Annex E
Report of the Sub-Committee on Other Great Whales

Members: Zeh (Convenor), Addison, Baker, Baldwin, Bannister, Berggren, Best, Borchers, Born, Borodin, Brownell, Butterworth, Carlson, Childerhouse, Clapham, Clark, Clarke, Cooke, DeMaster, Donahue, Donovan, Ensor, Findlay, Friday, Fujise, George, Goto, Hakamada, Hammond, Hatanaka, Hester, Hiby, Kasuya, Kato, Kawachi, Kawahara, Kim, Kock, Leaper, Lens, Melnikov, Mikhalev, Moronuki, Nishiwaki, Ohsumi, Øien, Okamura, Pastene, Pérez-Cortés, Perrin, Pinedo, Polacheck, Punt, Reeves, Robineau, Rojas Bracho, Rooney, Shimadzu, Slooten, Smith, Stachowitsch, Swartz, Tanaka, E., Tanaka, S., Tanakura, Thiele, Tomita, Van Waerebeek, Von Bismarck, Wade, Walløe, Witting, Yagi, Yamamura.

1. CONVENOR'S WELCOME AND OPENING REMARKS, ELECTION OF CHAIR, APPOINTMENT OF RAPPORTEUR

Zeh was elected Chair. She noted that because of time limitations, the major emphases of the sub-committee would be on new information relating to distribution and abundance, questions of subspecies and stock identity, and new catch information where appropriate. Documents relating to the Comprehensive Assessment of sperm whales and North Atlantic humpback whales would not be discussed in detail, but considered more in relation to how they might give direction to an assessment at the next (or a subsequent) meeting.

Best acted as rapporteur.

2. ADOPTION OF AGENDA

The adopted Agenda is given as Appendix I.

3. REVIEW OF DOCUMENTS

Documents considered by the sub-committee included SC/50/CAWS1-4, 7-12, 14-16, 18-40, SC/50/O3, 5, 14, 16, 18, RMP6, SC/50/Rep 1, 2, 4, McCauley *et al.* (1998b), Chaloupka and Osmond (1998), Baker and Medrano-Gonzalez (1998), Smith *et al.* (1998), McCauley *et al.* (1998a), Childerhouse and Dawson (1998) and Childerhouse *et al.* (1998).

4. SOUTHERN HEMISPHERE BLUE WHALES

4.1 Reports of the SOWER cruises

Findlay summarised the report of the 1997/98 IWC/SOWER blue whale cruise (SC/50/Rep2), the third to be undertaken as part of the IWC's research programme on Southern Hemisphere blue whales. The cruise was conducted in the southeastern Pacific Ocean off the coast of Chile during December 1997 and January 1998. The objective of the cruise was to obtain scientific information relevant to developing onboard identification methods for distinguishing between true and pygmy blue whales. Two summer concentrations of blue whales were identified off the coast of Chile by the SOWER planning meeting for the cruise, namely off Iquique (~18°S) and off Valparaiso (~34°S). The two vessels *Shonan Maru* and *Shonan Maru No. 2* departed Iquique on 12 December 1997. The *Shonan Maru* proceeded directly southwards to 38°S and searched northwards to cover the Valparaiso/Talcahuano concentration, while the *Shonan Maru No. 2* surveyed from 18°30'S southwards, covering the Iquique concentration. The vessels were to meet after two weeks and then to proceed to the region of highest concentration found during the initial two weeks of survey. As a result of sightings of blue whales made during the southward transit of the *Shonan Maru* in the region of Antofagasta-La Serena, the *Shonan Maru No. 2* surveyed this area en route southwards. A total of 389hrs 58mins of searching was carried out by both vessels combined, during which some 4,454 n.miles of trackline were surveyed. In total, 39 sightings of 47 blue whales (and 1 sighting of 1 like-blue whale) were made, of which 37 sightings of 45 animals were identified as pygmy blue whales and 2 sightings of 2 animals as 'undetermined' blue whales. Experimental work included collecting 19 biopsies from blue whales, and 462 still photographs, and 180.11min of video footage of blue whales were exposed for individual identification, morphological and behavioural analysis. Dive-time experiments were undertaken for 20 blue whales for a total of 16hrs 20min, and 225hrs 13min of acoustic monitoring was carried out: blue whale calls recorded ranged in frequency from 9-44Hz and from 1-32 seconds in duration. Both vessels arrived in Punta Arenas, Chile (53°S) on 10 January 1998. A list of recommendations for future blue whale cruises is included in the report.

