with slow recolonization of the area.

Minton provided a brief report on activities of the Indo-South Atlantic Consortium On Humpback Whales (ISACH). The intent of this network is to coordinate research among scientists from 12 member countries in the South Atlantic and Indian Ocean region. A research cruise was conducted in July 2002 with the intention of providing training to scientists and students from member countries. The network has developed standardized protocols to facilitate comparisons of data over all areas. An on-line photo-id database is being created which will be available to all network members. The Sub-Committee expressed its appreciation for this coordinated effort, and recommended that this extensive collaboration continue. The Sub-Committee also noted Oosterhuizen's report about a South-African-supported cruise off Mozambique; the Sub-Committee noted its appreciation of this support and strongly endorsed this project.

7.6 Work required to complete assessment

It was noted that substantial progress had been made in recent years in improving the understanding of humpback whales in the Southern Hemisphere and Arabian Sea. Appendix 7 provides a very useful summary of the existing state of knowledge and also identifies areas for further consideration. Such issues are identified in Appendix 7 and future research should be aimed at addressing these issues. Until these issues have been adequately addressed it is difficult to set a deadline for the completion of the Comprehensive Assessment.

7.7 Work plan

The sub-committee agreed that considerable progress had been made in some areas of the work plan from last year; however many items still required further effort. The sub-committee proposed the following work:

(1) Run the humpback population dynamics model with the following modifications:

(a) Exploration of different levels of depensation

(b) Splitting breeding stock E into 3 sub-populations (which will require catches to be to split along comparable lines)

(c) Run sensitivity test for Area C using combined Mozambique and low latitude Madagascar estimates (as reported in SC/52/IA10)

(2) Investigate whether data from Soviet illegal whaling operations (see IWC, 2001, p. 185) could be used to provide indices of relative abundance for input to population models

(3) Further investigate the use of abundance estimates from IDCR/SOWER and JARPA survey data in the population dynamics model.

(4) Update the Antarctic humpback whale photo-identification catalogue

(5) Investigate the issue of correlation between the minke and humpback whale distribution on IDCR/SOWER and JARPA surveys

(6) Update the report detailing the summary of information by Area of Southern Hemisphere humpback whales

The only item with budgetary implications is the Antarctic Humpback Whale Catalogue with a budget of £5,200.

8. OTHER

8.1 Fin whales

SC/55/SH18, the analysis of historical indices of abundance from the Durban (South Africa) whaling grounds, was again presented. In contrast to the other two species included in this analysis (humpback and blue whales), fin whale abundance indices increased markedly from the 1920's to the early 1950's, possibly indicating a response to the depletion of other baleen whales. From 1954 to 1975, however, catch rates for fin whales dropped by 89.4%, and sighting rates from spotter aircraft by 96.7%. These are far greater levels of depletion than suggested by contemporary analyses of stock condition.

In SC/55/SD6, a phylogenetic analysis of fin whale mtDNA control region sequences world-wide used samples and published sequences from the western and eastern North Pacific, the North Atlantic, the Mediterranean Sea, and the Antarctic. Sixty-six haplotypes were found overall. All samples from the Antarctic and the North Pacific grouped together in the same clade, which also included two samples from the North Atlantic. No clade specific to an ocean basin was found, indicating little time since divergence of oceanic populations. The study also suggested that assigning mtDNA control-region haplotypes from fin whale samples of unknown origin was difficult.

In response to question from Baker, Goto responded that there were no haplotypes shared between two or more ocean basins. The Sub-Committee accepted Goto's conclusion that the phylogeographic pattern of the fin whale was not as clear-cut as that for (say) right whales, where there are clear diagnostic differences among oceans. However, the fact that no shared haplotypes had been found among ocean basins suggested that assigning unknown fin whale samples to an ocean basin might not be as difficult as suggested by using a cladistic analysis like that presented in SC/55/SD6.

Brownell noted that many genetic studies were hampered by the need to constrain analyses of new data to the shortest published sequences available for comparison; for example, in SC/55/SD6 comparisons were made to 288-bp sequences published by Martine Bérubé. Based on information provided by Baker, the Sub-Committee recommended that, when possible, analyses should use the 460-bp segment at the 5' end of the mtDNA control region, which in mysticetes likely captures approximately 98% of variation within the control region.

The Sub-Committee also recommended that efforts be made to obtain biopsies of fin whales from SOWER cruises.

In SC/55/SH14 and For Info 5, the acoustic monitoring from the West Antarctic Peninsula region found a strong seasonality in fin whale calls, with a peak in April-May 2001 and an absence of calls from July 2001 through January 2002.

8.2 Other

There were no papers to consider under this item.

9. ADOPTION OF REPORT

The report was adopted at 18:50 on 2nd June 2003. The Chair thanked participants for all their hard work, and expressed particular appreciation to the rapporteur.

Appendix 1

AGENDA

1. Introductory remarks

2. Election of Chair and appointment of rapporteurs

3. Adoption of agenda

4. Review of documents

5. Schedule

6. Southern Hemisphere blue whales – review progress on in depth assessment
    - 6.1. Abundance and trend estimation
    - 6.2. Population dynamics modelling
    - 6.3. Progress on sub-species identification
        - 6.3.1. Behaviour and morphology
        - 6.3.2. Acoustics
        - 6.3.3. Genetics
    - 6.4. SOWER – blue whale component
    - 6.5. Other
    - 6.6. Work plan

7. Southern Hemisphere humpback whales – review progress on in depth assessment
    - 7.1. Report from intersessional group
    - 7.2. New estimates of abundance and rate of increase, stock structure information
    - 7.3. Further population dynamics modelling
    - 7.4. Antarctic humpback whale catalogue
    - 7.5. Other
    - 7.6. Work required to complete assessment
    - 7.7. Work plan

8. Other
    - 8.1. Fin whales
    - 8.2. Other

9. Adoption of report

Appendix 2

PLAUSIBLE INCREASE RATES FOR ANTARCTIC BLUE WHALES

TREVOR A BRANCH

Estimates of rates of increase (δ) can be obtained from the Euler-Lotka equation (Equation 1) derived from Leslie matrix theory, using the values obtained from literature in SC/55/IA4.

$$e^{t_m \delta} = e^{(t_m - 1)\delta} S + p q_f S_j S^{t_m - 1} \quad (1)$$

Age at first parturition: t_m ~ N(10, 3^2); bounds [5,15];

Adult survival rate: S ~ N(0.96, 0.02^2); bounds [0.93, 0.99];

First-year (calf) survival rates (S_j): S-S_j ~ U(0.02, 0.12);

Annual pregnancy rate: p ~ N(0.43, 0.17^2); bounds [0.33, 0.50];

Proportion of births that are female: q_f = 0.473.

We can obtain a table of possible rates of increase by looking at three levels for each of these parameters (low, median, high), and fixing the proportion of births that are female.

		S=0.93			S=0.96			S=0.99		
Tm	p	S-Sj = 0.02	0.07	0.12	0.02	0.07	0.12	0.02	0.07	0.12
5	0.33	2.6%	2.2%	1.8%	5.7%	5.4%	5.0%	8.8%	8.5%	8.1%
	0.43	4.5%	4.0%	3.6%	7.7%	7.2%	6.8%	10.7%	10.3%	9.9%
	0.5	5.7%	5.2%	4.7%	8.8%	8.4%	8.0%	11.9%	11.5%	11.1%
10	0.33	0.2%	0.0%	-0.3%	3.4%	3.2%	2.9%	6.5%	6.3%	6.0%
	0.43	1.4%	1.2%	0.9%	4.6%	4.4%	4.1%	7.7%	7.5%	7.2%
	0.5	2.2%	1.9%	1.6%	5.4%	5.1%	4.8%	8.4%	8.2%	7.9%
15	0.33	-1.0%	-1.2%	-1.4%	2.1%	2.0%	1.8%	5.2%	5.0%	4.9%
	0.43	-0.2%	-0.4%	-0.6%	3.0%	2.8%	2.6%	6.1%	5.9%	5.7%
	0.5	0.4%	0.2%	0.0%	3.6%	3.4%	3.2%	6.6%	6.4%	6.3%

Appendix 3

FACTORS WHICH MAY INFLUENCE ESTIMATES OF ABUNDANCE AND RATES OF INCREASE (ROI) OF "TRUE" BLUE WHALES FROM IDCR/SOWER SURVEYS

The following is a list of potential factors, and the likely direction of their influence, on abundance and rate of increase estimates for Antarctic ("true") blue whales from IDCR/SOWER surveys. They are intended to address issues raised in the discussion of papers SC/55/IA6 and SC/55/IA20. An intersessional group will further investigate these and other sources of bias, and suggest methods to investigate or account for these factors. The factors are grouped into (A) factors related to bias in the absolute abundance estimates; and (B) factors which might cause bias in the estimation of rates of increase (ROI) in blue whale abundance.

