

Annex F

Report of the Sub-Committee on Bowhead, Right and Gray Whales

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1. OPENING REMARKS, ELECTION OF CHAIR AND APPOINTMENT OF RAPORTEURS

Walløe welcomed the participants and was elected Chair. Brandon, Hoelzel and Waples were appointed to act as rapporteurs.

2. ADOPTION OF AGENDA

The adopted Agenda is given as Appendix 1.

3. REVIEW OF AVAILABLE DOCUMENTS

The documents available for discussion by the subcommittee included SC/59/Rep 3, 4, BRG1-23, 25-30, 32-41, SD3, AWMP1, O18, SH10, ASW5, ProgRep Argentina, Australia, Brazil, Denmark, Japan, Norway, USA, Jackson *et al.* (2007) and Moore *et al.* (2007).

4. BOWHEAD WHALES

4.1 Bering-Chukchi-Beaufort (B-C-B) Seas stock of bowhead whales

4.1.1 Stock structure hypotheses

SC/59/BRG3 summarises research conducted over the past three years to investigate the stock structure of the Bering-Chukchi-Beaufort (B-C-B) population of bowhead whales (*Balaena mysticetus*), as requested by the International Whaling Commission Scientific Committee (IWC SC) during its 2004 meeting (IWC, 2005, pp.23-24). Stock investigations essentially started in the late 1970s during the intensive years of population assessment, and the NSB conducted considerable research in Russia using Native observers during the 1990s to determine the distribution and relative abundance of bowhead whales summering along the Chukotka coast. Research directed towards testing hypotheses concerning the stock structure of B-C-B bowhead whales included five elements: (1) research planning and hypothesis testing; (2) genetics sampling and analysis; (3) animal mixing and abundance; (4) spatial distribution and abundance; and (5) migration patterns. Each of these elements was comprised of several projects including: photo-ID surveys, collection of tissues from harvested whales, traditional knowledge, biopsy sampling in Russia and Alaska, stable isotope analysis of baleen plates, analyses of catch data from the Yankee commercial whaling period, development of new microsatellite loci for bowhead whales, development of new single nucleotide polymorphisms (SNPs) genetic markers, analyses of the updated genetic datasets (SNPs, microsatellite and mtDNA), development of a model for pairwise microsatellite allele matching probabilities, simulation modelling of genetic and demographic population trajectories for comparison to empirical data, genetic modelling simulations, analyses of photo-ID data related to stock structure, estimation and classification of whale ages, estimation of abundance of whales seen in late spring in waters off Chukotka, collection and analyses of passive acoustic data, and satellite tracking of tagged whales. Collectively, these studies have resulted in over 80 research papers (and over 300 IWC SC submitted papers) and contributed new information on B-C-B stock structure, in particular the genetic structure of the B-C-B bowhead whale population. These robust research programs demonstrate that the US has made a major effort to determine if the B-C-B bowhead whale stock has significant population sub-structuring.

The three decades of research have determined that the B-C-B population is a highly labile stock whose distribution is likely driven by prey and ice densities. While the stock is clearly not in genetic equilibrium, there is no compelling evidence of a multi-stock condition within its range, nor compelling evidence of conservation risk under the current single-stock management regime (even if there were more than one stock).

SC/59/BRG3 is intended to be a summary of diverse types of information not only for scientists, but also the wider public with a general interest in these topics. Although the report summarises work that has greatly increased our understanding of the biology of B-C-B bowhead whales, some noted that data are sparse in some areas where there are few whales or little hunting, and stressed the importance of continuing efforts to collect new biological information. George confirmed the intention to continue the project and to encourage peer-reviewed publication of information and analyses developed to date. The sub-committee appreciated the willingness of the US to continue to collaborate with scientists from other member nations to advance our understanding of bowhead biology, including stock structure across the Arctic.

General discussion of stock structure information was deferred until after a number of new papers were presented

4.1.1.1 GENETIC INFORMATION

SC/59/BRG8 presented preliminary results of efforts to develop a new class of nuclear genetic markers, single nucleotide polymorphisms (SNPs). Nineteen SNP assays were optimised initially and used to genotype modern and historical bowhead DNA samples from St. Lawrence Island and Barrow, Alaska. The authors developed novel methods for genotyping multiple nuclear loci from historical and poor quality samples, demonstrating high efficiency and estimated error rates of 0.1% for most samples. Preliminary population analyses with this limited set of loci show no evidence of

population structure for various spatial and temporal strata analysed previously with mtDNA and microsatellite analysis. Power analysis indicates that 29 available SNPs will have sufficient power to detect F_{ST} values of 0.01 with current sample sizes. [F_{ST} is a measure of genetic differentiation among samples ranging from 0 to 1, with 1 indicating maximum differentiation and 0 indicating only random differences due to sampling error.] Ongoing application of additional loci and samples should demonstrate the power of SNPs for population structure analysis, providing a strong alternative to microsatellite loci.

The SNPs developed to date are from random DNA sequences. They have been BLASTed (compared with sequences of known genes in *GenBank*) but with one exception do not correspond to known coding genes. The mutation rate for these markers is not known precisely, but the frequency with which they are encountered in the genome seems to be comparable to what is found in other mammals. Since each SNP only involves 2 alleles, heterozygosity can be no larger than 0.5, considerably less than is typically found with microsatellites. Two somewhat different viewpoints were expressed regarding the distinctiveness of SNPs. One view was that SNPs are not qualitatively different from other markers like microsatellites and should be thought of as complementing, rather than replacing, other markers. Others disagreed, arguing that SNPs have a higher repeatability and therefore require less inter-laboratory standardisation; they involve shorter DNA sequences and therefore can be more easily recovered from degraded specimens; and they have a much simpler mutation model than microsatellites and show much lower levels of homoplasy.

SC/59/BRG11 analysed nearly the same SNPs data presented in BRG8 and found similar results to those in BRG8. It also presented a preliminary analysis looking for a temporal pulse signal in autumn Barrow samples using an adaptation of the method of Givens and Ozaksoy (2006). No temporal pulse signal was detected.

A question was raised about the biological meaning of the strongly negative F_{ST} estimate for Barrow vs. Savoonga. As the method for estimating F_{ST} is unbiased, it is not uncommon to see negative point estimates. However, in this case the bootstrapped confidence intervals were all negative and did not include zero. This indicates that the two samples are substantially more similar than one would expect to occur by chance, even assuming that both were drawn randomly from a single population. Two possible explanations were suggested for this result. First, this might reflect at least in part the comparison of parents with their offspring (discussed in SC/59/BRG16). Second, if a polymorphism is present in only one population, permutation tests can be biased toward $F_{ST} < 0$.

SC/59/BRG9 summarised analysis of mitochondrial DNA (mtDNA) control region sequences of B-C-B bowhead whales from the North Slope, St. Lawrence Island and the Chukotka Peninsula in Russia. Twenty different spatial, temporal, and age-related strata were compared. None of the spatial comparisons yielded a significant difference. Only one temporal comparison was significant, that between autumn and spring whales from St. Lawrence Island. In the age-related comparisons, the youngest stratum (those born after 1979) was significantly different from the oldest (born before 1918), from the next oldest (born 1918-1949), and from these two strata combined. These results did not lend support for the existence of multiple stocks within the B-C-B population. It was proposed that the seasonal differences from St. Lawrence Island might be due to age-related differences, because one of the seasons (autumn; Nov-Jan) is just prior to the breeding season and may therefore include a greater proportion of older whales.

Much of the discussion focused on a comparison of the results of two tests of population differentiation: the chi square contingency test, which uses a randomisation process to generate an empirical distribution of the test statistic, and bootstrapped confidence intervals for F_{ST} . Two questions were raised: Why are some of the low chi square values (~1.5) statistically significant? Why is there a big difference in P values between the two types of test in some cases—specifically, in several examples that show low and significant P values for the chi square test but much higher (non-significant) P values for the F_{ST} test? Two possible explanations were suggested: First, some of these comparisons involved relatively low sample sizes, which could lead to more variability in results. Second, the chi square test might have generally higher power, at least for mtDNA. Regarding the latter, it was noted that some published comparisons of the two tests with microsatellite data have found very similar levels of power.

SC/59/BRG29 presented updated results of a genetic analysis of variation in mtDNA control region sequences in samples of B-C-B bowhead whales. Laboratory work was carried out by US scientists, and access to these data was possible under the Scientific Committee's data access protocol (Procedure A). A total of 399 sequences were available, with 68% coming from a single locality (Point Barrow). An additional 24 sequences from the Okhotsk Sea were used for comparative purposes. As reported previously, nucleotide diversity was lower in whales from the Okhotsk Sea stock than from other localities. Temporal (seasonal) differentiation was examined in those localities with sufficient sample sizes (St. Lawrence Island and Point Barrow), and then geographical mtDNA differentiation among four localities (Point Barrow, St. Lawrence Island, Chukotka and Okhotsk Sea) was examined. No significant mtDNA heterogeneity was found among B-C-B stock whales, apart from a marginally significant seasonal heterogeneity for F_{ST} found in St. Lawrence Island. In contrast with a previous mtDNA result, no significant heterogeneity was found at Barrow when the samples were grouped into spring and autumn. Significant genetic heterogeneity was found between B-C-B stock localities and whales from the Okhotsk Sea. In general, these mtDNA results provide no strong evidence for genetic population structure within the B-C-B stock. Sample sizes for several localities and months, however, remain low; therefore, negative results in some comparisons could be due to low statistical power. Furthermore, summer samples from Chukotka and St. Lawrence Island, which are essential to investigate some of the multiple stock hypotheses, are not available because they are difficult to collect. At Barrow, nuclear DNA markers have suggested the possibility of additional stock structure and mixing of stocks. It is possible, therefore, that the mtDNA analysis could not identify structure if two stocks mix in similar proportion when they pass through that locality in spring and autumn.

The year for dividing the samples into 'early' and 'late' groups was chosen to produce approximately equal sample sizes and did not reflect a biological hypothesis. Sampling of whales in the Okhotsk Sea was considered sufficient to characterise this population, since this is a geographically isolated population of resident whales; it was included as an outgroup, so it is not a problem for the current analyses even if sampling was imperfect.

SC/59/BRG33 was an update of BRG9 and a response to BRG29. Errors in the sample strata from BRG9 were corrected, and further analyses of the St. Lawrence Island strata were conducted, incorporating the putative matches among skull, baleen and skin samples found in BRG8 and in analyses of skulls and whaling records. After removal of putative duplicates, all the analyses were run anew. Qualitatively, the results mirrored those of BRG9, with only the seasonal St. Lawrence Island comparison and the same age-related comparisons yielding significant results.

Some sub-committee members remarked that it is important to report negative results, such as presented in this paper, to provide an accurate overall assessment of levels of differentiation within cetacean species. A general comment about the mtDNA analyses is that none included information about the phylogenetic relationships of the different haplotypes. The authors noted that they had examined this information but had found no geographic patterns that appeared to provide insights into population structure.