It was asked during discussion whether the distribution of blue whales on the cruise had shown any noticeable effects of the strong 1997/98 El Niño event. The reply was that there was not much historical data on blue whale distribution in the area from which conclusions could be drawn, apart from catch positions for which there were no associated effort data. In any case, the cruise was probably located too far south to feel the full effects of the El Niño. Nevertheless, Brownell proposed that efforts should be made to obtain appropriate satellite imagery data for the area and time of the cruise, so that the observed distribution of blue whales could be plotted against oceanographic features.

In reply to a question regarding what criteria had been used for distinguishing between blue and pygmy blue whales on the cruise, Findlay replied that the identifications were all provisional and had been made by the topmen. The criteria they had used (e.g. blowhole shape, head shape, etc.) had been systematically recorded on the sighting data sheet. The boatswains on both vessels had also had previous experience with chasing and catching pygmy blue whales before protection. It was recommended that a paper should be submitted to next year's meeting, documenting the criteria used on each of the three blue whale cruises for identifying the two blue whale forms, listing the results and the personnel responsible for making the identifications, and providing an analysis of the photographic and video material in support of the criteria used. Kato pointed out that much of this had already been done for the first two cruises (SC/50/CAWS1), and that the 1997/98 cruise material had been preliminarily evaluated, but only for the purposes of individual identification.

Ensor summarised SC/50/Rep1, in which the results of the 1997/98 IWC/SOWER cruise to Area IIW (60°-25°W) were presented. Although the primary objective of this cruise had been to estimate the abundance of minke whales south of 60°S, two of the 30 available research days had been allocated for research on blue whales. Eleven sightings of 18 blue whales were made in the research area; eight of these sightings (14 animals) were identified as true blue whales, two sightings (3 animals) as pygmy blue whales and one sighting (1 animal) as an 'undetermined' blue whale. Research was conducted on 10 groups of blue whales for a total of 14.42 hours, during which time biopsies were obtained from 3 true blue and 3 pygmy blue whales, acoustic monitoring was carried out for 13hrs 25mins, dive-time experiments were run for 2.83 hours, video-taping of surfacing behaviour was recorded for 26min 47secs, and 8 true blue and 2 pygmy blue whales were photographed for identification purposes.

4.2 Progress towards assessment

4.2.1 Abundance and trends

The sub-committee noted that, due to problems of accessing the DESS database from Cape Town, it had not been possible to develop revised estimates of blue whale abundance from the IDCR/SOWER cruise programme in time for this meeting. It looked forward to receiving such estimates at the next Scientific Committee meeting.

Best introduced SC/50/CAWS14, which had been written with a view to possible future developments in the IWC's research programme on southern blue whales. Catches of blue whales off Walvis Bay, Namibia, in the 1920s had been substantial, and size composition data for 681 whales revealed that 12.3% of the catch was more than 79ft in length. This was bigger than the maximum recorded length of a pygmy blue whale, indicating that these were probably true blue whales. Catches peaked strongly in July/August. There were at least six apparent cow-calf pairs included in the catch, and the region had the reputation of being resorted to by particularly large, fat females. If the area is a winter 'breeding ground' for true blue whales, this would offer new opportunities for monitoring their status.

In reply to a question, Best stated that although there were no locations available for these catches, extrapolation from information on the offshore distribution of blue whales off the west coast of South Africa would suggest that the whales were between 60 and 95 n.miles offshore. This was well outside territorial waters, but of course within the EEZ of Namibia. Clapham pointed out that, if experience with North Atlantic humpback whales could be drawn on, assessing the status of blue whales on a breeding ground might not be straightforward, and would have to take into account possible structuring and segregation by sex or reproductive condition. The sub-committee agreed to refer further discussion of this matter to a group planning the future of the SOWER cruises, under Kato.

4.2.2 Subspecies and stocks

The sub-committee stated its concern that reliable distinction between true and pygmy blue whales in the field was becoming increasingly important, given that the results of the 1996/97 SOWER cruise had indicated that the simple geographical separation of the two forms in summer previously used may no longer be entirely valid. This meant that sightings estimates in high latitudes in summer may contain some proportion of pygmy blue whales.