(A) Factors related to abundance estimates for Antarctic ("true") blue whales. "Increase" indicates that if the factor were taken into account, then the abundance estimates would likely increase.

Factor	Likely direction of effect on abundance
A1. Animals north of 60ºS	Increase
A2. Animals within the pack ice	Increase
A3. Probability of observing a blue whale on the trackline $g(0) < 1$	Increase or no effect
A4. Proportion of pygmy blue whales in the survey region	Decrease
A5. Long-term circumpolar events and processes	Uncertain

(B) Factors affecting estimates of the rate of increase for Antarctic blue whales. "Increase" indicates that if the factor were taken into account, then the ROI estimate would likely increase.

Factor	Likely direction and size of effect on ROI
B1. Introduction of IO mode in CPII and CPIII	Decrease
B2. Probability of observing a whale on the trackline g(0)	Increase or no effect
B3. Changes in "like blue" classification	Increase
B4. Timing of surveys	Increase
B5. Increasing proportion of pygmy blue	Decrease
B6. Northward extrapolation to unsurveyed areas for CPI and CPII	Increase, or no effect
B7. Long-term circumpolar events and processes	Uncertain
B8. Changes in survey design from CPI to CPII/CPIII	Uncertain
B9. Introduction of blue whale research may have inflated CPIII estimates	Uncertain
B10. Changes in analysis options	Uncertain

Appendix 4

PREVIOUS ANALYSES ESTIMATING THE IMPACTS OF FACTORS IN APPENDIX 2 ON ESTIMATES OF ABUNDANCE AND RATES OF INCREASE (ROI) OF "TRUE" BLUE WHALES FROM IDCR/SOWER SURVEYS

Trevor A. Branch

Appendix 3 provides a list of factors, and the likely direction of their influence on estimates of abundance and rates of increase for Antarctic ("true") blue whales from IDCR/SOWER surveys. This appendix provides estimates of the likely magnitude of these biases by reviewing currently available information. The size of these biases is qualitatively indicated by 'small', 'medium' (of the order of 10%) and 'large' (some tens of a percent). Sources of information describing each possible factor, and its effect on blue whale abundance or trends, are specified.

(A) Factors related to abundance estimates for Antarctic ("true") blue whales. "Increase" indicates that if the factor were taken into account, then the abundance estimates would likely increase.

Factor	Likely direction and size of effect on abundance	Sources of information describing the hypothesis and the size of its effect on the abundance estimates
A1. Animals north of 60ºS	Increase, uncertain, possibly medium	JSV data have been used to extrapolate estimates from CPI and CPII to the region south of 30ºS (Butterworth and Geromont 1995). They found that this extrapolation increased CPII estimates ('true' + pygmy blue) by 3.0-7.9 times. Nearly all of this increase is likely due to pygmy blue whales which largely remain north of 60ºS during the surveys.
A2. Animals within the pack ice	Increase, small	"Like-blue" whale blows have been reported close to the edge of water and pack ice during the IDCR/SOWER surveys.
A3. Probability of observing a blue whale on the trackline *g*(0) < 1	Increase or no effect, none to small	Blue whale blows have highly visible blows, which can be observed from up to 7 nmi. Given surfacing intervals on long dives are approximately 12-17 minutes (P.Ensor, pers. comm.), a vessel speed of 11.5 knots, and search half-width of 1.6-2.1 nmi (Branch and Butterworth 2001a), *g*(0) is likely very close to 1.0 for blue whales.
A4. Proportion of pygmy blue whales in the survey region	Decrease, small	A series of papers have thoroughly investigated this factor, concluding that there may be a small proportion of pygmy whales south of 60ºS, but no more than 7% (Kato et al. 1995, Donovan 2000, Kato et al. 2000, Kato et al. 2002, IWC 2003). Acoustic studies recorded only one type of call, putative Antarctic blue, around the Antarctic (SC/55/SH7).
A5. Long-term circumpolar events and processes	Uncertain, possibly medium	Events and processes (e.g. Antarctic Circumpolar Wave) affect aspects of regional and local scale ecosystems, i.e., ice cover and formation rates, krill survival and growth, and krill distribution. If the surveys systematically follow these long-term circumpolar events, this could introduce bias in the estimates.

(B) Factors related to estimates of the rate of increase for Antarctic blue whales. "Increase" indicates that if the factor were taken into account, then the ROI estimate would likely increase.

Factor	Likely direction and size of effect on ROI	Sources of information describing the hypothesis and the size of its effect on the abundance estimates
B1. Introduction of IO mode in CPII and CPIII	Decrease, small	It is likely that *g*(0) for blue whales is very close to one, although there may be some decrease in low visibility conditions. Estimated densities of minke whales are lower in closing mode than in IO mode (Branch and Butterworth 2001b), but are likely more similar for blue whales because of their greater visibility. Regardless of the size of the impact, the CPIII/CPII ratio would remain unchanged because there were equal amounts of closing and IO mode effort in those CPs.
B2. Probability of observing a whale on the trackline *g*(0)	Increase or no effect, none to small	It is likely that *g*(0) for blue whales is very close to one although there may be some decrease in low visibility conditions. Duplicate sighting probabilities for minke whales are lower in poor weather (greater amounts in northern areas in CPIII), and for inexperienced observers (SC/54/IA6). These factors are less critical for blue whales because of their highly visible blows. There are much lower densities of blue whales in the northern strata, limiting any possible impact of this factor. Any latitudinal distribution of school sizes will likely have little effect on ROI, because schools of any size are still highly visible.
B3. Changes in "like blue" classification	Increase, small to large	No "like blue" sightings in CPI, two in CPII and four in CPIII to 1997/98 (Branch and Butterworth 2001a). Including "like blue" sightings increased the CPIII/CPII ratio from 2.8 to 3.3, i.e., by 18% (Branch and Rademeyer 2003).

B4. Timing of surveys	Increase, small	The peak period of blue whales in the Antarctic is November to February. Calculations for minke whales indicate that the effect of this factor may be substantial for some surveys (up to 15%) but is minimal at a circumpolar level, increasing the CPIII/CPII ratio by only 2-3% (SC/55/IA12). Acoustic recordings around the West Antarctic Peninsula recorded blue whale calls year-round, with a peak in March-April (SC/55/E11, SC/55/SH7). There is a suggested movement to lower latitudes during the southern winter (SC/55/SH7).
B5. Increasing proportion of pygmy blue	Decrease, small	It is possible that a small proportion of blue whales (no more than 7%) south of 60ºS are pygmy blue whales (see discussion of A4 above). However, none of the CPIII blue whale sightings in Area II+III were near 60ºS (Figure 1, SC/55/SH6). The area north of Area II+III was where pygmy blue catches were taken (Ichihara 1966).
B6. Northward extrapolation to unsurveyed areas for CPI and CPII	Increase or no effect, none to medium	SC/55/IA11 (for minke whales) assumed the density in these unsurveyed areas was half of that in the corresponding northern areas, this adjustment made virtually no difference to the circumpolar estimates; but if Area V is omitted, the CPIII/CPII ratio increases 10% for minke whales (SC/55/IA11).
B7. Long-term circumpolar events and processes	Uncertain, possibly medium	Sightings of blue whales in the pack ice are uncommon. A substantial change in the proportion in the pack ice would be required to influence estimates of ROI. While surveys do not circle the Southern Ocean in a systematic manner, these factors could add uncertainty to abundance estimates, and hence affect trends.
B8. Changes in survey design from CPI to CPII/CPIII	Unknown, possibly large	
B9. Introduction of blue whale research may have inflated CPIII estimates	Uncertain, probably small	
B10. Changes in analysis options	Uncertain, probably small	Different alternative options were investigated for the inclusion or exclusion of mixed schools, changing the truncation distance, and duplicate identification (Branch and Butterworth 2001a). These factors had only a small impact on abundance estimates. Pooling over all surveys (instead of at a circumpolar level) for the estimation of search half width and school size, was investigated in SC/52/O30 and also had only a small impact.