SC/59/BRG15 estimated genotype error rates using opportunistic replicate samples in the microsatellite data for bowhead whales. The estimated rate (1% per genotype) falls within normal ranges published in the literature. A jack-knife analysis identified five individuals that were highly influential on estimates of Hardy-Weinberg equilibrium for four different markers. In each case, the influential individual was homozygous for a rare allele. These results demonstrate that Hardy-Weinberg p -values are very sensitive to homozygosity in rare alleles for single individuals. This raises the possibility that even small, normal levels of laboratory errors can result in an overestimate of the degree to which markers are out of Hardy-Weinberg equilibrium, which in turn can lead to an overestimate of the potential to infer stock structure. To avoid such bias, the authors recommended routine identification of influential individuals and multiple replication of those samples.

Concern was expressed that the opportunistic experimental design did not produce truly random samples and therefore the estimated error rates are difficult to interpret. Concern was also expressed that the choice of a criterion for detecting errors could predetermine the outcome. The authors noted that a completely random selection of individuals would have been ideal, but it was not feasible in this case. Instead, they took advantage of individuals that had inadvertently been genotyped twice. Although opportunistic, this sample could arguably be considered to be quasi-random. Furthermore, individuals with putative genotyping errors are easily identifiable and not sensitive to choice of criterion: they have only one or a few allelic differences from another sample in the database, but many more identical alleles than are shared by any two different individuals.

SC/59/BRG20 presented a method for detecting pairs of related individuals in the B-C-B genetic samples, based on 33 microsatellite loci. Thirty-two potentially related pairs were detected; while it was stressed that the list should be treated with some caution until it has been validated using other data, such as SNPs. The geographical sampling location of the identified relatives did not suggest any population structure, with a larger than expected number of pairings between Barrow and St. Lawrence Island and Chukotka, although no formal test of this hypothesis was conducted. A more detailed evaluation of this topic is in progress.

Zeh noted that several individuals identified in SC/59/BRG20, table 2 as having relatives in the analysis are old females, which would be ones who have reproduced many times. George found it odd that only one large old male with large testes showed up on the list, as they would be expected to have fathered many offspring. The absence of any whales with a white ventrum was also noted. Skaug cautioned that power to detect relatives of some individuals (in particular, those carrying common alleles) will be relatively low. In response to another question, Skaug clarified that the false discovery rate procedure used in SC/59/BRG20 does not explicitly account for the lack of independence in the different pairwise comparisons of individuals, but published accounts suggest that the method might be relatively robust to non-independence.

SC/59/BRG14 presented analysis of 33 polymorphic microsatellite loci for B-C-B Seas (B-C-B) bowhead whales, including 22 new highly reliable markers for which scoring failure rates were half as frequent as the original 11 markers. Analyses were conducted using both the full 33-locus dataset and only the 22 new markers. Results indicate departures from completely random mating. Although B-C-B bowhead whales were found to be clearly genetically distinct from bowhead whales in the Sea of Okhotsk and Igloodik, Canada, there were also significant patterns of genetic inhomogeneity among the B-C-B samples. The B-C-B samples exhibited strong and widespread departure from Hardy-Weinberg equilibrium (HWE), and significant evidence of genetic patterns associated with birth year. The birth year effects were hypothesised to be associated with the demographic impacts of commercial over-exploitation, but no direct evidence was available to test this theory. A significant difference in allele frequencies between St. Lawrence Island and Barrow was also detected, although sample sizes were small and these spatial strata are partially confounded with birth year effects because of differences in age selectivity in the hunt at the two locations. No other statistically significant spatial differentiation was detected among the various villages/locations represented in the B-C-B samples, and no seasonal differences at Barrow were detected.

SC/59/BRG14 also estimated bowhead ancestries from the 22 new microsatellite loci using the correlated/admixture model in the *STRUCTURE* software program (Pritchard *et al.*, 2000; Falush *et al.*, 2003). *STRUCTURE* is a clustering method that attempts to determine the number of gene pools in a mixed sample without reference to *a priori* information about the potential source populations. Overall, the *STRUCTURE* results were strongly consistent with the hypothesis of a single B-C-B stock, but in BRG14 the *STRUCTURE* program was intentionally forced to produce two B-C-B substock clusters to investigate whatever spatio-temporal patterns were revealed in the resulting putative clusters. The results showed significant evidence that whales of different estimated ancestry intermingle during some spatio-temporal portions of the annual migration but partially segregate in other portions. The most notable such patterns were seen in migratory pulses passing Barrow in the autumn and in two significant analyses showing correlation between birth year and cluster membership. Despite these interesting results, the estimated F_{ST} associated with the putative clusters was not statistically significant and was extremely small compared to the value associated with the known separate stock in the Sea of Okhotsk. It was also smaller than the value obtained by separating suspected familial lineages within the B-C-B Seas samples. Furthermore, potential model mis-specification and the fact that *STRUCTURE* failed to differentiate Canadian and B-C-B samples justified scepticism about detected ancestry patterns.

When analysis was limited to the most trusted markers and samples, sensitivity analyses showed that most of the SC/59/BRG14 findings vanished, suggesting that the main sources of genetic signal in these data are scoring errors, non-random mating or familial relations, and birth year. The authors concluded that B-C-B Seas bowhead whales might comprise a complex spatio-temporal aggregation of animals with mixed and variable ancestry with an unknown degree of non-random mating, whose degree of genetic inhomogeneity is significantly less than what is seen between spatially isolated stocks. Despite these intriguing and complex biological findings, no convincing evidence was found that B-C-B bowhead whales represent more than one stock.

In discussion, the sub-committee noted that although this paper provides evidence for substantial departures from HWE at individual gene loci, the levels of linkage disequilibrium (non-random associations of alleles at different gene loci) were very modest and only slightly elevated from what is expected to arise from random processes. Since linkage disequilibrium is generally more sensitive to population mixture than is Hardy Weinberg equilibrium, this result suggests that the HWE departures might not be related to population subdivision.

SC/59/BRG27 analysed an extensive set of microsatellite and mtDNA data, with the aim of investigating potential population substructure in B-C-B bowhead whales. In contrast to previous results for a subset of the data, no significant temporal pattern was found in the genetic data from migrating bowhead whales along the Alaskan coast. However, different strata of the microsatellite DNA data deviate from Hardy-Weinberg genotype expectations and display significant spatial genetic differentiation. These observations indicate that the B-C-B stock does not represent a randomly mating, single population, although the precise structure of the stock remains unclear.

The Oslo bump analysis is intended to account for age structure and hence another explanation was needed to explain the observed patterns. However, it was questioned whether the Oslo Bump analyses fully accounted for age structure, since they used birth year rather than age as a metric.

The results of this paper (which show only modest evidence of HW departures) appear to be at odds with those of BRG14. New analyses show that essentially all of the differences in results can be explained by the use of a one-tailed test for heterozygote deficiency in BRG14 and a two-tailed test in BRG27. This comparison illustrated the importance of carefully considering the *a priori* hypothesis to be tested. In examining the results of the comparison, it was noted that P values for some of the two-tailed tests were lower than for the one-tailed test for heterozygote deficiency, which implies that the HWE departures were in the direction of heterozygote excess. As population subdivision is expected to produce heterozygote deficiencies, the finding of HW departures in both directions suggested that these departures might primarily be attributable to random noise rather than population subdivision.

When discussing the concept of 'genetic disequilibrium,' it is important to be explicit. Four types of departures from equilibrium were identified: Hardy-Weinberg disequilibrium within a single gene locus; linkage disequilibrium between pairs of loci; drift-mutation disequilibrium; and demographic disequilibrium. Demographic disequilibrium will cause appreciable genetic disequilibrium only if age classes differ substantially in allele frequencies. The authors noted that this is not likely to be the case with bowhead whales, because even at the presumed nadir following cessation of commercial whaling the population size was at least several hundred individuals. Jorde concluded that age structure effects and demographic disequilibrium are not plausible explanations for the observed allele frequency differences between Barrow and St. Lawrence Island (as proposed in SC/59/BRG35). In discussion it was noted that detailed simulations mimicking B-C-B population dynamics and genetics, and assuming a single stock, had found differences between cohorts (see SC/59/BRG16 & 17). It was clarified that cohort comparisons involving St. Lawrence Island samples were not possible because those individuals had not been, and now could not be, aged.

SC/59/BRG32 reported a closer examination of the finding (SC/59/BRG27) that bowhead samples from 1992 exhibited unusually high F_{IS} (a measure of HW deviations) compared to other years. 1992 is among the years for which the fewest samples were available, so the 1992 estimates of allele frequencies and F_{IS} had a larger variance compared to other years. The 1992 samples also originated from whales having much earlier and more variable birth years than samples from other years, so birth year is confounded with the observed F_{IS} patterns. Most importantly, three of the eight individuals from 1992 exhibited unusual genotypes: all were clear outliers, having about triple the typical homozygosity seen in the dataset, and all were homozygous for rare alleles. SC/59/BRG32 hypothesised that these whales had been mis-scored at several loci. When these three whales were removed from the analysis, F_{IS} for 1992 fell in line with the other years. This called into question the suggestion in SC/59/BRG27 that the unusual F_{IS} in 1992 might reflect interannual variation in migration timing of putative multiple stocks.

It was confirmed that the three 1992 whales in question had been re-scored in the last week, and that these whales were found to be more heterozygous than previously indicated. There was considerable discussion of the paper and concerns about data sharing under the Data Availability Agreement (DAA) were raised. The following points were clarified:

- 1) The scoring errors for the individuals in question were only discovered the week before the meeting, too late for inclusion in any of the shared datasets;
- 2) Results for all the papers presented at SC59, including BRG32, were based on the same data, which included the mis-scored individuals;
- 3) All parties had made extensive efforts to limit formal consideration to datasets agreed to under the DAA;
- 4) Evaluations of data quality (e.g., in response to findings of BRG32) continued after the data were finalised for the DAA, leading to discovery of the new errors;
- 5) Discovery of these errors was reported as soon as feasible to the BRG community.
- 6) Discovery of these errors has prompted a more extensive evaluation of errors in the remainder of the dataset. This process is ongoing. Although discovery of additional errors is possible, the recently discovered errors were associated with a few poor-quality samples and should not be indicative of broader problems in the dataset. However, there appears to be increased evidence of poor amplification at some of the old loci (esp. tv14 and tv19).