The surfacing behaviour of putative true and pygmy blue whales had been recorded on the first two blue whale cruises, using high-resolution digital video recording. In SC/50/CAWS1, Kato and Komiya analysed 12hrs 56mins of these recordings, representing 4 surfacings by 4 true blue whales and 103 surfacings by 45 pygmy blue whales. Seven patterns of surfacing were identified, based on whether the snout or whole rostrum surfaced first, whether the back was rounded or not, whether the dorsal fin was exposed or not, and finally whether the keel of the caudal peduncle was exposed or not. Although the sample size of true blue whales was very small, there appeared to be a definite difference in surfacing behaviour between true and pygmy blue whales. Whereas pygmy blue whales never exposed the caudal keel (and rarely their dorsal fin), true blue whales seemingly always exposed both. The authors recommended that more data should be collected from true blue whales, that the biological context of different surfacing behaviours should be investigated, and that other morphological features (especially those involving the nasal region of the skull) should be examined.

The sub-committee welcomed this analysis as an objective approach to investigating behavioural differences between the two forms of blue whale, and looked forward to a fuller analysis next year, in which the results of the 1997/98 blue whale and SOWER cruises would be included. This would *inter alia* increase the sample size for true blue whales. Concern was expressed, however, that the process of closing with the whales to obtain video footage may be altering surfacing behaviour, so that the difference in behaviour seen between the two forms might be partly a result of the true blue whales having been filmed at a greater distance from the vessel. Brownell reported that blue whales in the Maldives, believed to be pygmy blue whales, fluked frequently, even during boat approaches.

In SC/50/CAWS23, 23 sightings of blue whales made in the vicinity of the Galapagos Islands between 1978 and 1995 were discussed. All but one occurred in the austral winter or spring. Some apparent feeding behaviour was observed, and the region seemed to be a productive habitat. One animal was observed with dorsal scarring possibly attributed to contact with ice. The paper concluded that the whales could either be Southern Hemisphere animals on their wintering grounds, or members of a resident Eastern Tropical Pacific stock.

Kato reported that he had examined photographs of animals from the Galapagos region, including a sequence showing surfacing behaviour, and that from morphological and behavioural characters he had concluded that these whales resembled true blue whales.

Thiele reported on incidental sightings of more than 60 blue whales made on one day from a ro-ro ferry in a fjord in southern Chile in January 1998. Some of these animals were apparently feeding at a frontal zone between oceanic and glacial meltwater. A single cow-calf pair had been seen from the same ferry in November 1997.

In discussion, Thiele stated that the observers (who had just left the blue whale cruise) believed that the animals they had seen looked similar to the blue whales seen on that cruise and identified as pygmy blue whales by the boatswains on the *Shonan* boats. There were historical catch records for the area. It was pointed out that future surveys of such areas would require permission for access to territorial waters, as the whales had been found within 12 n.miles of the coast.

Clark reported on an analysis of sounds recorded in the vicinity of blue whales off Chile on the 1997/98 blue whale cruise (SC/50/CAWS29). During 13 approaches to blue whales for biopsy attempts that were acoustically monitored, a total of 20 very low frequency calls was recorded during eight approaches. All these calls were similar, having a fundamental frequency of about 11Hz with up to five harmonics and lasting up to 60 seconds. As such they were typical of blue-whale type vocalisations, but were unique in the consistency of the fundamental harmonic and the production of multiple harmonics, creating a harsh, growly quality. Such calls were only recorded in the context of one of the boats closing with the whale for biopsy, and were characteristic of calls made by other animals in an agonistic or threatening context.

In response to a query regarding what the results of the three cruises to date could tell us about any acoustic distinction between true blue and pygmy blue whales, Clark summarised as follows. All the recordings made in the Antarctic in 1996/97 in the vicinity of putative true blue whales differed greatly from anything recorded on the cruises off Australia in 1995/96, south of Madagascar in 1996/97 or off Chile in 1997/98. Preliminary reports from the 1997/98 Antarctic SOWER cruise suggested that calls similar to those recorded in the Antarctic in 1996/97 had been heard. It therefore appeared that true blue whales may produce different vocalisations from pygmy blue whales. The best documented comparison was between pygmy blue whales sampled south of Madagascar in November/ December 1996 and blue whales recorded in the Antarctic the same summer (IWC, 1998b; Ljungblad, 1997): these were as distinct as the calls of North Atlantic or North Pacific populations of blue whales. Clark reported, however, that he had not had access to Australian recordings for analysis, and had not yet been sent any 'non-growl' recordings from Chile. He was therefore unable to comment on possible acoustic differences between 'populations' of pygmy blue whales off Australia, Madagascar and Chile. A small group under Clark was asked to draw up a working paper describing the current situation regarding the quantity, availability and disposition of acoustic recordings from the blue whale and SOWER cruises, and the state of their analyses. Their report is attached as Appendix 2.