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Appendix 5

SUMMARY OF EVIDENCE FOR INCREASES IN ANTARCTIC BLUE WHALES

Trevor A Branch

INTRODUCTION

The Scientific Committee has been conducting an in-depth assessment of Southern Hemisphere blue whales since 1991, without any conclusion made about (1) whether they are increasing, (2) what possible rates of increase might be, and (3) what the "best" current estimates of abundance are. Two papers presented at this meeting, SC/55/SH6 and SC/55/SH20, examine in considerable detail whether Antarctic blue whales are increasing. Both papers conclude that there is statistically significant evidence for increases in Antarctic blue whales. A summary is presented of evidence from these and other sources, which supports the notion that Antarctic blue whales have increased since the end of whaling. Objections have been made that the IDCR/SOWER surveys, on which these analyses are largely based, may have introduced bias in the estimation of rates of increase. However, an examination of possible biases reveals that in most cases, these issues would further increase the estimated rates of increase, thus providing additional support for the recovery (to very low levels) of Antarctic blue whales since the 1970s.

General sightings rates from Soviet Union, JSV and JARPA data

Given the catches taken by Soviet Union vessels, the lowest abundance of Antarctic blue whales likely occurred in the early 1970s (SC/55/SH6). Two additional sources of evidence support this assertion. First, JSV records south of 60ºS between November and February recorded only a single blue whale from 1969/70-1975/76 despite 154,299 km of search effort (SC/55/SH6), implying a sighting rate (whales per 1000 km) of 0.0065. Second, Soviet Union whaling fleets in 1973/74-1974/75 did not encounter a single blue whale between the pack ice and 40ºS in the entire Pacific sector (IWC 2003). Given the number of catcher vessels involved in those whaling fleets, the Soviet Union search effort was likely substantial.

In contrast, in the later JSV data from 1979/80-1987/88, 63 blue whales were seen in 130,316 km of search effort, at a sighting rate of 0.48 whales per 1000 km (SC/55/SH6), some 74 times higher than in the early 1970s. Similarly, JARPA data from 1987/88-2000/01 sighted 120 blue whales in 275,389 km, at a sighting rate of 0.44 whales per 1000 km (SC/55/SH6). The IDCR/SOWER surveys from 1978/79 to 1997/98 encountered 75 *schools* in during 185,483 km of primary search effort, or approximately 0.6 whales per 1000 km given the effective school sizes (Branch and Butterworth 2001). Blue whale schools were seen during primary search mode on every IDCR/SOWER cruise except 1988/89 (Branch and Butterworth 2001).

Just considering these contrasts between JSV and Soviet sightings rates in the early 1970s, and those from JSV, JARPA and IDCR/SOWER cruises in the 1980s and 1990s, it seems reasonable to conclude that Antarctic blue whales have increased since the early 1970s.

Analysis of trends from IDCR/SOWER, JSV and JARPA data

Paper SH6 presents evidence for significant increases in Antarctic blue whales. When IDCR/SOWER, JSV and JARPA data are combined, the probability that the population is increasing is 0.992. For IDCR/SOWER+JARPA data, this probability is 0.992; for IDCR/SOWER+JSV, it is 0.973; and for IDCR/SOWER data alone, it is 0.966. In every case, this model provides strong evidence for increases in Antarctic blue whales.

When information from other sources are considered through informative priors, the posterior probability that the populations are increasing is >0.997 for all three alternative informative priors (SH6).

Analysis of sub-Areas from IDCR/SOWER data

The IDCR/SOWER data, by grouping surveys into circumpolar estimates, ignores the information available from areas that have been surveyed multiple times. SH20 considers these areas separately. Four different non-parametric tests indicate a statistically significant increase at the 5% level. A parametric approach also yields a statistically significant annual increase rate.

General comment on potential sources of bias in IDCR/SOWER surveys

There has been substantial discussion in IA (Appendix 10, IWC 2003) about potential biases in IDCR/SOWER surveys when trying to obtain trends for minke whale abundance. Two general points should be made. First, Antarctic blue whales have much more obvious cues than minke whales, because of their highly visible blows. Likely, g(0) for blue whales is very close to one (P. Ensor, pers. comm., K. Matsuoka, pers. comm.). Second, nearly all the discussion in IA has revolved around biases which tend to *increase* estimates from the third circumpolar set of surveys (CPIII) compared to CPII, and therefore imply that the rates of increase estimated for Antarctic blue whales should be even greater than those presented in SH6 and SH20.

Sources of bias which could increase the CPIII/CPII ratio

Increases in "like blue" sightings

The percentage of "like blue" and "large unidentified baleen whale" sightings has increased in CPIII compared to CPI and CPII (Table 1 in Branch and Butterworth 2001). Since these sightings are excluded from the standard analyses, this factor could introduce some bias. When "like blue" sightings were included into estimates for comparable areas, the CPIII/CPII ratio increased from 2.8 to 3.3, i.e., by 18% (Branch and Rademeyer 2003). Including "large unidentified baleen whale" sightings would likely further increase the ratio.

Observer efficiency

Given the high visibility of Antarctic blue whales, changes in observer efficiency would likely have little effect. Any effect would tend to further increase the CPIII/CPII ratio.

Weather conditions

In CPIII, the surveys extended further northward, encountering worse weather, and possibly reducing g(0). This factor would tend to increase the CPIII/CPII ratio.

Timing of surveys

The peak period of blue whale abundance in the Antarctic is November to February, somewhat earlier than that for Antarctic minke whales. Surveys in CPIII were 2-3 weeks later than in CPII. Calculations for minke whales indicate the effect of this factor may be substantial for some surveys (up to 15%), but is minimal at a circumpolar level (IA12), increasing the CPIII/CPII ratio by only 2-3%.

Extrapolations into northern areas

In the comparable areas estimates (Branch and Rademeyer 2003), unsurveyed regions north of the strata to 60ºS were assumed to have the same density as the corresponding northern strata. If the density in the unsurveyed areas is assumed to be half that in the northern strata, for minke whales, this adjustment makes virtually no difference to the circumpolar estimates (IA11). If Area V is omitted from these calculations, the CPIII/CPII ratio increases from 53%/41% to 59%/45% for minke whales (IA11), i.e., by about 10%, thus this factor may also increase the CPIII/CPII ratio for blue whales, which have a similar spatial pattern of distribution from the ice edge northwards (Kasamatsu et al. 1996).

Sources of bias which could decrease the CPIII/CPII ratio

Increased proportion of pygmy blue whales in CPIII

It is possible that the northward extension of the surveys in CPIII resulted in the inclusion of greater numbers of pygmy blue whales. Examination of Figure 1 in SH6 indicates no blue whale sightings near 60ºS in the Indian Ocean sector in CPIII, where pygmy blue whales were caught (Ichihara 1966). Given previous analyses, the SC concluded that the proportion of pygmy blue whales south of 60ºS is small, no more than 7% (Kato et al. 1995, Kato et al. 2002, IWC 2003). Recent acoustic analyses characterising blue whale songs did not record any non-Antarctic-type songs in the Southern Oceans (SH7). The impact of this factor is therefore likely to be small, with an upper bound of 7% increase for the CPIII estimate.

Inclusion of BB (Blue whale mode) effort

A small proportion of effort in recent years is recorded under BB mode from 1998/99 to 2000/01 (different from the formerly labelled BB mode in CPII, now renamed BK mode). In BB mode the vessels are researching on blue whales, generally in rough weather, and BB mode should not be considered primary effort. The comparable areas estimate may have inadvertently included BB mode effort for the 1998/99 and 2000/01 results. However, the relatively small amount of effort involved would indicate only a small amount of bias.

Combination of closing and IO mode

In obtaining the estimates, sightings and effort from closing mode and IO mode effort codes were combined. Given the high visibility of blue whales, there is likely little difference in sighting rates between the two modes. If this bias did occur, it would likely increase the CPI estimates slightly (since IO mode was introduced in CPII), but the CPIII/CPII ratio would remain unchanged because equal proportions of closing and IO mode effort is recorded in CPII and CPIII.