In discussion, it was agreed that the DAA process had been open and generally effective; but a low level of genotyping errors is inevitable and cannot be avoided in any laboratory. For example, for the bowhead microsatellite data, even an error rate far below typical published rates would still yield a number of errors among the roughly 27,000 scores made. The B-C-B genetic datasets have undergone an unusually intense and public scrutiny, which has called public attention to routine errors that are discovered without fanfare (or never discovered at all) in other laboratories. Finally, measurement error is by no means restricted to genetic data; rather, it pervades all aspects of studies of natural populations. Nevertheless, the demonstration in papers presented here (SC/59/BRG15) that a few mis-scored genotypes can have an unusually large effect in some genetic analyses emphasises the importance of taking all reasonable steps to minimise the number of such errors. Some of these difficulties were acknowledged at the January 2007 AWMP workshop (SC/59/Rep3) and it was suggested that the recommendations of the workshop should be followed and a set of protocols developed to address these issues in the future.

SC/59/SD2 provides information about error rates in minke whales that might be relevant to considerations here.

Collectively, information presented in several papers about HWE departures can be summarised as follows:

- 1) Some of the apparent departures can be explained by genotyping errors;
- 2) After accounting for genotyping errors, some departures from HWE remain, which indicate that B-C-B whales do not satisfy all assumptions of a randomly mating, closed population with discrete generations. These departures include both heterozygote deficiencies (which can result from population subdivision, among other causes) and heterozygote excesses (which are not produced by population subdivision).
- 3) The data exhibit only very modest levels of linkage disequilibrium, which is typically a more sensitive indicator of population subdivision than is HWE.

Several papers reported analyses using the program *STRUCTURE*, and these (along with the *STRUCTURE* results from BRG14) were discussed jointly at the end.

SC/59/BRG30 presented analyses of B-C-B bowhead whales using the two reference microsatellite datasets (22 and 33 loci) and the computer program *STRUCTURE*. Samples of the whales were obtained from several different Alaskan villages engaged in aboriginal whaling, Canada and Okhotsk. Analyses were conducted under two different models: no-admixture with independent allele frequencies and admixture with correlated

allele frequencies among stocks. Results of the analysis suggested the possibility of multiple stocks. In particular, individuals passing by Barrow, during both the spring and autumn migrations, probably came from at least two genetically distinct stocks from the Bering Sea. The no-admixture model was better supported from estimates of the marginal likelihood and the parameter α . The mixing rate of stocks passing by Barrow was estimated based on the results of assignment probabilities under the assumption of no-admixture in each of the seasons, and the results indicated that multiple stocks were well-mixed during migration at that locality. Furthermore, the results showed a clear temporal migration pattern in autumn season, while no temporal pattern was observed in spring season.

SC/59/BRG34 provided an overview of the different models that can be used with *STRUCTURE* and argued that the admixture/correlated model (the program default) is most appropriate for the bowhead dataset. Simulation-based performance testing of *STRUCTURE* was conducted using the datasets generated by BRG17, and thus contained a single population. Use of the admixture/correlated model resulted in correct inference of the number of populations K in 98.7% of the simulated datasets, while use of the no-admixture/independent model resulted in inferring the presence of two populations in 30% of the datasets. An alternative method, developed by Evanno *et al.* (2005), for inferring the number of populations from *STRUCTURE* results, was also evaluated. The Evanno *et al.* method favours a single population within the B-C-B stock. Although *STRUCTURE* easily identified samples from the Okhotsk Sea as a separate population, it was unable to distinguish the B-C-B samples from those from the north western Atlantic, suggesting that it does not have the power to detect subtle differentiated populations.

The sub-committee noted that even the 'low' migration scenario in these simulations represented very high levels of gene flow (20-40 migrants per generation). This would lead to low levels of genetic differentiation and low power of resolution for *STRUCTURE*. The results for the no admixture, true $K=1$ model presented by BRG34 seem to be in conflict with results presented at an intersessional TOSSM workshop held in 2006 in Potsdam, Germany.

SC/59/SD3 was also presented here as its results directly bear on the B-C-B bowhead stock structure. SD3 extended the simulation performance testing presented in BRG34 to situations with more than one population. Simulated datasets were generated for use in the Testing of Spatial Structure Methods (TOSSM) project (IWC 2004). SD3 examined three population structure scenarios: 1) a single population with a carrying capacity of 7,500, 2) two populations, each with carrying capacities of 3,750, exchanging dispersers at the annual rate of 5×10^{-4} , and 3) two populations with carrying capacities of 3,750 and an annual dispersal rate of 5×10^{-3} . The probability of correctly inferring the number of populations from the results of *STRUCTURE* was low. The admixture/correlated model performed well for the single stock scenario, but consistently underestimated the number of populations for the two scenarios in which there were two populations. The no admixture/independent model was biased toward too many populations for scenario one, was unbiased when applied to scenario two, and was biased toward too few populations for scenario three. Both models did a poor job of assigning individuals to the correct population, with assignment success equal to that expected if individuals were assigned at random. Assignment probabilities for the admixture/correlated model were close to 0.5, accurately reflecting the degree of uncertainty in the assignments. The no admixture/independent model, on the other hand, produced very high estimated assignment probabilities, even when those assignments were wrong.

Table 1 in SC/59/SD3 illustrates the importance of balancing Type I and Type II errors in translating genetic information (or indeed any type of information) into management decisions about stock structure. Statisticians are typically most worried about Type I errors, even at the cost of substantial power to detect true population differences. In applied conservation, Type II errors often are a greater concern.

Kitakado responded to the statement in BRG34 that the conclusions of BRG30 are unwarranted. The particular points addressed were as follows: 1) BRG34 was incorrect in claiming that the difference in parameters estimated between the no-admixture and admixture models should be taken into consideration in deciding which model is better. In fact, *STRUCTURE* assesses the marginal likelihood, in which the parameters are integrated out, so the penalty for estimating parameters has already been taken into account. 2) As indicated by the authors of *STRUCTURE*, as a parameter showing strength of admixture (α) approaches 0, the admixture model approximates the no-admixture model. The estimates of α for B-C-B whales are all low, so use of the no admixture model is appropriate. 3) Use only of true $K=1$ in the simulations in BRG34 biased the results, since it is well known from published literature that the admixture model tends to underestimate K when population differentiation is low. 4) The Evanno *et al.* (2005) method suggested by BRG34 has been shown to perform well only at strong levels of population differentiation; at moderate or low levels, it performed no better or worse than the standard method used (Waples and Gaggiotti, 2006).

Considerable discussion ensued on the details of *STRUCTURE* analyses and meaning of the results. No consensus was reached on two methodological points. Some members of the sub-committee were of the opinion that the admixture model is more appropriate for a situation (such as exists for bowhead whales) in which the alternative hypothesis to a single stock is two, potentially very closely related populations exchanging migrants; furthermore, the admixture model performed better in the simulations reported here. Others thought that, in addition to the arguments presented in BRG30, the no admixture model has greater power to detect low levels of differentiation. Similarly, no agreement was reached regarding the preferred method for inferring K . The 'standard' method, originally recommended by the program's authors (Pritchard *et al.* 2000), simply selects the K with the highest likelihood. In some cases, however, this method overestimates K because the likelihood continues to creep up with increasing K even after the true number of populations is exceeded. The program's authors have since changed their recommended approach to inferring K , and now favour an approach akin to that of Evanno *et al.* (2005). The Evanno *et al.* (2005) method is intended to be a formal approach for inferring K based on the point of inflection ('knee') in the plot of likelihood vs. K , where the rate of increase in likelihood with K declines sharply. However, published evaluations (Evanno *et al.* 2005; Waples and Gaggiotti, 2006) show that which method performs better depends on a variety of circumstances, and for weakly differentiated populations the Evanno *et al.* (2005) method might perform no better (and perhaps worse) than the standard method. The fact that results of *STRUCTURE* analyses with bowhead datasets were sensitive to these two methodological choices increased uncertainty in the interpretation of these results.

These difficulties notwithstanding, the sub-committee did reach consensus on some important points regarding the *STRUCTURE* analyses. First, the whales from the Sea of Okhotsk were clearly identified by the program, indicating that it can perform adequately with bowhead data for populations that exhibit moderate levels of genetic differentiation. In contrast, the program consistently failed to detect the Canadian whales (originating from the Hudson Bay area) as a separate population, whereas standard statistical tests consistently show significant differences in allele frequency between Canadian and B-C-B whales. This result suggests that the power of *STRUCTURE* to detect subtle population subdivision within B-C-B whales is likely to be low. This result is consistent with published accounts of the power of *STRUCTURE*, which (assuming adequate amounts of data) generally performs well at F_{ST} values of about 0.03-0.05 or higher but poorly when differences are smaller. For reference, the estimated F_{ST} values for the comparisons of B-C-B whales with those from the Sea of Okhotsk and Hudson's Bay are 0.034 and 0.006, respectively (BRG14). This reduced power no doubt reflects the fact that, as a clustering method, *STRUCTURE* is attempting the very difficult problem of identifying multiple gene pools within a potentially mixed sample without reference to estimates of allele frequencies in the source populations.

The sub-committee struggled to find any interpretation of the results of *STRUCTURE* analyses that would indicate important stock structure for B-C-B whales. For example, the program did not cluster individuals into groups that had any apparent relation to geography; furthermore, the groups were of approximately equal size, and many individuals were inferred to have large fractions of mixed ancestry (in the admixture model) or intermediate probabilities of population assignment (in the no admixture model). According to the *STRUCTURE* user's manual and other empirical observations, this behaviour is often found when the program is asked to assign individuals to more populations than actually exist. That these scenarios can sometimes produce higher likelihoods than the true K (as noted above) is one of the factors that significantly complicate interpretation of results.

The subcommittee concluded that, since the distinctiveness of the Okhotsk whales was clearly identified by *STRUCTURE*, it is unlikely that multiple stocks of B-C-B whales exist with levels of differentiation that strong. In addition, the 'Oslo Bump' and the Chukchi-circuit hypothesis, which require relatively large F_{ST} values between stocks, do not appear to be consistent with the *STRUCTURE* results. Beyond this, it is not clear that *STRUCTURE* provides any useful information about B-C-B whales. The failure of the program to distinguish Canadian and B-C-B whales indicates that the program is being asked to perform in a region of parameter space that is outside its ability to provide useful information. The *STRUCTURE* results for runs assuming more than one population of B-C-B whales were not biologically convincing; conversely, the inability to distinguish Canadian and B-C-B whales suggests that if one or more weakly differentiated populations actually exist, their presence might not be detected by the program.

SC/59/BRG17 presented results of a comparison between the empirical genetic data and an individual-based model of bowhead whale population dynamics and genetics. The model closely re-created aspects of the demography, genetics, and whaling history of B-C-B bowhead whales. The simulated datasets were generated by sampling from the simulated population in a way that matched the age, sex, and geographic distribution of the empirical samples. These simulated datasets were then used to generate null distributions for a variety of genetic analyses, against which to compare the empirical bowhead dataset. The degree of Hardy-Weinberg disequilibrium in the empirical data was significantly greater than in the simulated data, however the degree to which it differed dramatically decreased when errors were added to the simulated data. Of the 55 spatial, temporal, and cohort comparisons examined (11 stratifications for 5 measures of genetic differentiation), only the mitochondrial F_{ST} between autumn and spring St. Lawrence Island, and the microsatellite F_{ST} between Barrow and St. Lawrence Island were inconsistent with the simulated single-stock model. The results of the *STRUCTURE* analyses on the empirical data were also found to be entirely consistent with the model.