4.2.3 Other

Following problems experienced on previous blue whale cruises with obtaining biopsies from whales that were difficult to approach, Larsen had developed a more powerful delivery system based on a Remington Rolling Block System rifle, adapted to fire darts of a diameter of 26mm using 9mm blank ammunition (SC/50/O15). The gun also carried an electronic aiming device and a valve for adjusting gas pressure. Field trials on humpback whales off Provincetown had been promising, but it had not been possible to get the gun to Chile in time for the 1997/98 blue whale cruise.

The sub-committee agreed that the question of using this new system on future blue whale cruises should be referred to the small planning group that had been set up under Kato.

5. RIGHT WHALES

5.1 Report of the Cape Town workshop

Bannister summarised the report of the special meeting on the Comprehensive Assessment of right whales that was held in Cape Town in March 1998 (SC/50/Rep4) – see Appendix 3.

In discussion of the report, most members of the sub-committee did not agree that there are any data to support the statement attributed to Best, regarding the possibility that some recovery must have taken place in the western North Atlantic population following protection in 1935, with a possible slow recovery until at least the 1980s (SC/50/Rep4, section 10.1).

Clapham, Wade and Baker commented that the regression given in SC/50/Rep4, annex G, item 2, may not reflect a population increase in western North Atlantic right whale adult females between 1985 and 1997 but rather a 'rate of discovery' of newly observed parous females over the period.

As regards the use of sloughed skin for DNA analysis (SC/50/Rep4 section 9.1.2.2), Clapham commented that although DNA yield from sloughed skin was sometimes lower than from biopsies, sloughed skin was nonetheless a valuable source of genetic material and its collection from right whales should be encouraged.

In discussing the issue of so-called relict populations, the sub-committee felt it was important that the recommendation in section 11 of the report should be extended to cover not only right whales in the eastern North Pacific, but also those in the eastern North Atlantic.

The sub-committee commended the organisers of the meeting and agreed to forward its recommendations to the Scientific Committee. Best, however, expressed reservations over recommending the creation of a Southern Hemisphere Right Whale Consortium, on the grounds that it was unnecessary, and that the time and funds envisaged could be much better spent in support of actual research programmes.

5.2 Action arising

A summary of the most important recommendations for which action by the Commission might be required will be prepared by Bannister and presented to the Scientific Committee in Plenary.

Although the results of the special meeting represented a major advance in understanding the status of right whales worldwide, the sub-committee felt that there were still a number of outstanding questions regarding the status of the population in the western North Atlantic. Although the population was known to be small (*ca.* 300 individuals), and well below its unexploited size, its current dynamics were unclear. At the same time, it was subject to a range of anthropogenic threats, including ship strikes and fishery entanglements, some of which were proving fatal. The sub-committee therefore recommended to the Scientific Committee that the Comprehensive Assessment of the western North Atlantic right whale should be a priority topic for next year's meeting, with its objectives being to establish the current status and dynamics of the population. It was proposed that three days be reserved for this topic, possibly immediately preceding next year's Scientific Committee meeting. A budget should be developed that would allow for a number of invited participants to attend. It was recommended that a steering committee under Clapham be established.

5.3 Other

De Master introduced SC/50/CAWS18, in which the sightings of two groups of right whales, a single animal and a group of 5-7, in one day were reported for the southeast Bering Sea in the summer of 1997. The paper produced a population estimate from these two sightings, and deduced from the distribution of sightings since 1985 that there has been a shift in distribution since the mid-twentieth century.

In discussion of this document, members of the sub-committee expressed several reservations about the findings of the paper. Specifically, they were concerned over the validity of a population estimate based on only two sightings, and believed that the associated CV (already 106%) had been under-estimated because the uncertainty associated with the use of an effective search width for another species (humpback whales) had not been included. They also considered that it was not possible to conclude that there had been a shift in habitat usage because the survey had not covered the main area in which sightings had been made in the twentieth century.

6. SOUTHERN HEMISPHERE HUMPBACK WHALES

6.1 Progress in catch and marking data coding

Allison reported that no catch data had been coded since the last meeting, and it appeared that most individual catch data available for southern humpback whales had been coded already.