CONCLUSIONS

Given the results presented at this meeting, and the discussion above, it seems reasonable to conclude that Antarctic blue whales have increased from the 1970s to the present. Sources of bias are shown to generally support this assertion, or to be minor.

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Appendix 6

ON THE RELATIVE UTILITY OF BIOPSY, SLOUGHED SKIN AND HISTORICAL SAMPLES IN POPULATION GENETIC ANALYSES

R. LeDuc and C.S. Baker

For over a decade, biopsy sampling has become a widely accepted means of collecting tissue samples for genetic analyses. Biopsy sampling provides small samples of skin and blubber that are useful for a number of genetic and biochemical analyses. The collection of biopsy samples can be integrated into a directed survey design, providing for systematic sampling required for many population-based analyses (e.g., capture-recapture). The quality and quantity of DNA extracted from biopsies is high and creates a permanent archive of the individual whale.

However, due to logistical problems or permitting issues, some researchers have had difficulty with this type of sampling, and have turned to sloughed skin or historical samples as a source of DNA. These latter include bone, baleen and preserved tissues. Some studies have utilized historical materials for addressing specific questions, such as Rosenbaum et al.'s (1997) study comparing haplotypes from museum archived baleen to those from contemporary right whales. This study included a temporal component that necessitated the use of the baleen, the only material available from the whaling era. In Dalebout et al.'s (2002) phylogenetic study of beaked whales, bone material from museums was used for some species, due to the rarity of fresh material from these rarely seen and difficult to sample whales. In other cases (e.g., Clapham et al. 1993), sloughed skin was used in genetic analyses of modern populations of humpback whales. These successes understandably lead some to question the need for obtaining biopsies from living whales for population genetic studies, enquiring instead if sloughed skin and/or museum material would suffice. Here we outline some of the problems encountered with these other materials and the advantage of using biopsy samples.

The primary problem with museum and historical samples is that they usually yield very small amounts of degraded DNA, which can be difficult to extract and work with. The studies mentioned above all generated sequences from the mitochondrial genome, which has a high copy number in cells, which in turn increases the chances for amplification the target sequences. Even this data generation is much more labor-intensive, often requiring multiple extractions and special workspaces in the laboratory (to avoid contamination from other, more robust, DNA sources). In population genetic studies, nuclear markers, such as microsatellites, SNPs and nuclear gene sequences are becoming increasingly important, providing data that are independent of the mitochondrial genome and allowing individual-based analyses through genotyping. The fragmentary nature of the DNA in historical samples usually precludes the examination of nuclear markers, whose lower copy number in the cell significantly decreases one's chances of successful amplification. This problem is not necessarily unbiased, in that larger target segments have a lower chance of amplification than smaller ones. This "allelic dropout" can be a serious source of error in studies that use markers such as microsatellites, in which size polymorphisms are the primary source of variation. These missing alleles would not necessarily be uniformly distributed across the sample set, introducing considerable bias. Some museum materials, especially soft tissues, are preserved in formalin. In addition to the low yield and fragmented DNA, these materials often contain PCR inhibitors, adding yet another layer of difficulty to obtaining usable data.

In some cases, sloughed skin or "scrubbed" skin samples yield high quality DNA, albeit in very small amounts. Their utility appears to vary between species, perhaps even between populations. In some ways, their limitations are similar to those of historical samples, in that studies involving nuclear DNA markers face more difficulties than those targeting mitochondrial DNA. For example, Gendron and Mesnick (2001) had only a 55% success rate in genetically determining the sex of blue whales from sloughed skin. In addition to the technical limitations involving DNA, there are other problems associated with depending on sloughed skin for any particular study. Sloughed skin sampling is opportunistic, in that the researcher has no control over whether a given whale will slough any skin, and when there are multiple whales around, there will be some uncertainty about which whale is the source. The difficulty of genotyping the sample, which involves nuclear DNA, prevents identification of individuals. Determining the molecular identity of individual whales also allows estimation of abundance through capture-recapture, and assessment of relatedness, paternity, male-mediated gene flow and reproductive success. These analyses would be difficult or impossible with sloughed skin samples.

Obviously, none of the problems discussed above apply to biopsy samples. Although some studies have reported some success with sloughed skin and historical samples, and new laboratory techniques are continually being developed for their use, these alternatives should not be considered preferable to biopsy for population genetic studies, especially in light of the increasing emphasis being given to large sample sizes and multiple markers for effective analysis. It should also be mentioned that biopsy samples also enable other important data to be collected from the skin or blubber, such as quantification of contaminants, stable isotope analyses and determination of reproductive status from hormone levels.

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Appendix 7

REPORT OF THE INTERSESSIONAL GROUP: WORK REQUIRED TO COMPLETE ASSESSMENT OF SOUTHERN HEMISPHERE HUMPBACK WHALES

At the 2002 meeting an intersessional group (members: Bannister – convenor, Baker, Best, Findlay, Garrigue, Matsuoka, Nishiwaki, Olavarria, Rosenbaum, Zerbini) was established to review the current state of knowledge of Southern Hemisphere humpbacks, with the following terms of reference (IWC 54, SC Report Item 10.4.4):

i) summarise current knowledge by population or management area;

ii) identify major gaps in knowledge;

iii) establish research priorities to fill the gaps.

Information under (i) was to include abundance and trends, catches and incidental takes, population structure and stock identity, biological parameters, environmental concerns and assessment models. In summarising information, the North Atlantic humpback whale Comprehensive Assessment was to be the model.

The intersessional group was to report to the Southern Hemisphere Subcommittee at SC55, in Berlin.

The intersessional group has completed its task to the following extent:

Term of Reference 1. Summarise current knowledge by population or management area.

Following RIWC 48, p 181, the group took the seven putative Southern Hemisphere breeding stocks, A-G, as the basis for a tabulation of current information. Areas were allocated to group members as follows:

A: Western S Atlantic - Zerbini, Rosenbaum

B: Eastern S Atlantic - Best, Findlay, Rosenbaum

C: Western Indian Ocean incl Madagascar - Best, Findlay, Rosenbaum

D: Eastern Indian Ocean - Bannister, Matsuoka, Nishiwaki

E: Western Pacific Ocean

a) E coast of Australia - Bannister, Matsuoka, Nishiwaki

b) New Caledonia/Fiji/Tonga – Baker, Garrigue

F: Oceania - Baker, Garrigue

G: Eastern Pacific - Baker, Olavarria

The table headings corresponded with the subjects considered by the North Atlantic humpback whale assessment (JCRM 4, Supplement, Annex H, pp 230-237, April 2002). Entries were to be based, as far as possible, on published information, with references footnoted.

Tables 1a-c presents the results to date. As far as possible it includes information presented in papers to this meeting. For convenience Table 1 is partitioned into three sections a-c, covering breeding stocks (BS) A,B; C,D; and E-G, with associated references. In line with recent evidence, BS E was initially subdivided into two (E (i) and E (ii)) to allow for a distinction between animals breeding close to the eastern Australian coast and in New Caledonia /Tonga. Subsequently E (ii) was further subdivided (into E (ii) 1 and E (ii) 2) to allow for the likelihood of separate breeding stocks in New Caledonia and Tonga. In the table there is also comment on the possibility of further division within BS C (into C1 – coastal Mozambique, C2 – coastal central Mozambique Channel Is, and C3 – coastal Madagascar). Similarly there is the possibility of two breeding stocks within BS F – centred on a) French Polynesia and b) the Cook Is.

Some unevenness of approach is evident in parts of Table 1. This is particularly true of column 5, Commercial catches, where some entries are quite detailed (e. g. for BS G, Eastern Pacific), while others refer simply to references (e. g. for BS D). It seems useful to retain the former, which reflects the complex catch history, with different operations, land station and pelagic, over different time periods in a number of localities.

Term of Reference 2. Identify major gaps in knowledge

To simplify the task, the information for each entry in Table 1 has been 'scored', from unknown to well-known, on the following basis:

0 = unknown

1 = poorly known

2 = moderately well-known

3 = well-known

The results are given in Table 2. While much of the scoring has to be somewhat subjective, entries for column 7 (population abundance) have been given the highest score, 3, where the CV or s. e. of the estimate is less than 0.25, or where the 95% C I, converted as indicated, is also less than 0.25.