The modelling of non-equilibrium population dynamics (BRG16 and 17) was intended to be faithful to the empirical data and what is known about biology of the species. No attempt was made to attribute the empirical results to any particular demographic feature, such as a demographic bottleneck.

SC/59/BRG16 presented analyses based on a simplified version of the model presented in BRG17. In the simplified model, all historical whaling mortality is modelled as having occurred in a single year. The population is then allowed to grow exponentially for the remainder of the simulation. This simplification allowed the authors to explore three factors that could not be addressed using the model in BRG17: the minimum population size, age selective commercial harvest, and variance in male reproductive success. None of these factors had a marked impact on the probability of detecting genetic differentiation between cohorts nor on the probability of the population being out of Hardy Weinberg equilibrium. Thus, the conclusions drawn in BRG17 are robust to these parameters.

The skew toward high P values in comparison of different age classes, which was reported by SC/59/BRG16, was attributed to comparison of parents and offspring. This effect is largest if the ratio of effective population size to census size is high (0.5-1), and since the number of adults in the parental years was relatively low, this condition was probably satisfied. It should be noted that 31% of all the bowhead whale kills from 1848 through 2005 occurred in a five-year period around 1850, so to the extent any bottleneck occurred it was earlier, and perhaps of longer duration, than indicated in some of the models.

4.1.1.2 OTHER INFORMATION

SC/59/BRG18 described passive acoustic surveys conducted in support of a comprehensive effort to investigate stock structure in the B-C-B population of bowhead whales. Two types of survey were conducted: (1) an over-winter survey (2003-04) northeast of Barrow, Alaska, using autonomous recorders; and (2) a dipping-hydrophone survey (2005) along a cruise track northwest of Barrow to investigate bowhead occurrence at the head of Barrow Canyon and near the Chukchi Borderland from 28 June to 21 July. Although recorder malfunction limited sampling to only 7.5 months during the over-winter survey, bowhead calls were detected only during periods when whales would be expected to be migrating past Barrow on autumn and spring migrations. No bowhead calls were detected during 30.5 hours of sampling at 16 stations along the summer cruise track between Barrow and the Chukchi Borderland. Thus, in neither survey were bowhead calls detected in areas or at times supportive of any of the putative multiple stock hypotheses.

The experimental design was such that the whales should have been heard if they were using the areas surveyed. The authors were surprised to hear bowhead calls in November, but no more so than hearing gray whale calls throughout the winter. These data might indicate a shift in late-autumn and winter habitat use by both species in response to global climate change.

SC/59/BRG13 compared stable carbon isotopes from St. Lawrence Island (SLI) and Barrow bowhead baleen to examine the possibility of sub stocks in the B-C-B stock. Oscillations in the baleen of bowhead whales killed at Barrow have been hypothesised to result from feeding on isotopically distinct prey sources at migratory endpoints in the Bering/Chukchi region and Beaufort Seas. It is hypothesised that a lack of migratory behaviour, and hence feeding in an isotopically homogenous region, by (SLI) bowhead whales would result in stable carbon isotope values in baleen that remain constant. Baleen from six adult SLI bowhead whales demonstrated marked oscillations of stable carbon isotopes along the length of baleen indicating migratory behaviour. Furthermore the isoscape of the Bering/Chukchi region does not possess an isotopic gradient sufficient to produce the observed patterns in baleen. The report also used stable carbon and nitrogen isotopes to determine whether feeding and fasting behaviours could produce isotopic patterns that mimic migratory behaviour. Nutritional stress in fasting animals results in ^{15}N enrichment of proteinaceous tissues because animals in this state essentially consume themselves. If the increase in stable nitrogen values represented fasting in bowhead whales, the peak value would represent the height of nutritional stress. Peak stable carbon isotope values in baleen have been attributed to feeding in Chukchi Sea prior to movement to wintering grounds and, presumably, a period of fasting. Stable nitrogen oscillation peaks were examined in relation to stable carbon peaks because there is a lag time between the cessation of feeding and subsequent enrichment of proteinaceous tissues if fasting is occurring. It was determined that the majority of peak nitrogen isotope values occurred at a similar temporal periodicity and could therefore not result from fasting because there was no lag time.

In discussion the group noted a gradual increase in isotope values in figures 3 and 4, in addition to the oscillation pattern. It was suggested that this could reflect underlying levels in the ocean changing over time. There was some disagreement about the potential to assess fasting from a change in ^{13}C -values. It was noted that data on girth suggested feeding at both ends of the migration. The group noted that Table 1 includes several whales caught near St. Lawrence Island in late autumn or winter showing migratory cycles, which speaks to ideas about stock structure. These results complement genetics papers showing evidence for considerable mixing.

SC/59/BRG12 represented a cooperative effort by Lori Quakenbush and Bob Small of the Alaska Department of Fish and Game (ADF&G), with the AEWG and the NSB and funded by the US Minerals Management Service (MMS), to study bowhead whale movements and behaviour using satellite telemetry. On 12 May (2006), an approximately 13.7 m (45 ft) male bowhead (#60010) was tagged near Barrow. The whale travelled directly across the Beaufort Sea and arrived in Amundsen Gulf (east of 127° W Longitude) in early June and stayed there presumably feeding until early August when he travelled directly to the northwest end of Banks Island and back. While somewhat unexpected, this behaviour is not unprecedented. This whale began his westward migration in early October when he moved rapidly across the Alaskan Beaufort Sea to arrive at Barrow on 14 October. Another whale (#60009), tagged near Barrow on 21 September, gave fewer locations, but both whales occurred together along the northern Chukotka coast, which is an important feeding area in November. The movements of the two whales described here are consistent with published literature and behaved in a manner consistent with our understanding of bowhead migratory behaviour based on years of aerial and ship-based surveys, and harvest monitoring. By contrast, in cases where other arctic species have been tracked using satellite telemetry, unpredicted behaviour was seen. However, important new information on swimming speeds, probable feeding areas, precise migratory routes and migration timing are provided by these data.

Further work is planned for this coming season. There was some discussion about implications of movement to the isolation of B-C-B and Canadian stocks, but the sub-committee noted that genetic evidence was consistent with some level of gene flow between separate stocks (while the level of gene flow is not known).

SC/59/BRG6 provided a summary of progress on analysing vertical bowhead whale photographs collected at Barrow in spring 2003 and 2004 and autumn 2005 and in the Bering Sea during spring 2005. All images have been scored for quality and markings, all within-study matching has been completed, and all between-study matching has been completed. Recapture rates between Barrow spring 2003 ($n=179$ different marked whales in good photos) and Barrow spring 2004 ($n=275$) (0.042 recaptures/marked whale) were similar to Barrow spring 2003 and Bering spring 2005 ($n=71$) (0.040 recaptures/marked whale). A computer-assisted matching program is being developed and matches identified by people will be compared to matches identified by the computer program. Data are now available to make a mark-recapture estimate of population size using photos from spring 2003 and 2004.

4.1.1.3. REVISION OF HYPOTHESES

The biological rationale for restricting consideration of the two-stock hypothesis for B-C-B whales (Hypothesis D for implementation review testing) to proportions that are skewed no more than 40/60 or 60/40 was questioned by a member of the sub-committee. The uncertainties identified with the reliability of *STRUCTURE* questioned the underlying assumption of the trials based on stock structure hypothesis D, that the split of the current sizes of the two stocks could be reasonably assumed to lie between 40:60 and 60:40 (the results of *STRUCTURE* had indicated a 50:50 split). A variable fraction of E and W whales present at Barrow in the spring and autumn from year to year might explain the 'Oslo bump'. Therefore there may be no justification for any particular split in the current population sizes. Other members noted that the original motivation for stock hypothesis D included the results from *STRUCTURE* runs and the 'Oslo bump'. Since *STRUCTURE* is now not considered reliable for application to the B-C-B bowhead whales and because the 'Oslo bump' is no longer evident in the data, the plausibility for stock hypothesis D is now sufficiently small that conducting additional trials in which one of the stocks is a very small fraction of the total population size was inappropriate. It seemed inconsistent to use the results from *STRUCTURE* to provide justification for a hypothesis, but to reject the inference of the same results that implied an approximately even split.

The sub-committee agreed on the following scientific points. The best available science was used to develop the two-stock hypothesis and establish the mixing fractions to be considered. More recent information has called into question the biological basis for the two-stock hypothesis and the appropriate mixing fractions to consider. The SWG of the AWMP agreed that there had been sufficient discussion of the new genetic information to allow finalisation of its work. In particular, it was clear that no new information had been presented to suggest that the stock structure hypotheses it had already examined did not cover the plausible range; if anything, that range had been too broad. The issue of the appropriate trial specifications for hypothesis D would be further discussed by the SWG.

SC/59/BRG35 synthesised lines of evidence to examine the plausibility of multiple bowhead whale stocks in the B-C-B (B-C-B) region. The four lines of evidence that related to understanding stock structure were: (1) movement and distribution, (2) basic biology, (3) history of commercial whaling, and (4) interpretation of genetic patterns. The paper reviewed 30 years of research plus contributions from traditional ecological knowledge. In reviewing bowhead biology, bowhead whales have adapted to living in an arctic ecosystem where ice coverage and food resources vary through time. This varying environment makes both the evolutionary reason for multiple breeding stocks within the Bering Sea and the biological feasibility of maintaining separation within a relatively small pelagic area unlikely. There is variability in the timing that individual bowhead whales migrate, in the timing of the peak of the migration itself, and in the location of both summering and wintering grounds. The variation is a result of both changing environmental conditions and changes in the whales' age and reproductive state. Furthermore, the available area for any potential segregation of feeding or breeding groups is well within the ability of individual whales to travel in a few days time. No evidence was found that a small discrete stock, like the stock in the Sea of Okhotsk, is present and killed in any numbers during the spring or autumn migration of B-C-B whales. No data were found to support risk to a separate feeding group. Other insights using genetic data are weak, but nearly all results are consistent with a single stock that is out of equilibrium following commercial depletion. Bowhead whales being out of genetic equilibrium is supported by differences found between age cohorts, both in empirical data and simulated data. The only significant genetic findings worth further consideration are differences involving St. Lawrence Island. However, the comparisons that were significant involved small sample sizes and could just as well result from genetic patterns found between different age cohorts.