6.2 Establishment of Southern Hemisphere directory and Antarctic catalogue

Last year the sub-committee on Southern Hemisphere humpback whales had recommended that a centralised directory of Southern Hemisphere humpback whale identification photographs be established, and it was recommended that the IWC Secretariat create and maintain the directory. A suggested format for such a directory had been published in IWC (1997b, p.134). The Secretary reported that no progress with the creation of the directory had been possible, given the short time since the 1997 meeting. After referring the matter to a small group under Carlson, the sub-committee recommended that the IWC Secretariat continue with arrangements to create the directory.

Last year the sub-committee on Southern Hemisphere humpback whales had also recommended that Carlson be nominated and funded to undertake certain tasks related to the establishment of a centralised catalogue of humpback whale identification photographs from the Antarctic. Carlson reported that, as instructed, she had inspected both the JARPA and IDCR collections of photographs and assessed them for quality and distinctiveness for matching. She had also approached the College of the Atlantic to determine whether they would be interested in taking on the responsibility for such a catalogue, which would include creating separate catalogues for lateral views from each side. The College of the Atlantic had replied positively, and a specific proposal was contained in Appendix 4, which also contains the results of further discussions of a small group convened by Carlson.

In sub-committee discussion, some members raised concerns about the appropriateness of such a catalogue, and whether consideration should be given to having it in an electronic form rather than as a physical catalogue. After referring the matter to the small group under Carlson, the sub-committee recommended that the Commission should proceed with arrangements for a contract to be drawn up with College of the Atlantic to create an IWC Antarctic catalogue of humpback whale photographs, provided that such a contract contains written specifications of (a) how the catalogue is to be made available to researchers, under what conditions and in what format; and (b) what protection will be afforded for the proprietary rights of any contributors to the catalogue.

6.3 Progress towards assessment

6.3.1 Abundance and trends

Nishiwaki presented an analysis of the humpback whale sightings in Area IV during JARPA 1997/98 (SC/50/CAWS8). In 21,594.4 n.miles of searching in closing mode, 117 primary sightings of 246 humpback whales were made by the dedicated sighting vessel, and 431 sightings of 819 humpback whales by three sighting and sampling vessels. For the first time since the JARPA programme started, humpback whales were the dominant species throughout the region surveyed. Densities were particularly high between 83°-108°E, even at the ice edge, and there was clear segregation from minke whales. Indices of abundance were clearly indicative of an increasing density of humpback whales from 1989/90 to 1997/98.

In answer to a query, Nishiwaki confirmed that the area coverage was comparable between years. The sub-committee was informed that it would be unwise to attempt to calculate a rate of increase from the JARPA abundance indices at present because there may have been undersampling of high density areas. This problem had arisen with minke whale abundance indices from the same surveys, and was the subject of a current IWC contract.

Thiele presented the results of a shipboard survey in Area IV during the 1995/96 summer, from the Australian ice-breaker *Aurora Australis* (SC/50/CAWS16). The ship was occupied on a krill acoustic survey, so searching was in passing mode only, but data collection procedures followed standard double-platform line transect methodology. The resultant population estimate for humpback whales was 900, with a CV of 0.46.

In clarification, Butterworth explained that the estimate had involved a considerable degree of extrapolation northwards (to 60°S) to make it comparable with those from the IDCR/SOWER programme. Although the resultant estimate in the strictly statistical sense was significantly different from the estimate of 3,309 (CV 0.445) from the second set of circumpolar IDCR cruises (SC/50/CAWS37), this should not be a matter of concern, not only for the reasons stated in SC/50/CAWS16 (different survey timing, 'additional variance', possibly lower $g(0)$), but also because the *Aurora Australis* survey was in passing mode, which would have produced a tendency to underestimate group size, and because particularly strict criteria had been used in accepting a sighting as identified. These factors might have combined to reduce the estimate of abundance. Nishiwaki pointed out that the estimate from the JARPA southern stratum in Area IV in 1995/96 was 760 (CV 0.31), which was not too different from the estimate in SC/50/CAWS16. However the effective search half-width from the *Aurora Australis* data was much narrower than that from JARPA or

IDCR/SOWER, and he queried whether this might be indicative of lower observer efficiency, a point also raised by Ohsumi, in referring to his paper that compared the sighting efficiency of experienced whalers and inexperienced observers (Ohsumi and Kasamatsu, 1982). In response, Butterworth cautioned against (a) accepting the JARPA abundance estimate, given the problems mentioned SC/49/Rep1, and (b) making a correlation between narrow *esw* and low $g(0)$, given that the former may have been affected by the strict species confirmation criteria used on the *Aurora Australis*.