Inspection of Table 2 shows obvious major gaps in current information, particularly for column 8 (population trend), and columns 9-11 (Biological parameters). Knowledge is also far from complete for Population structure/Stock Identity, although (as well-recognised already) less so for breeding grounds and migration routes than for feeding grounds.

Findlay et al (2000) concluded that from their preliminary assessment the '*results are surprisingly insensitive to the existing range of suggestions concerning allocation of historic catches to stocks, but are more strongly influenced by possible negative bias in abundance estimates and uncertainties concerning estimated rates of population increase'*. This suggests that in examining Table 2 in the context of stock assessment, attention should be given particularly to columns 7 and 8 (population abundance, population trend). That is of course on the assumption that information in columns 2-4 (Population structure/Stock Identity) is as complete as possible.

On that basis, the following main conclusions[1] can be drawn:

(i) Population Structure/Stock Identity (columns 2-4)

Breeding grounds (column 4) are moderately well-known for most groups apart from BS F (Oceania), which anyway may well comprise two separate elements (French Polynesia, Cook Is)

Migration routes (column 3) are moderately-well known for 4 groups (BS B, C, D, E(i), ie E S Atlantic, W Indian Ocean, Eastern Indian Ocean, E coast of Australia), poorly known for 3 others (BS A, E(ii)1 and E(ii)2, ie W S Atlantic, New Caledonia, Tonga) and not known at all for one (BS F, Oceania).

Feeding grounds are only well-defined for one group (D, E Indian Ocean) and either poorly defined, or not known at all, for the remainder

(ii) Population abundance (column 7)

There are moderate-good estimates for 4 groups (A, C, D, E(ii)1: W Atlantic, W Indian Ocean, E Indian Ocean, E coast of Australia) but only poor estimates, or none at all, for the remainder

(iii) Population trend (column 8)

There are moderate-good estimates for only two groups (D, E: W Indian Ocean, E coast of Australia), and only poor estimates, or none at all, for the remainder

(iv) Commercial catches (column 5)

Most catch histories appear to be more or less complete, with the exception of the central Pacific (BS E (ii) 2 - F), where the coverage is generally poor. The question remains, however, of how to apportion Antarctic catches to the various breeding stocks. This is particularly true for BS E as a whole, and also perhaps for BS A.

Term of Reference 3. Establish research priorities to fill the gaps

The IG has not addressed this item.

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[1] From here on the conclusions are those of the convenor and not of the group as a whole

Table 1a Southern Hemisphere Humpback Whales - Summary of information available for Breeding Stock (BS) A and B

	Population Structure/Stock Identity			Catches				Biological parameters				
								(9)	Survival		(12)	(13)
(1) BS	(2) Feeding grounds	(3) Migration routes	(4) Breeding grounds	(5) Comme-rcial	(6) Subsistenc e/Incidental	(7) Pop. abundance	(8) Pop. trend	Age at sexual maturity	(10) Juvenile	(11) adult	Environ-mental concerns	Assess -ment models
A	Unknown, possibly IWC Management Area II (Weddell Sea)[1,2]	Unknown, possibly oceanic waters off the eastern Coast of South America[3]	Eastern coast of South America from ~3 to 22°S[3,4,5] Significant genetic structure based on mtDNAhaplotype frequencies for breeding areas and migratory corridors of A cf B and C. Updated analysis underway[6]	1542 (1910-1967)[7,8] Antarctic , 1904-1974, see refs [15, 16] - allocation to be determined	0-3/year, 1983-2003 (n = 1)[9]	*Mark recapture*: Abrolhos Bank [10](273-1519) EMPIRICAL BAYES[11]***: (1995)*** 1634 (90% probability interval = 1379-1887) *Chapman corrected Petersen*[12]: (1996-2000) 1389 – 3977 CV=27% *Max. likelihood*[12]: 1996-2000 2393 (95% CI = 1924-3060) *Max. likelihood + growth rate*: (2000)[12] 3871 (95% CI = 2795-5542) *Line transect*: Ship Survey (5 to 12°S) (2000) 580 (95% CI = 315-1069)[5] *Aerial Survey* (12-20°S) (2001) 2291 (95% CI = 970-5460)[13]; (2002) 2396 (95% CI = 1691 – 3100)[14]	?	?	?	?	Oil and Gas Exploration , Boat traffic, Whalewatc hing,	?
B	Suggested as Area IIE and Area III[1] Preliminary connection demonstrated by satellite telemetry [2] Genetic analysis comparing breeding and feeding for B and C and Areas II and III underway (Rosenbaum et al.) Some mixing with C and A being tested	W African coast from S Africa to Bight of Benin/Gulf of Guinea, extending from nearshore to >2000 km offshore [,3,4, 5, 6, 7, 8]	Equatorial waters of central w Africa from ~6 °S to 6°N including Angola, Congo, Gabon, Benin and other range states in the Gulf of Guinea[,3,4, 5, 6, 7,8] Large concentrations and breeding activity documented off the coast of Gabon ~4 °S to 0° [7,8] Significant genetic structure based on mtDNAhaplotype frequencies for breeding areas and migratory corridors of B cf A and C. [9] Significant variation in haplotype frequencies and Φ_{ST} between west S Africa cf Angola and Gabon, but not between Gabon and Angola. [10] Updated analyses underway	South Africa-Gabon coastal 21671 (1909-1930)[11] post 1930, see BIWS and refs [1, 12] Aboriginal whaling off Pagalu (Equatorial Guinea) estimated at 1-3 whales/yr from 1950-70s [13] Antarctic , 1904-1974, see refs [17, 18] - allocation to be determined	?Subsisten ce catches in Pagalu (Equatorial Guinea)	*Line transect*-coast of Gabon: surveys completed in 2002: 14 *Photographic and genetic capture-recapture* projected for 2004-2005	Comparing catch rates in the last few years of humpback whaling with current sighting rates, it seems qualitatively that there must have been an increase off w S Africa	?	?	?	Oil and Gas Exploration , Production and Transport [15, 16]	?

Table 1b Southern Hemisphere Humpback Whales - Summary of information available for Breeding Stock (BS) C and D

	Population Structure/Stock Identity			Catches				Biological parameters				
									Survival			
(1) BS	(2) Feeding grounds	(3) Migration routes	(4) Breeding grounds	(5) Comme-rcial	(6) Subsistenc e/Incidental	(7) Pop. abundance	(8) Pop. trend	(9) Age at sexual maturity	(10) Juvenile	(11) adult	(12) Environ-mental concerns	(13) Assess -ment models
C	Suggested Antarctic 0-50°E, centred on 10-40°E. Possible mixing with B stock.[a] Two mark returns from Area III to s Madagascar.[b] Genetic analysis linking breeding and feeding for B and C and Areas II and III underway (Rosenbaum et al.) Possible connection/ exchange with n Indian Ocean, but further analyses needed[c]	C1 – east coastal waters of southern Africa[d]; C2- possibly central Mozambique Channel[d]; C3- Star Bank, Walters Shoal and possibly Madagascan Ridge.[d] E coast of Madagascar, from s. Madagascar n. to Antongil Bay[e].	C1 – coastal waters of Mozambique (n. limit unknown, probably into Tanzania); C2 – coastal waters of central Mozambique Channel Islands, possibly as far n as s. Seychelles; C3 – coastal waters of Madagascar, w. coast unknown, s. and e. coasts as far north as Antongil Bay[e] Significant genetic structure based on mtDNAhaplotype frequencies for some breeding areas and migratory corridors between B and C. Updated analysis underway[c] structure found among C1-C3 ncies.[f] Updated analysis underway Several photographic recaptures between C2 (Mayotte) and Madagascar (C3) [g]	Modern whaling (1908-1963) Cape: 68; Natal: 9785 Moz: 3128; Madagascar: 6181; Antarctic Area III (BIWS) -7074; Soviet Fleet (known up to 1974) -1280.[h] Unsubstantiated reports of direct takes in southern Madagascar[i]	?	C1 *Shore-based sighting survey* – migration stream at Cape Vidal, SA (1990) - 1777.[j] C1 – *Vessel-based line transect survey* -s and central Mozambique (1991) – 1,954 (CV 0.38).[k] C3 - *Vessel-based line transect survey* - s Madagascar (1994) - 2,532 (CV 0.27).[l] *Photographic Capture-Recapture* C3- Antongil Bay, n e Madagascar (1996-1999) 1,746 (CV 0.19)[m] Updated estimates from photographic and genetic capture-recapture for C3 available within 2-3 years	Unknown – raw data from 2002 surveys at Cape Vidal suggest an increase since 1988-1991. There must have been some recovery in southern Madagascar since 1950[l]	Potentially available from C3 breeding grounds within 2-3 years	Potentially available from C3 breeding grounds within 2-3 years	Potentially available from C3 breeding grounds within 2-3 years	General concerns about threats and critical habitat discussed in ref [i]	?
D	Antarctic Area IV, 80-110°E; some mixing with E(i)[1]	Between Antarctic and WA coast[1]	Coastal w Australia, esp. ca 15-16°S[2]	See refs[1,3]	Possibly 1-2/year from entangleme nt[7]	*Aerial survey*: 8000-14000 (1999)[4]; *Est from catches and increase rate*:8000 (1999)[5]; *Antarctic sightings*: 29856 (CV 0.27); (2000/2001)[6], SOWER: 17300 (CV 0.17) (1998/99)[6]	10.15±4.6% (1982-94)[4]; 12.5% , CV 0.58 (1989-2002))[6]	4-5 yrs, both sexes (1951-59, assuming 2 laminatio-ns/yr)[1]	?	0.93 (range 0.91-0.95) (1949-62)[1]	Oil and gas exploration/pr-oduction (breeding grounds), ship traffic, entangl-ement (coastal migration corri-dor); climate change (feeding grounds)	?