As the issues summarised in BRG35 had already been thoroughly discussed, the Chair closed by concluding that the available evidence best supports a single-stock hypothesis for B-C-B whales. The sub-committee concurred with this conclusion.

4.1.2 Other new scientific information

SC/59/AWMP1 describes classification trees that use morphometric data to classify bowhead whales lacking direct age estimates into three age brackets: over 90 years (very old), 60-90 years (old), and under 60 (younger). Recursive partitioning was applied to data from post-mortem examinations of 74 females and 49 males with direct age estimates and high quality morphometric data on, e.g., body length, girth measurements, flipper length, fluke width and baleen length. The recursive partitioning algorithm uses binary splits (yes or no responses for each whale to questions like 'is body length <14.55m?') to split the whales at a node into more homogeneous groups than the group at that node. Starting with all whales of a given sex, the algorithm chooses the value (e.g. 14.55m) of the morphometric predictor (e.g. length) that achieves the maximum reduction of some measure of 'impurity' at the node. For males, body length and peduncle girth provided the most useful information for this age classification. For females, anterior flipper length and body length were the key variables. For females lacking anterior flipper length data, body and baleen length and peduncle girth could be used instead.

With so few old and very old whales in the data set, classification likely appeared to be more successful than it would be if applied to a larger data set. It was noted that it was feasible to partition the younger group more finely, as had been done in SC/59/BRG17.

SC/59/BRG10 applied the method for estimating the age-composition of harvests of bowhead whales developed by Schweder and Ianelli (2000) to updated data on age-at-length and catch-at-length to produce revised age-compositions by sex. The results indicate a smaller proportion of very old (100+) animals and a greater incidence of very old males in catches since 1974 than estimated by Schweder and Ianelli (2000).

SC/59/BRG7 presents a calf index to monitor year to year changes in reproductive success in B-C-B bowhead whales. Most mothers and calves pass Barrow, Alaska during the mid-May to early June but many past surveys have had inconsistent sampling during this period, and hence have not provided a reliable index of the proportion of calves. The index combines data on the proportion of calves from surveys during weekly periods 14 May-3 June with historic information on the proportion of whales passing during those periods. The proportion of calves can be obtained from aerial surveys or photographic surveys. The calf index is a robust and unbiased estimate of the proportion of calves because it accounts for unequal sampling during the survey. The calf index is calculated for years with photogrammetry data collected near Point Barrow during 1985 to 2004.

The calf index could potentially (eventually) provide information on inter-annual variability in reproductive success. An estimate of this parameter would be useful during future implementation reviews (i.e. 2012).

SC/59/BRG5 was an attempt to reconstruct the sizes of whales taken during the Yankee commercial harvest primarily to determine if there may have been selectivity in the commercial B-C-B catch for consideration in the genetic simulations by Martien and Archer e.g. BRG 16 and 17. That is, the selection pattern of the historical harvest is needed if changes in the genetic structure of the population are to be modelled. Information on oil yields from 392 bowhead whales during the Yankee commercial whaling in the 1800s was used to investigate harvest selection patterns in the commercial hunt. Length-structure of the harvest is an important parameter when estimating how the age structure of a population may have changed through time. Age structure shifts are included in stock assessments and hence determine, in part, population size and trends, and present status relative to reference points such as *MSYL*.

Oil yield from blubber, blubber-mass, and mass-length data were analysed to develop a preliminary approach for estimating the relationship between oil yield (where 31.5 gallons is equated to a barrel of oil) and whale length (m). This relationship was then used (together with Yankee oil-yield estimates) to estimate the length-frequency distribution for whales harvested during the historic period. Parameter uncertainty, estimated using a bootstrap procedure, indicates that considerable uncertainty remains regarding the predicted length-frequencies. It should be possible to reduce this source of uncertainty given additional data. Whalers were not selective in their catch, however the length-frequencies from oil data suggest that the average size of whales during commercial whaling was somewhat larger than the average size of whales harvested from the B-C-B population today and length-frequencies based on photogrammetry. These data also suggest that whales taken early in the fishery were somewhat larger than those taken later. Further refinement of this analysis may help determine if age/length structure shifts occurred through the fishery.

It appears that there were very few whales harvested <12 m. This would be consistent with segregation by sex on the feeding grounds. Smaller, juvenile whales are known to lead the spring migration. So, if the whaling ships arrived after the juveniles had left the whaling grounds, then these younger whales would not have been available to the commercial hunt. There is a large amount of early data on barrels of oil harvested and there was agreement that this work should be continued with an emphasis on increasing the sample size for the oil yield data as well as that for data pertaining to weight at length. However, it should be remembered that: a barrel is not always a barrel, whale condition changes throughout the feeding season, and misreporting of barrels is likely.

There is some indication that the size of whales decreased in the catch until the steam fishery began (which enabled whalers access to new grounds). This might explain the pattern in the oil yield data showing a subsequent increase in the size of landed whales around the same time that the steam ships began operation. Unfortunately there aren't more data on barrels of oil at the end of the fishery. It was also noted that a few early oil yields are consistent with the suggestion that some extremely large whales were taken at the inception of the fishery.

SC/59/BRG2 summarises inter-year re-identifications of bowhead whales from photographic surveys conducted 1984-94 near Barrow, Alaska in spring. Forty different bowhead whales were seen in more than one season providing 44 pair-wise inter-year comparisons. Re-sightings of larger whales (>12 m) were randomly distributed throughout the season (1-31 d apart, $n=41$) but re-sightings of small whales based on a small sample size seemed to be close together (2-3 d apart, $n=3$). Mothers had slightly larger intervals between re-sighting dates in years with and without calves (mean -14.0, SE=3.8) than other large whales (mean 10.7, SE 1.2), but the difference was not significant. These data suggest that larger whales pass Barrow on almost any date during the spring migration and there is no pattern in their passage dates. This project will be developed further to include modelling the migration.

SC/59/BRG28 reports the development of a model for estimating abundance, intrinsic growth rate, and mortality rate for B-C-B bowhead whales from the data collected during the systematic photographic surveys at Barrow, AK. Each whale is assumed to be encountered at a fixed rate during the survey period. Marks are allowed to be acquired during the life of a whale, and the degree of marking between whales can differ. Images are also allowed to differ with respect to quality. The probability of correctly matching an image to that from a previous encounter of the same whale is assumed to vary with degree of marking and quality of image. The parameters in a logistic model for this probability are estimated simultaneously with demographic parameters. Confidence curves are obtained for parameters of interest by employing a bootstrap approach.

The model was originally fit to the entire photo-ID dataset, including all years for which aerial surveys were flown around Barrow in the spring during 1976-2004. During the course of the sub-committee meeting however, the authors were made aware that no attempt had been made to match images from 1976-80 to later images, nor were images from 2003-04 matched to earlier images in the dataset. This discrepancy led to estimates of abundance and growth rate which were grossly consistent with other estimates, but to an estimate of mortality that was off mark (11.9%). The application presented in the paper was thus based on a misunderstanding of the data. The model was then re-fitted to the data from 1981 and on, accounting for no matching between 2003-2004 and earlier periods. The revised estimates included: a mortality rate of 2.2%, a population growth rate of 2.54%, and abundance estimates in agreement with estimates from visual and acoustic surveys (Zeh and Punt, 2005).

The sub-committee expressed their appreciation of the authors' progress in developing this modelling framework and **recommended** that the matching of existing photos be completed in the near future to maximise the potential wealth of information contained in the full photo-ID dataset.

George gave a short presentation on a recently published paper on a traditional knowledge study of bowhead whales near St Lawrence Island (SLI) (Noongwook *et al.*, 2007). Surveys of senior whale hunters from SLI indicated that the number of adult and sub-adult bowhead whales seen near the island has increased over their lifetime, and that in the last decade more whales are wintering near (and north) of St. Lawrence Island—particularly since 1990. The harvest of bowhead whales in autumn and winter has increased in the last two decades. The paper also describes some very old traditional ecological knowledge that suggests bowhead whales use two migration paths in the vicinity of the Island.

4.1.3 Catch information

SC/59/BRG4 reported catch information for the 2006 Alaskan subsistence harvest. A total of 39 bowhead whales were struck resulting in 31 animals landed. The efficiency (the ratio of the number landed to the number struck) of the hunt was 79.5%, which is about the same as the average efficiency over the past 10 years (79%). Of the 31 whales landed, 21 were males and 10 were females. Of the 10 females, only one was presumably mature (>13.4m in length). Ice and weather conditions challenged hunters during spring, resulting in the lowest harvest in the past 35 years. Only Wainwright and Barrow were able to land a total of five whales during the spring. The challenging spring conditions contributed to an overall lower harvest in 2006 when compared to the previous 10 years (average of 41.8 whales per year).

If the AWMP SWG continues with their *Implementation* modelling as is, then it would be helpful if future tables of catch reports include a column containing the month during which whales were struck and lost. Some progress on photographing of landed whales has been made. However, when whales are landed, difficulties arise in photographing potential marks because the animals are often hauled out with mainly their ventral side exposed.

SC/59/ASW5 reported that no catches were taken of bowhead whales off Russia due to adverse ice and weather.

4.1.4 Management advice

After full consideration of the stock structure discussions that had taken place here, the SWG on the AWMP had strongly recommended that the *Bowhead SLA* remains the best tool for providing management advice on bowhead whaling (Annex E). The results from the *SLA* show that the present strike and catch limits are acceptable.

4.2 Davis Strait/Baffin Bay and Hudson Bay/Foxe Basin bowhead whales

4.2.1 Stock structure

The study reported in SC/59/BRG36 augments the existing data on the movement patterns of bowhead whales (*Balaena mysticetus*) in waters between West Greenland the eastern Canadian high Arctic and provides further data supporting the single stock hypothesis. Recent results of satellite tracking of whales from West Greenland in 2005 and 2006 support the previous data demonstrating that the bowhead whales inhabiting Foxe Basin, Hudson Bay, Hudson Strait, Eastern Baffin Island, Lancaster Sound with tributaries and West Greenland belong to one highly segregated population. These satellite tracking results are also in agreement with genetic studies, the catch history from Baffin Bay and Foxe Basin, and the reproductive and sex segregation of bowhead whales throughout the tracked area.

For the authors, the most important problems with the two-stock hypothesis are that (1) too few calves have been found in the putative Baffin Bay stock to maintain a viable population; and (2) too few adults have been found in the putative Hudson Bay stock to produce the calves and sub-adults that have been seen there. Satellite tracking data have shown that there is no geographical separation between the two putative stocks, that whales occupying Foxe Basin move through Fury and Hecla Strait into Prince Regent Inlet (waters traditionally associated with the Baffin Bay stock), and that whales from the two putative stocks occupy the same wintering areas in Hudson Strait. The simplest explanation for these findings is that bowhead whales summering in the eastern Canadian Arctic, and wintering in the Hudson Strait and off the west coast of Greenland consist of a single population. Those occupying Baffin Bay are mainly the adult males and resting females and those occupying Prince Regent Inlet, Gulf of Boothia, Foxe Basin and north-western Hudson Bay are mainly the nursing females, calves and sub-adults.

The stock structure of bowhead whales in Foxe Basin, Hudson Bay, Hudson Strait, East Baffin Island, West Greenland and the Canadian high Arctic was discussed in light of substantial information questioning the current two-stock delineation.

The original stock delineation of 2 putative stocks was based on the assumption that bowhead whales do not migrate through Fury and Hecla Strait. Satellite tracking in both West Greenland and Canada has clearly demonstrated this assumption is not correct. Bowhead whales in Canada and West Greenland share the same summering grounds (along East Baffin Island and the Canadian high Arctic) and the same wintering grounds (Hudson Strait). Furthermore, bowhead whales circumnavigate Baffin Island in both clockwise and counter clockwise directions, overlapping throughout their range and rendering the putative geographic barrier of Fury and Hecla Strait spurious. Information on sex and age segregation based on photo-ID, satellite tracking, and aerial surveys throughout the current range indicate a clear division of almost exclusively sub-adults and cows and calves in Foxe Basin and southern Prince Regent Inlet and mature adult whales with virtually no calves in Baffin Bay. This division is not consistent with a hypothesis of two self-sustaining populations of bowhead whales. Furthermore, the number of whales in both West Greenland and the Canadian eastern Arctic appears to be increasing based on aerial survey results and local observations, a phenomenon which is only biologically possible if the two separate aggregations of whales belong to one highly segregated stock. Finally, genetic analyses conducted to date and presented at the last three SC meetings detected weak, but significant, genetic differences and no clustering between whales from Igloodik and those from Baffin Bay. These results, when interpreted in the larger biological context, point to the existence of a single population.

All geographic boundaries previously hypothesised to separate the two putative stocks have been demonstrated not to constitute barriers for whales. Given the data and analyses presented by Greenlandic and Canadian scientists at this and previous meetings, the sub-committee concludes that a single shared Canada-Greenland stock in the eastern Arctic should be recognised as the working hypothesis. The sub-committee **recommended** a thorough discussion on stock structure, including comprehensive analyses of genetic data, be held at the next annual SC meeting. This discussion may clarify stock structure questions for these whales.

4.2.2 Other new scientific information

SC/59/BRG21 indicated a re-examination of abundance estimates for bowhead whales of the eastern Canadian Arctic, based on surveys conducted in 2002-04 is currently underway, but has not been completed. A satellite-linked telemetry project was conducted in 2006. Nine bowhead whales were tagged during July near Kerkerton Island in Cumberland Sound, southeast Baffin Island. Eight tags provided data from one to 9.5 months, and documented the spring and autumn migrations, as well as summering and wintering distributions. Whales migrated to summering areas in Prince Regent Inlet and Gulf of Boothia, using both northern and southern routes around Baffin Island. Fall migration routes to wintering areas included both northern and southern routes as well. Wintering sites included the mouth of Cumberland Sound, Hudson Strait, and northeast Hudson Bay. Collection of genetics data for eastern Canadian Arctic and western Greenland samples was expanded to include 22 new microsatellite loci. These data were standardised with American data collected for the B-C-B bowhead population and will be combined for analyses in a larger study. Statistical analyses of the complete Canadian bowhead whale genetics dataset to examine recaptures and genetic relationships among groups of samples is in the process of being redone, but has not yet been completed. A summary of historical bowhead harvest from 1500 to 2005 was done in 2006 by examining available English publications. Preliminary results indicate that the total harvest in the years 1500-2005 was approximately 80,000 whales. The geographic region reflected by this analysis includes the eastern Canadian Arctic and western Greenland only. Specifically, the areas examined include the Strait of Belle Isle, Gulf of St. Lawrence, Hudson Bay, Hudson Strait, Newfoundland and Labrador, Davis Strait, West Greenland and Baffin Bay. Although the harvest series is still incomplete, the use of this expanded harvest series, in combination with more detailed modelling techniques that incorporate uncertainty, will provide more accurate estimates of pre-whaling population size and improve conservation and recovery planning for bowhead whales in eastern Canada and West Greenland. In the eastern Canadian Arctic, one bowhead was observed entangled in a net and another dead beached whale was observed. In the western Arctic, two dead beached bowhead whales were reported. Fisheries and Oceans Canada's National Marine Mammal Peer Review Committee met in two meetings in 2006 to discuss the available current scientific information relating to HB-FB and BB-DS bowhead stock structure. All of the lines of evidence were considered (geographic boundaries, distribution with some age and sex segregation, satellite tracking results and genetics). It was felt that these data provided little support of a two stock hypothesis and it was decided to treat the eastern Arctic bowhead as a single population.

SC/59/BRG23 presented the results of a dedicated survey for bowhead whales conducted in April 2006 on the former whaling ground in West Greenland in efforts to determine the current population status. This effort included a double platform aerial survey design, satellite tracking of the movements of nine whales, and estimation of high resolution surface time from 14 whales instrumented with time-depth recorders. A total of 34 sightings with distance estimate less than 1,500m were included in the abundance estimation calculated for 6 strata.

The estimated abundance of bowhead whale groups corrected for perception bias was 267 (CV=0.47; 95% CI=111-641) and the corresponding total abundance of individuals was estimated to be 295 (CV=0.47; 95% CI=129-708). Using data from the instrumented whales, animals were estimated to spend an average of 24% (CV=0.03) of the time at or above 2m depth. The survey was conducted over clear water and it was assumed that bowhead whales could be seen to a maximum depth of 2m similar to narwhals. Applying this availability factor and correcting for sightings missed by observers resulted in a fully corrected abundance estimate of 1229 (95% CI=495-2939) bowhead whales. This surprisingly large population estimate is puzzling given that the change in abundance cannot be explained by a recent or rapid growth in population size. One possible explanation is that the population recently has attained a certain threshold size where mature females start to appear abundantly on the feeding ground in West Greenland. This in combination with the latest severe reduction in sea ice might explain the surprising increase in bowhead whale abundance in West Greenland.

After discussion the sub-committee concluded that this survey was properly conducted. The sub-committee **accepted** these abundance estimates. While the abundance estimate does not reflect a total population size, it is representative of the number of animals in West Greenland in winter.

SC/59/BRG25 investigates the role of the bowhead whale as a predator in the West Greenland ecosystem. The spatial and temporal linkage between primary production, zooplankton distribution and density, and bowhead whale foraging behaviour in Disko Bay, West Greenland were examined using concurrent ship-based oceanographic and net sampling together with instrumentation of whales with satellite-linked transmitters and dive recorders. Estimates of bowhead whale abundance were used in a bioenergetic model to calculate the potential consumption of zooplankton during their four-month stay in Disko Bay. Between 2001 and 2006, 30 whales were instrumented with satellite transmitters providing information on daily movements and fourteen whales were instrumented with archival Time-Depth or Time-Depth-Fluorescence recorders providing detailed dive data. Simultaneous data were collected on water column structure, phytoplankton and zooplankton density, taxa, and biomass at 25 stations south of Disko Island in 2003, 2005 and 2006. After the retreat of annual winter sea ice, bowhead whales explored a limited area along the south coast of Disko Island and had high interannual site fidelity. Mean dive depths varied between 53 (\pm 35) to 109 (\pm 41) m but maximum dive depths were >400m. Most dives targeted the bottom and dive durations >40min were observed for several whales. Available prey for bowhead whales was dominated by calanoid copepods, with *Calanus finmarchicus*, *C. glacialis*, and *C. hyperboreus* occurring at 90-100% of all stations between 0 and 50 m and contributing 78% \pm 25 of the total biomass. Bottom sampling for epizooplankton in 2006 resulted in unprecedented densities of *C. finmarchicus*, several orders of magnitude higher than any other depths. Bioenergetic modelling indicated the population consumes ~220 tons of zooplankton per day or >21,000 tons during the 4-month stay in Disko Bay. Although the total biomass of zooplankton in the upper 50m of the water column theoretically could support this predation level, benthic zooplankton densities and behavioural data suggest whales target pre-ascension stage epibenthic copepods in high density patches.

The use of the Kleiber estimate might not be appropriate for bowhead whales because of their very low metabolic rates, and so metabolic rates may need to be adjusted down.

4.2.3 Catch information

No catches were reported.

4.3 Other stocks of bowhead whales

ProgRep Norway reports on observations of bowhead whales made in a relatively small area in the Fram Strait between Svalbard and Greenland during the second half of April 2006. A total of eight observation events included 17-20 bowhead whales. Observations were done along the ice edge in the same general area (80-81°N, 0°E) during a 12 day period. All whales were detected visually from the vessel's bridge and all observations were made over the continental slope at depths between 1,030 and 2,785m. Age and sex of the animals were not determined, but those whales which were approached with small boats for biopsy darting were at least 15m long. Seven biopsies for genetic analyses were collected from these whales; however, preliminary genetic analyses indicate that several samples were taken from the same whale.

The sub-committee thanked Norway for reporting these important results. It further **recommended** the continuation of these surveys in order to increase the limited amount of information available for these whales.

5. RIGHT WHALES

5.1 North Atlantic right whales

There were 149 sightings of right whales on a North Atlantic Right whale systematic survey conducted on 1-26 May 2006 from the nearshore waters of Cape Cod to throughout the Great South Channel Right Whale Critical Habitat Area. An aerial survey carried out under the North Atlantic Right whale Sighting System recorded 410 right whale sightings in 88 survey flights in 2005. An aerial circle-back abundance survey, 24 July-26 August 2006, between New Jersey, the Gulf of St. Lawrence and the Bay of Fundy recorded 20 right whales among over 4000 cetaceans seen. 442 identification photographs were obtained in 2006. For the year 2004, two ship strikes were reported, both fatal, one off Virginia, the other off North Carolina. An additional animal was recorded as bycatch in Roseway Basin, Nova Scotia. (SC/59/ProgRep USA)

5.2 North Pacific right whales

In the offshore component of a western North Pacific JARPN II cruise, 16 May-29 August 2006, sightings were recorded of 14 right whales in 10 schools at *ca* 48°N, 165E. 13 head and a small number of other identification photographs were obtained (SC/59/ProgRep Japan; SC/59/O5).

It is as yet unclear whether the photographs taken of North Pacific right whales will be made available to IWC.

There has been limited funding in the U.S. to survey for North Pacific right whales in recent years. But, due to the recent opening of oil leases for sale in the south eastern Bering Sea, funding is currently forthcoming and surveys are being planned for the immediate areas during the summer of 2007.