Table 1c Southern Hemisphere Humpback Whales - Summary of information available for Breeding Stock (BS) E, F and G

	Population Structure/Stock Identity			Catches				Biological parameters				
								(9) Age at sexual maturity	Survival			
(1) BS	(2) Feeding grounds	(3) Migration routes	(4) Breeding grounds	(5) Comme-rcial	(6) Subsistence/Incidental	(7) Pop. abundance	(8) Pop. trend		(10) Juvenile	(11) adult	(12) Environ-mental concerns	(13) Assess-ment models
E (i)	Antarctic Areas IV-V, 110°E -?	Between Antarctic and e Australian coast/Coral Sea[1]	Coastal e Australia, esp. 18-21°S[2]	See refs[1,3]	Probably more than for BS D, but number not known[22]	*Shore-based survey*: 3600 ± 440 (1999)[2] *Antarctic sightings*: 4251(CV 0.48), (2000/2001)[4]	10.9% ± 1%[2] (1984-1999); 10.08% (s.e. ??, 1980-2000), 8.52% (s.e 0.05, 1986-2000), 8.54% (s.e.0.05, 1991-2000)[5]; 10.3 % (CV 0.59) (1990-2001)[4]	4-5 years, both sexes (1951-59 assuming 2 laminations /yr)[1]	?	0.91 (lower limit, 1957, 1958)[1]	As for D	?
E (ii) 1	Antarctic Area V ?-?°E	Within Oceania[,21] , past eastern Australia and New Zealand	New Caledonia 22°S[3]	?	?	*Petersen capture-recapture, photoID*:327 (CV 0.11) *genotyping*:533 (CV 0.15), both weighted mean of Petersen (1995-2001)[4]	?	?	?	?	Unregulated whale watching[5]. Nickel mining	?
E (ii) 2	?	Within Oceania[2] (one record between Bellingshausen Sea, Area VI, and Tonga; one between Area V and Tonga[1])	Tonga[3]	Small-scale coastal hunt until 1979[5]		*Weighted Petersen capture-recapture:* 990 (SE 0.15, 1991-2000)[4]; 730 adjusted for 3% adult mortality[5] (2000)	?	?	?	?	?	?
F	?	Within Oceania[1]	French Polynesia[2], Cook Islands[3] Significant difference in mtDNA suggests 2 breeding grounds[5]	Rurutu, Austral Is (22°30'S, 151°15'W). Local capture for food until 1959	Rurutu - entanglements (2)	*Cook Is/French Polynesia catalogue size* :232 individuals (to 2002)[4]	?	?	?	?	?	?
G	Antarctic Area I, 60-120ºW[1], recommended shift of eastern limit to 58°W.[2] Strait of Magellan[3] possibly Perú and northern Chile[4]	Unknown, possibly oceanic waters off w coast of South America	Coastal waters w South American, between south Panamá and north Perú[5], but mainly Colombia[6] and Ecuador[7,8]	Antarctic, Chile, Perú. Occasionally Ecuador, Colombia[9, 10, 11] 1726 (1904-1939)[12] 1985 on w coast S America (1912-1967)[14] 70 off Peru and Chile by pelagic whaling (1935-1951)[14] 105 off Chile-Peru-Ecuador by Olympic Challenger in 1954[15] 8879 (min) in South Shetland Is (1905-1926) by land and floating factories[14] 1295 in Area I by Antarctic Pelagic Whaling (1923-1963)[14] 414 in Area I by Soviet Antarctic whaling fleet (948-1973)	Entanglements, vessel strikes in Colombia[16] and Ecuador[17]	Colombia: Petersen capture recapture: Gorgona Island, 170-450 (1986-1988)[6] Gorgona Island:1495 (1994-1995, 95%CI= 919-2071) Málaga Bay: 857 (1994-1995, 95% CI=547-1167) Colombia: 1655 (1994-1995, 95%CI= 1120-2190)[18] *Ecuador:* Bailey-modified Petersen capture recapture: 1922 (1996-1997, 95%CI= 77-3,767)[19] 2683 (1991-1997, 95%CI= 397-4,969)[19] *Chapman-modified Petersen capture recapture*: 405 (1998-1999, 95%CI= 221-531)[8]		?	?	?	?	?

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Table 2 Southern Hemisphere humpback whales - gaps in knowledge

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
A	1	1	2	2	3?	2-3	0	0	0	0	2	?
B	1	2	2	3?	0	1	0-1	0	0	0	2	?
C	1	2-3	2	3?	0	2-3	0-1	0	0	0	2	?
D	3	2-3	2-3	3?	0	2	2	?	0	?	2	?
E(i)	1	2-3	2	3?	1-2	2-3	3	?	0	?	2	?
E(ii) 1	1	1	2	1	1	3	0	0	0	0	2	?
E(ii) 2	0	1	2	1	0	1	0	0	0	0	0	?
F	0	0	1[2]	1	2	0	0	0	0	0	0	?
G	1-2	1	2	2	1	2	1-2	0	0	0	0	?

Column key

1 Breeding stock

2 Feeding ground

3 Migration route

4 Breeding ground

5 Commercial catches

6 Incidental and other catches

7 Population abundance

8 Population trend

9 Age at sexual maturity

10 Juvenile survival

11 Adult survival

12 Environmental concerns

13 Models

Row Key

0 = unknown

1 = possibly known

2 = moderately well-known

3 = well-known (for col 7, score 3 where CV or s.e <0.25, or , for 95% C I, where (Upper bound/Lower bound)^{¼} -1 <0.25)

[2] Possibly 2 breeding grounds

Final Draft of the Report of the IWC/SOWER Blue Whale Acoustics Workshop, 23-26 August 2002, Elk Mountain, WY

Members (bold attending): **C.W. Clark**, G. D'Spain, **D. Ljungblad**, M. MacDonald, **R. McCauley**, H. Shimada, **K. Stafford**, and **G. Gagnon** (special guest)

The Working Group met on 23-25 August, 2002 at the Elk Mountain Hotel in Elk Mountain, Wyoming. Those in attendance included C. W. Clark, G. "Chuck" Gagnon, D. Ljungblad, R. McCauley and K. Stafford. M. MacDonald and H. Shimada could not attend due to other commitments. G. D'Spain was hoping to attend but had to cancel for personal reasons at the last moment. Chuck Gagnon (Ret. LCDR, US Navy) was invited by Clark because Gagnon was in the Wyoming area and has at least a decade of experience detecting and tracking blue whales via the Navy's SOSUS system.

Adoption of Agenda and format of meeting

The draft agenda was adopted and included the following items for the group to consider.