5.3 Southern right whales

At Head of Bight, South Australia, the maximum, shore-based, single day count of southern right whales in 2006 was 98 (including 45 calves), on 19 August. The annual aerial survey along the southern Australian coast between C Leeuwin, WA and Ceduna, SA recorded 447 sightings (allowing for duplication between flight legs), including 152 calves, between 26 August and 2 September; the calculated increase rate for cow/calf pairs, 1993-2006, is 7.56% (95% CI 4.61, 10.51). Current population size for the survey area is estimated as 2100, and for the 'Australian' population (including animals visiting the southeast coast) as *ca* 2400. 557 identification photographs were obtained from the Australian coast in 2006: 419 from the aerial survey, 125 at Head of Bight, 11 from Tasmania and 2 from Hervey Bay, Queensland (SC/59/ProgRep Australia). A total of 147 sightings were reported to the South Australian Museum in 2006.

208 right whales including 34 cow/calf pairs, were recorded during a three week survey at the Auckland Islands during winter 2006. A count on identical lines in 1997 yielded 146 animals including 18 cow/calf pairs. 142 biopsies and a similar number of identification photographs were obtained in 2006 (SC/59/ProgRep New Zealand).

SC/59/SH10 reported distribution and abundance of southern right whales off the southern coast of Australia, from the line transect sighting data by the 1995/96 Japan/IWC blue whale survey cruise. Southern right whales were only confirmed by *SM1* in the 1995/96 cruise. From 42-45°S, and 116-117° 30'E, *SM1* encountered a total of 35 right whales, in 27 schools over a searching distance of 346.7 miles in the five day period, 10-14 December. Right whales were frequently seen in the zone between 42°S and 44°S to and from 45°S, an area where the subtropical convergence was probably present. And the abundance was estimated to be 2,110 (95% CI: 548-8,126) in water surrounded by lines of latitude 38S and 45S, and lines of longitude 115E and 124E.

The point estimate of this population of right whales is higher than would be expected (e.g., given a 7% per annum rate of increase), but given the high CV on the abundance estimate it would be premature to conclude inconsistency. A previous survey had looked for right whales in the same area during February but not found any, noting that these whales might be farther south at that time of year.

Four aerial surveys off southern Brazil (Santa Catarina State) in July-October 2006 recorded 162 sightings comprising 335 individual right whales, of which 85 were calves and 7 were juveniles, but the figures include double counting (SC/59/ProgRep Brazil). 98 different individuals were counted on the aerial survey in one day in September; the survey took two days to complete because of the record number of whales (totalling 194 animals). Two animals were seen on ship cruises off the south east coast (São Paulo State) where two cow/calf pairs were also sighted from land observations. Off the north coast (Bahia State) during a humpback whale survey, three groups of southern right whales were recorded. 240 identification photographs were obtained off southern Brazil in 2006, but have yet to be analysed; the photographic catalogue now totals 332 images.

Van Waerebeek briefly summarised the status of southern right whales off Chile and Peru. The last major review of the species was conducted in 1998 (IWC, 2001), but little information was available for the SE Pacific although thousands of animals were taken in the 19th century. During the austral winter and spring, these whales are found in the coastal waters off southern Chile north to central Peru, and in southernmost Chile during the summer and autumn. In recent years, southern right whale stocks have grown significantly in three major regions in the Southern Hemisphere (South Africa, Argentina and Australia). Since there were no known major catches by coastal whalers off Chile and Peru during the 20th century, it is surprising that no increase has been observed in this population. Between 1964 and 1991, only 16 female-calf pairs have been recorded from south-central to northern Chile and till today only 3 from Peru. Although no abundance estimates exist, the paucity of sightings in the past half century makes it very probable that the mature population size is below 50 individuals, where it was once numerous. At least two calves are known

to have been killed from anthropogenic causes. More effective conservation measures and additional efforts are needed to better document all sightings in Chile and Peru and to improve our understanding of this critically endangered population.

The sub-committee thanked Van Waerebeek for this summary. It was noted that there is little information available on historical abundance for right whales in the eastern South Pacific, although several thousand catches have been recorded off Chile, and some unknown proportion of catches from the South Pacific was taken from this stock.

Approximately 10 right whale baleen plates have been recovered from animals killed off Chile. If these are representative of more than one individual, then it would be possible to arrive at an estimate of genetic diversity for this sample.

The annual photo-ID studies of southern right whales in the winter breeding area off Pensínsula Valdéz, Argentina that began in 1971 continued in 2006. An analysis of calving success showed that calving rates are correlated with water temperature around South Georgia, a known feeding ground, and with the breeding success of other krill predators at South Georgia (Leaper *et al.* 2006). The sub-committee noted that these findings illustrate the importance of continuing long-term photo-ID studies of southern right whales. Only with such long time series is it possible to identify the environmental factors that determine breeding success and hence population dynamics.

6. GRAY WHALES

6.1 Eastern North Pacific gray whales

6.1.1 New scientific information

SC/59/BRG1 reported on the 2006/07 census of the eastern North Pacific stock of gray whales by the Alaska Fisheries Science Center (AFSC) of the NMFS. Southbound migrating gray whales were counted at Granite Canyon, California from 12 Dec 2006 to 22 Feb 2007. Previous counts were carried out in 2000/01 and 2001/02. This was the 23rd census since 1967. The research protocol was the same as that used in previous surveys. In addition to the primary watch, a second, independent watch was conducted 1 to 3 times daily from 6 Jan. to 1 Feb. These data will be used to estimate the probability of observers missing animals. From 2 to 27 Jan. counts were also carried out by the Southwest Fisheries Science Center (SWFSC). These counts will be compared with counts made by the AFSC. In the future, the SWFSC will be conducting the gray whale census at Granite Canyon. The median date of the migration this year was close to 21 Jan. whereas in previous years it has been around 15 Jan. Counts of gray whales in fair to excellent visibility conditions totalled 1,770 pods during 73 days of standard census, representing 651.6hr of effort. In 200/01 1,684 pods counted in 599.4hr of effort and in 2001/02 1,712 pods were counted in 531.5hr of effort.

SC/59/BRG26 presented an application of a population dynamics modelling framework that incorporates a hypothesised relationship between an environmental variable and a life history parameter for a cetacean population. A method was adopted, which integrates an environmental index hypothesised to be related to calf production, into the stock assessment for eastern North Pacific stock of gray whales.

The sub-committee noted that progress towards incorporating environmental factors into models of population dynamics is extremely valuable. However, the manner in which birth rates are modelled could be improved. For example, the probability of calving for southern right whales does not appear to be independent of an individual's recent reproductive history. It was noted that this was an area that had been identified in the report for the next iteration of model development. However, it might be more complicated to model such 'boom and bust' dynamics using a numbers-at-age model compared to an individual based model.

Calculation of the ice index used in the analysis followed previous work by Perryman *et al.* (2002). Future work will provide a framework for testing hypotheses regarding the role of alternative indices (including different temporal and spatial resolutions of sea-ice) on population dynamics.

Moore *et al.* (2007) described observations of ENP gray whale occurrence year-round near Ugak Bay, Kodiak Island Alaska, based on opportunistic sightings from coastal aerial surveys conducted between 1999 and 2005. Gray whales were seen feeding in every month of the year, with seasonal sighting rates ranging from 41 to 100 whales/hour. Benthic sampling conducted near feeding whales in 2002 found extremely high densities of cumaceans, an atypical gray whale prey, which has a low dry weight energy content compared to amphipods, a more common prey. The ENP gray whale population may be meeting with new and more variable forage challenges in the wake of alteration of marine ecosystems associated with global climate warming. Because of the existing long-term database, research focus on this population could provide insight into large whale population dynamics, behavioural ecology, and the capacity of a mysticete species to respond to environmental changes.

6.1.2 Catch and stranding information

SC/59/BRG40 reported on a recent preliminary review of all stranded gray whales along the coast of North America from Alaska to Baja California, Mexico. A total of 1,892 dead gray whales were found during the period 1975-2006. Due to annual variation in searching effort between years in some areas (Alaska, British Columbia, and Baja California), data from California, Oregon and Washington were summed and used as the core region to examine the change in mortality patterns over the study period. In 2001, after the die off ('unusual mortality event') in 1999 and 2000, the number of stranded gray whales was equal to the lowest in the study period (1975). During the past three years (2004-06), the number of dead gray whales was about equal to or lower than the numbers reported dead before the die-off during the period between the mid 1980s to the mid 1990s. At this time there is indication that strandings may increase. The authors made a number of recommendations to enhance the understanding about stranded gray whales. The most important was the development of a central stranding database to better track the trend in gray whale strandings and to enhance communication and monitor effort. Brownell noted that a more in-depth review of these data will be made for next year's meeting.

Although there was an apparent interannual variation in strandings, there was a slight increasing trend and then a levelling out, which seems consistent with the pattern in abundance estimates and the hypothesis that this stock has approached K .

The issue of wind and currents is a problem for any stranding network. But, due to this species' affinity with the coast, such effects should be minimised. As far as the notion that the stranding data support the hypothesis that this stock has reached K -there are some issues that need to be considered first, including the standardisation of effort for the stranding network over this time period.

SC/59/ASW 5 summarised information relevant to the Russian aboriginal hunt for gray whales in 2006. The Russian Federation landed a total of 129 gray whales (including 55 males and 74 females) in 2006. Twenty two villages harvest whales in Chukotka. Only 16 of the 22 villages in Chukotka were able to participate in the hunt due to severe ice and weather conditions. Body length of whales taken in Chukchi Sea varied from 8.3m to 14.0m, the average length was 9.81m. Body weights of those whales ranged from 6.0 - 23.3 tons, with an average weight of 10.18 tons.

Body length of whales taken in Bering Sea ranged from 8.0m-14.9m, with an average length of 9.2m. Body weights of those whales ranged from 6.25 - 35.3 tons with an average weight of 9.14 tons. The largest male was harvested in the Chukchi Sea. It was 12.0m long and weighed 18.1 tons. The largest female was harvested in the Bering Sea by hunters of Sireniki settlement. It was 14.9m long and weighed 35.3 tons. Only one foetus was found out of 75 females. Scars from killer whale attacks were observed on 9 gray whales. 5 whales were 'stinky', exhibiting a strange smell and an unpleasant taste. 'Stinky' whales are not edible for human consumption and are lost for the nutritional needs of the Native people. Biological samples were taken from 29 harvested whales in 2006. A total of 5 gray whales were struck and lost during the harvest season 2006, yielding a total of 134 whales struck.

6.1.3 Management advice

At this meeting, the sub-committee reaffirmed its advice from last year that the *Gray Whale SLA* remained the most appropriate tool for providing management advice for this harvest. The Secretariat has calculated strike limits for this stock given the agreed abundance estimate and catch history. The results show that no change is needed to the current block quota for 2003-07. An *Implementation Review* is scheduled for 2009.