1. Review of relevant and available documents
2. Review of IWC-SOWER cruises 1995-2002
3. Blue whale acoustics
4. Low frequency sound propagation of blue whale signals
5. Field methods of data collection
6. Recommendations

The three primary objectives from the "Extracts regarding the Acoustics meeting from the 2000 planning meeting report" were used as a guide. These were:

1. to review sounds
2. to reappraise the value of acoustics
3. to make recommendations

Review of relevant and available documents

The group reviewed the history of the acoustics IWC-SOWER efforts starting with the cruise in 1995/96 (Australia and Antarctic) and ending with the cruise in the 2002 (Antarctic only). Clark and Ljungblad discussed the status of the various tape collections from the different cruises. Approx. 507h of the 710h of material collected through 2000 have been archived and screened for whale sounds (blue, fin, humpback and other) at Cornell. A paper on the results of the preliminary analysis was presented at the 2001 IWC-SC meeting in Hammersmith (Clark and Fowler, SC53/IA28). Ljungblad has more tape recordings ready to send to Cornell. The 2002 IWC-SOWER tapes need to be sent by Shannon Rankin to Cornell for archiving, copying and analysis as soon as possible.

Review of IWC-SOWER cruises 1995-2002

The group reviewed the cruise reports from the 1995 Australia cruise up through the 2002 Antarctic cruise. Summaries and details of the acoustic field efforts and acoustic recording results are given in cruise reports for each of the cruises. We did not go through all these in detail, but did refer to them to clarify where, when and how many acoustic samples were collected in which years and by whom. Ljungblad helped lead this discussion and answered questions concerning field protocols and mechanics. Members of the group had numerous comments and suggestions some of which are included below under "Data Collection Methods". Ljungblad also reiterated important recommendations to improve data collection and data quality. These and others distilled from the group's discussion are provided in the section below under "Recommendations".

Blue whale acoustics

Six representative samples of blue whale songs have been collected on IWC-SOWER cruises, two in mid-latitudes off Madagascar and Chile and four from south of 60º S off Antarctica (Ljungblad *et al*. 1998). Two important results have emerged from this IWC-SOWER acoustic effort: 1) All songs recorded south of 60º S ("Antarctic" region) are of the same type independent of year or location. This now includes song samples collected on four different years in four different Antarctic locations. 2) The song types recorded off Madagascar and Chile are different from each other and from the Antarctic. These IWC-SOWER results are augmented by recordings made by others in both hemispheres (e.g., McCauley for Australia, Stafford for North and South Pacific, Gagnon and Clark for North Atlantic, Hildebrand *et al*. for the Antarctic Peninsula, Cummings *et al*. for Chile, and Alling and Payne for Sri Lanka). To simplify discussion on where samples have been collected, nine regions were identified: Antarctic, Australia, Chile, Madagascar, North Atlantic, Northeast North Pacific, Northwest North Pacific, Eastern Tropical Pacific and Sri Lanka. Figure 1 illustrates a global perspective showing spectrographic examples of songs for the different regions from which blue whale sounds have been recorded. Overall, the global picture that is emerging for blue whale songs is extremely interesting. It indicates that there is a limited number of song types throughout the world, that there are large regions within which song structure is similar, but there are regions in which multiple song types are found (e.g., the ETP). For some regions it appears that a song type has remained constant over periods of several decades (e.g., Chile: Cummings *et al*. 1971, IWC-SOWER 1997, Stafford *et al*. 1999), while in some regions with multiple song types different song types occur at different times of year. This emerging pattern is encouraging and does not contradict the notion that song type might serve as an indicator of male population affiliation. Unfortunately, there is as yet no phylogenetic evidence (molecular or morphological) to specifically compare with these acoustic data. The need to describe molecular genetic sequences for different regions and to compare these with the acoustic evidence is critical. Evaluation of the utility of acoustic signatures for population identification is dependent on such data.

The benefits of a common nomenclature for referring to blue whale sounds were discussed. Blue whales are know to produce songs and calls, where songs are long, often very intense, patterned sequences of stereotypic sounds, and calls are individual utterances not predictably found in combination with other sounds. It is assumed that singers are males, but this has yet to be proven. Similar types of frequency-modulated calls in the 30-80Hz frequency band and lasting ca. 2-8s, have been recorded throughout the world, sometimes in the context of observed surface activity. All recordings of blue whale songs share common acoustic features that distinguish them from other balaenopterid species. Song sound units are frequency-modulated or amplitude-modulated tones with fundamental frequencies in the 10-40Hz band and durations of 5-40s. Song structure is hierarchical, with individual sound units combined into phrases, phrases repeated to form a song and songs repeated in a bout. Singing occurs throughout the year and is often associated with areas of high productivity where feeding is either known or assumed to occur. There are now cases in both the North Atlantic and North Pacific where songs have been recorded which combine characteristics of both blue and fin whale songs from the region.

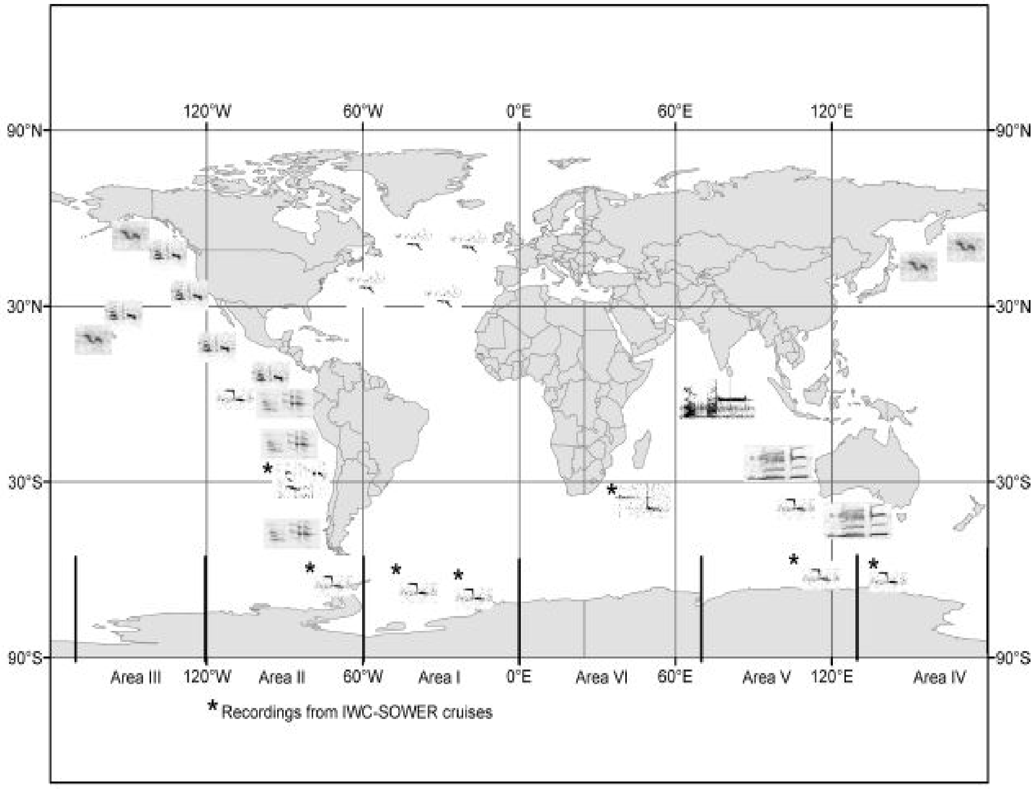

Figure 1. Map of the world showing the currently identified blue whale song phrases.

Low frequency sound propagation of blue whale signals

Blue whale signals have features that are adapted for long-range communication in the open ocean. With the proper equipment and survey protocols, vocalizing blue whales can be detected at distances of many tens of miles, long before they would be seen from a ship. The acoustic detection range of a singing blue whale may be at least an order of magnitude greater than the visual detection range. The group thought it was important to emphasize that oceanographic acoustic propagation conditions can have a profound affect on acoustic detection range and detection probability, with detection ranges varying by several orders of magnitude. Therefore, the group decided to provide some details on this topic including a table listing predicted detection range under a variety of conditions as expected for the typical IWC-SOWER Antarctic survey region.