6.2 Western North Pacific gray whales

6.2.1 New scientific information

SC/59/BRG19 presented research on the western gray whale population summering off northeastern Sakhalin Island, Russia. This collaborative Russia-U.S. research program is ongoing since 1995 and has produced important new information on the present day conservation status of this critically endangered population. Photo-ID research conducted off Sakhalin Island in 2006 resulted in the identification of 79 whales, including four calves and three previously unidentified non-calves. When combined with data from 1994-2005, a catalogue of 158 photo-identified individuals has been compiled, although not all of these whales are assumed to be alive. Five biopsy samples were collected in 2006, when combined with 124 biopsies from past years a total of 129 (82%) biopsies of the 158 whales photo-identified have now been collected. As part of the annual work to visually assess body condition, 5.1% of the 79 whales identified in 2006 were observed to be 'skinny' (i.e. poor body condition).

SC/59/BRG22 presented a preliminary report of seasonal and annual variation in body condition of western gray whales off northeastern Sakhalin Island, Russia. Photo-ID images of 150 whales collected by the Russia-US western gray whale research programme between 1994 and 2005 were used to visually assess western gray whale body condition by evaluating the relative amount of subcutaneous fat in three body regions presumed to reflect reductions in body condition. Findings from a preliminary evaluation of the body condition determinations indicate that: (1) the proportion of whales in compromised body condition varied annually and seasonally throughout the study period; (2) the proportion of whales in compromised body condition generally decreased during each field season, while the proportion of good condition whales increased; (3) lactating females were typically found in compromised body condition while nursing calves were almost always in good condition; and (4) individual variation in the body condition of both male and female whales is high. Over the short-term, western gray whales appear to recover from periods of compromised body condition; however, the long-term consequences on reproduction, survival, and other factors are unknown.

SC/59/BRG37 provided a report on anthropogenic scarring of western gray whales and was an update of a preliminary report made last year (SC/58/BRG12). Photo-ID images of 150 whales amassed by the Russia-US western gray whale research program from 1994 to 2005 were used to examine and quantify non-lethal fishing gear entanglement and vessel collisions using a scar-based approach. The results of an inter-rater agreement study and an expert review of the scar determinations indicate that the western gray whale scar quantification protocol can be used by more than one trained researcher to produce comparable results that would largely be consistent with expert opinion. Twenty-eight male and female western gray whales were found to have been entangled in fishing gear at least once and three to have survived at least one vessel collision. These estimates are likely to be conservative given the nature of the photo-ID dataset, but indicate that male and female western gray whales are subject to anthropogenic interactions.

The sub-committee commended the authors on their work. There was some discussion about the persistence and accumulation rates of scars. There have been a couple of cases that had provided insight into these issues. For example, some individuals were observed to have accumulated scars during the course of the study period which provided information on the relative timing of some anthropogenic interactions and the relative age of individuals involved.

SC/59/O18 reported on the status of conservation and research on the western gray whales in Japan, following IWC Resolution 2001-3, 2004-1 and 2005-3. No sightings of the western gray whales were made during either systematic or platform of opportunity surveys around Japan, during June 2006 to April 2007. However, unfortunately a juvenile female gray whale was incidentally entangled by a set net located off Snariku-cho, Ohfunato city, Iwate prefecture (39°09N - 141°54E) on the morning of 18 January, 2007. The animal was a female which measured 9.19m in body length. Biological samplings and surveys were conducted by ICR scientists under the instruction of the Fisheries Agency of MAFF, Japan. Currently, the Fisheries Agency is exploring alternative actions in order to eliminate anthropogenic mortality.

It was **recommended** that the Japanese implement a plan similar to those off the U.S. east coast which aims to train experts in releasing whales entangled or entrapped in fishing gear. There was some discussion regarding plans to better inform fisherman about this problem. It was noted that such plans were being considered at present.

A joint effort between Japanese, Russian and US scientists was conducted during the SC meeting to attempt to match the female western gray whale reported by SC/59/O18 to have been fatally entrapped in a set net on 18 January 2007 in Yoshihama Bay, Iwate Prefecture, Japan with the four known western gray whale calves photo-identified during their 2006 Russian-U.S. field season off the northeastern coast of Sakhalin Island, Russia (SC/59/BRG19). A photographic match was made between the fatally entrapped gray whale and one of the 2006 calves off Sakhalin. This match represents the first link of a western gray whale from the Sakhalin Island feeding area to a location within the migratory corridor and raises two important points. First, it is now clear that at least some western gray whales that utilise the northeastern Sakhalin Island feeding area migrate along the Pacific coast of Japan. Second, the relatively low survival rates estimated for northeastern Sakhalin calves in their first year post-weaning could partially be attributed to bycatch mortality off the Japanese coast. Additional cooperative research on these issues was **recommended** by the sub-committee.

SC/59/BRG41 presented an updated population assessment of the western gray whale using the photo-ID data collected off Sakhalin Island under the joint Russia-US programme from 1994 to 2006. An individually-based population model was fitted to the data to obtain estimates of population size, population parameters, and probabilistic projections of the population. New median estimates of key population parameters (with 90% Bayesian confidence intervals) are 0.983 (0.972 - 0.991) for the adult survival rate; 0.76 (0.66 - 0.85) for the survival rate from calf to yearling; 2.9%

(1.9%-4.0%) for the average annual rate of population increase over 1994-2006; 0.45 (0.38 - 0.52) for the female sex ratio and 121 whales (113 - 130) for the 1+ (non-calf) population size in 2007. Forward projections of the population model to 2050, assuming no additional mortality or disturbance to reproduction, indicate a high probability (>99%) of population increase. Four whales (all female) have been trapped and killed in trap nets on the Pacific coast of Japan during the past 24 months. Projections of the female population incorporating this level of extra mortality indicate a high (>25%) probability of population decline and a substantial (>10%) risk of extirpation by 2050. It is important to avoid any further human-caused deaths in this depleted population.

SC59/BRG/38 reviewed various human related threats to western gray whales, especially bycatch. One of the main objectives of the paper was to call attention to efforts in other parts of the world to release whales from fishing gear with good results. Due to the critically endangered status of the western gray whales the authors recommended that Japanese authorities develop a program to release any live gray whales. Two whales (a humpback in 2003 and a minke whale in 2006) were released alive in Okinawa. These efforts need to be expanded and additional efforts need to be considered such as cutting the trap nets and compensating the fishermen for damage to their gear and the loss of any catch. It was also noted that such a program for the release of live dugongs in Okinawa has been established by the Ministry of the Environment. This type of programme is critical to the future survival of the western gray whale population.

SATELLITE TAGGING OF WESTERN GRAY WHALES – AN UPDATE

Background:

Last year the SC acknowledged the anthropogenic risks (four deaths from fishing gear in two years, vessel strikes, and petroleum development activities) to the western gray whale population and the lack of information on this species' migratory routes, breeding destinations, and extent of its feeding range. The SC subsequently **recommended** that a satellite program be initiated on the feeding grounds near Sakhalin and **strongly recommended** that the work be carried out only by experienced investigators tagging known males with proven technologies. The Committee agreed to consider the general issue of the use of telemetry and potential effects on whales at this year's meeting, when the report from the 2005 Society of Marine Mammalogy workshop was expected. The need for an IWC workshop was to be assessed this year.

With regard to progress, the Society for Marine Mammalogy workshop is not yet available, but is under development by Weller for September 2007. Mate *et al.* (2007) described how duration of tag operation and reliability have improved over time and are linked to evolution of tag design, size, and application techniques. Relevant subjects included: identification of breeding, feeding, and migration areas; habitat characterisation; individual variability; behaviour; anthropogenic risk assessment; responses to tagging; and tag loss process. Such spatial-temporal information can inform population estimation, stock identification, and response to environmental change. The Western Gray Whale Advisory Panel (WGWAP), which was established by the IUCN at the request of Sakhalin Energy Investment Corporation to advise about needed studies regarding development of offshore Sakhalin oil and gas. The WGWAP has met twice (November 2006 in Switzerland and April 2007 in Russia) and has added criteria, including: testing new tags on the relatively large eastern population; not tagging 'skinny' whales; a variety of reviews; engaging appropriate range-states for follow-up; and making positional updates available.

A proposal for moving forward:

Despite a great interest in developing seasonal distribution information to improve conservation and mitigation, tagging studies of western gray whales have not been initiated. It is not obvious how to fund the work. Industry worries that direct funding of a tagging study will cause potential credibility issues or consequences if adverse impacts occurred. To encourage progress, the sub-committee **recommended** that the IWC itself undertakes the project. With such wide-spread international interest, the sub-committee further **recommended** that some form of the telemetry results (sampled and edited for quality control) be available on the web. This project will involve the participation of several research groups (for whale identification, tagging, and follow-up re-location efforts) in a remote area with difficult logistics, so its cost will likely exceed \$1M. The sub-committee recognises this far exceeds normal IWC funding levels and therefore proposes that this research be included in the Committee's budget but with: (1) a zero funding request, but a suggestion that individual governments or others consider making voluntary contributions to the IWC research fund for this end and; (2) a reminder that this work will only be undertaken if the conditions already agreed to by the IWC and WGWAP are met.

7. WORK PLAN

- 1) Review new information on Western North Pacific gray whales
- 2) Review stock structure and abundance for Eastern Arctic bowhead whales
- 3) Review new information on all stocks of right whales
- 4) Prepare for the *Implementation Review* of Eastern North Pacific gray whales in 2009
- 5) Perform the annual review of catch information and new scientific information for the B-C-B Seas stock of bowhead and Eastern North Pacific gray whales

8. ADOPTION OF REPORT

The report was adopted 2:15 pm on 14 May 2007.

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Appendix 1

Agenda

1. Opening remarks
 1. Opening remarks, election of Chair and appointment of rapporteurs
2. Adoption of Agenda
3. Review of available documents
4. Bowhead whales
 - 4.1 Bering-Chukchi-Beaufort (B-C-B) Seas stock of bowhead whales
 - 4.1.1 Stock structure hypotheses
 - 4.1.1.1 Genetic information
 - 4.1.1.2 Other information
 - 4.1.1.3 Revision of hypotheses
 - 4.1.2 Other new scientific information
 - 4.1.3 Catch information
 - 4.1.4 Management advice
 - 4.2 Davis Strait/Baffin Bay and Hudson Bay/Foxe basin bowhead whales
 - 4.2.1 Stock structure
 - 4.2.2 Other new scientific information
 - 4.2.3 Catch information
 - 4.3 Other stocks of bowhead whales
5. Right whales
 - 5.1 North Atlantic right whales
 - 5.2 North Pacific right whales
 - 5.3 Southern right whales
6. Gray whales
 - 6.1 Eastern North Pacific gray whales
 - 6.1.1 New scientific information
 - 6.1.2 Catch and stranding information
 - 6.1.3 Management advice
 - 6.2 Western North Pacific stock of gray whales
 - 6.2.1 New scientific information
7. Work plan
8. Adoption of report