Although there are many factors that influence detection range, three of the most important are source level (SL), transmission loss[1] (TL) and ambient noise (N), where source level is the intensity of the sound produced by the whale, transmission loss is the amount of intensity that the sound loses as it propagates through the ocean and ambient noise is the level of background noise at the receiving hydrophone, where the hydrophone could be at the surface, mounted off the bottom, or a suspended beneath a sonobuoy (e.g., Don's sonobuoy hydrophone).

Source level is a biological variable that has only been properly calculated a few times. The best estimates of source levels range from 170 to 185 dB re 1mPa (mean squared pressure) at 1m (Thode *et al*. 2000).

A modified version of the sound propagation model "Bellhop" was used with a variety of sea states, and bathymetric and sound speed profiles to predict transmission loss . The model was run for receiver depths from 5 to 300m depth in 5m increments, out to 100km range in 0.2km steps, and a 30m source depth and at a frequency of 20Hz. A resultant transmission loss function was computed with three values of blue whale source level

[1] There are numerous models available to predict transmission loss. These require information on sound velocity as a function of depth, bathymetric contour, source frequency, source depth, receiver depth and in some cases information on the acoustic impedance of the ocean bottom. For sound velocity in the Antarctic regions of interest one can assume a very slight thermal gradient or an almost isothermal condition yielding either a surface duct or a slightly downward refracted condition (see Jensen *et al*., 1994). For blue whales we assumed a tonal sound at a frequency of 20Hz, a source depth of 30-40m and a receiver depth 200-300m. For bathymetric contour, four whale-hydrophone were considered: continental shelf (200m) to continental shelf (200m), continental shelf (200m) to deep water (4000m), deep water (4000m) to continental shelf (200m), and deep water (4000m) to deep water (4000m). Seafloor impedance was ignored for this exercise. Ambient noise in the 15-25Hz frequency range of blue whale signals may vary by as much as 20dB, and wind speed is the primary predictor of noise in this frequency band. Therefore Beaufort scale was used as a proxy for ambient noise level.

(175, 180 and 185 dB) and three values of sea state (B-3, B-5 and B-7), which serves as a proxy for ambient noise level, to estimate the received level of a singing blue whale as a function of range and depth.

These predicted received level curves were then used to estimate the range within which 95% of singing blue whales could be heard. This 95% detection range was obtained by:

- Choosing the appropriate broadband ambient noise level in the 20Hz 1/3 octave frequency band,
- Scoring the received level curve for the appropriate source level as a "1" if the value was above the ambient noise level or a "0" if below ('detection' curve),
- Calculating the cumulative sum of the 'detection' curve, and
- Finding the range at which the cumulative sum curve reached 95% of its maximum value.

The resulting predictions of the estimated range in which 95% of calling blue whales could be heard are shown in Table 1 for a 200 or 300m depth hydrophone receiver. Although these ranges are considered rough estimates, they do indicate that even under near-gale conditions one can expect to detect a singing blue whale on a sonobuoy hydrophone at a range between 18-50 nautical mile, depending on the animals source level.

Table 1: Estimated 95% probability of detection range (nautical mile) for blue whale song under four different bathymetric conditions, for three levels of ambient noise given by Beaufort wind strengths of 3, 5 and 7 and for whale song source levels of 175, 180 and 185dB (re. 1 μPa at 1m).

	Bathymetry path		Source level								
	Receiver location	Source location	175			180			185		
			B-3	B-5	B-7	B-3	B-5	B-7	B-3	B-5	B-7
A	On shelf, 200m water/receiver depth	On shelf, 200m water depth, 30m source depth	48	22	18	> 50	44	22	> 50	49	43
B	On shelf, 200m water/receiver depth	Down-slope, 30m source depth	48	42	37	> 50	46	41	> 50	49	45
C	Off shelf, 4000m water depth, 300m receiver	Off shelf, 4000m water depth, 30 m source depth	> 50	> 50	47	> 50	> 50	> 50	> 50	> 50	> 50
D	Off shelf , 4000m water depth, 300m receiver	Up-slope to 200m depth, 30 m source depth	47	41	37	> 50	45	41	> 50	48	45

Field methods of data collection

The group had considerable discussion on the need to improve the methods used to collect acoustic data. Some of this discussion was conducted under the assumption of ideal conditions regarding location, time of year, vessel and research team. The group believed that if the objective was to obtain unambiguous genetic and acoustic signatures for individual Southern Ocean animals, then dedicated research should be conducted in locations where blue whales are seasonally abundant (e.g., southern Australia) and where they could be studied from well-equipped research platforms within close proximity to local resources. However, given the constraints of the IWC-SOWER cruises, most of the benefits of such thinking are not applicable. The group therefore concentrated on the IWC-SOWER situation, and in particular the need to collect acoustic samples in coordination with biopsy samples from along the ice edge.

There is now evidence from three Areas (I, II and V) that supports the conclusion that blue whale songs from south of 60ºS are similar, with song similarity suggesting that males are from the same breeding population. The 2003 IWC-SOWER cruise offers an opportunity to collect recordings from Area VI. Of considerable importance is the need to carefully link a biopsy sample with a specific singer. Thus, every effort should be taken by the chief scientist to closely coordinate the activities of those collecting the biopsy samples with the acoustic information coming from the bioacoustician who is monitoring the sonobuoy. This is the reason we recommend using a VHF microphone system for communication from the deck to the bioacoustician. Given the limited number of scientists and the constraints of the ship's scientific equipment, it is not possible to conduct a research program that could reliably detect, locate and track a vocal animal and direct the biopsy effort to that individual (as in Croll *et al*. 2002 for fin whales). At one level it might be possible to use two vessels working in close proximity (< 10 nmi) to detect and position a singer. This would require that both ships deploy DIFAR buoys, determine DIFAR bearings to the singer in close-to-real-time (<1 minute after a sound), and communicate bearings to a person responsible for coordinating the vocal-biopsy effort. This person would then use the two DIFAR bearings to estimate the whale's range and bearing from each ship, direct the ship to the area of the whale and keep the visual and biopsy teams informed.

There was a lengthy discussion about the mechanics of collecting acoustic data from the ships. In particular, there are obvious limitations with regard to acoustically detecting a blue whale, determining a bearing to the whale, and then coordinating the collection of a biopsy sample from that singer. It seems that with the proper equipment and cooperation between the scientific team members that all three tasks could be achieved.

From experience and as illustrated in Table 1 above, if a whale is singing, the chances of detecting it acoustically are far greater than detecting it visually. The benefit of using acoustics as a primary detection mechanism further increases when considering the impact of visibility conditions on sighting probability (night, high sea states, fog). This consideration underscores the recommendation that more opportunities be given to listening whenever possible, and not just when a whale is sighted from the ship.

Recommendations

In past years, several recommendations have been consistently made that, if implemented, would greatly improve preparations and planning of the acoustics field effort. These include:

1. Have the ad hoc planning meeting, which occurs at the annual IWC-SC meeting, dedicate some funds early in the year so that sonobuoys can be sent by surface shipping rather than air freight. This would eliminate complications caused by hazardous materials going by air and reduce shipping costs from around $8000 to $2000. Another problem associated with shipping hazardous materials by air is that the captain can refuse to carry the material on his aircraft. This happened on a shipment to Cape Town and caused the Shonan Maru to be delayed in port for a week while waiting for the sonobuoys.
2. Some funds should be made available for acoustic personnel early in the year so that equipment can be built, purchased and tested for the upcoming cruise. For example, to date Don Ljungblad has funded this work out of his own pocket.
3. Each vessel should have back up equipment. This should include: two laptop computers., at least two hydrophone with pre-amp cable assemblies, two modified sonobuoys, two VHF radios, associated backup equipment and cables, and an extensive repair kit.
4. Both systems must be thoroughly checked out prior to leaving Hobart and both acoustic personnel must be totally familiar with all hardware and software operations.
5. If possible the two acoustic personnel should be selected at the ad hoc IWC meeting so as to give them time to prepare the acoustic equipment. This would also give them the opportunity to discuss and test the equipment in a common way prior to shipping.

The group agreed with these recommendations and strongly recommended that they be implemented on future cruises.

The group agreed that this report should be shared with other scientists with interest in and experience with blue whale sounds. This includes, but is not necessarily limited to: G. Gagnon, J. Barlow, D. Cato, G. Donovan, J. Hildebrand, D. Mellinger, S. Moore, P. Gill, D. Thiele, S. Rankin and T. Norris.

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