In reply to a question about future cruises and how to improve the ability of observers to identify species at distance from the trackline, Thiele responded that the next survey was currently being conducted using 'big-eye' binoculars to improve species identification during passing mode. Butterworth commented that the utility of these estimates would be greatly improved if they could be incorporated with other data in a GLM approach to achieve better estimates of population size and particularly trend. In this respect, he would like to see distributional and environmental data for Area IV so that the potential importance of 'additional variance' could be evaluated. The sub-committee agreed that the evaluation and comparison of such sighting data would be greatly facilitated if the distributions of both angles and radial distances to sightings were given. In addition, it was important at the outset to decide on whether such cruises were designed to provide estimates of absolute or relative abundance, or were intended simply to relate whale density to environmental correlates. Certainly if the ultimate objective was to obtain estimates of absolute abundance, then experiments to calculate $g(0)$ would be required. The sub-committee considered that the issue of using such surveys to obtain estimates of trend should be referred to the proposed workshop on planning joint GLOBEC/SOWER/CCAMLR surveys. Thiele said that the Australian surveys were conducted to incorporate data from all disciplines to look at broad scale physical and biological patterns and processes in relation to cetacean distribution, but that they would provide estimates of abundance if enough sightings were made.

During the 1997/98 summer, sighting surveys were carried out in the Antarctic Peninsula area from the Brazilian Antarctic supply ship *Ary Rongel*, using line transect methodology (SC/50/CAWS36). Densities of humpback whales were obtained and 54 individuals photo-identified (including one match between 27 January and 7 March, suggesting some individuals might be resident for substantial periods during the summer).

The sub-committee was pleased to receive these results, and recognised that this was another instance of the possible use of a platform of opportunity for obtaining absolute or relative indices of abundance.

The results of an aerial surveillance programme over the Great Barrier Reef, Australia, from 1982 to 1996 were presented to the sub-committee (Chaloupka and Osmond, 1998). In year-round surveys a total of 414 sightings of 812 humpback whales had been made, including sightings of 25 cow-calf pairs with 27 individual calves. Most sightings were made in winter and spring, but occasional sightings north of 16°S in summer suggested a year-round residency. A crude birth rate of 0.072 was obtained from the incidence of calves, and a median calving rate of 0.3 calves per mature female per year calculated. Time series regression analysis of the annual trend in sightings suggested that the east Australian population was increasing at 3.9% (95% CI 1.95%, 5.7%) per year.

In discussion the sub-committee expressed a number of reservations over this paper and its analysis. There was insufficient information on the searching strategy and methodology used, and the experience of the observers and protocol used in recording sightings were unknown. Concern was also expressed over the reliability of calf counts from such flights, and there seemed to be no way of confirming many of the species identifications made. Although the time series of the flights (14 years) was extensive, the number of sightings made (an average of only 30 a year) was approximately what might be seen on one day in a shore-based survey at the peak of the season, so the efficiency of the surveys was presumably low. Thus while in principle such surveys could be used as indices of relative abundance, there had to be strict standardisation of techniques and effort for the results to give a reliable measure of trend. There was no indication from the paper that such standardisation had been carried out.

Butterworth presented an analysis of the sightings of humpback whales made on two, and an incomplete third, circumpolar IDCR/SOWER surveys, covering the period 1978/79 to 1995/96 (SC/50/CAWS37). He explained that there had been problems with gaining access to the DESS computer package from Cape Town, so that these estimates had only been prepared shortly before the meeting. He had subsequently been able to make the results of the three circumpolar surveys more comparable by adjusting for differential area coverage (Appendix 5). These estimates had used sighting rates by stratum, but *effective search half-widths* (*eshw*) and mean school sizes had been obtained by pooling over each set of surveys. Closing and passing mode estimates had been pooled, except for calculations of mean school size, which had used closing mode data only. He pointed out that the results for each Area had large CVs but those for each set of circumpolar surveys had CVs that were more acceptable. The results indicated an increase from 7,500 humpback whales in the first set of surveys to 11,800 in the second set and 15,700 whales in the third (as yet incomplete) set of surveys. Scaling up further, to take account of humpback whales north of 60°S, could be carried out using data from Japanese scouting vessels, but had not yet been done.

In reply to a question about how these results could be interpreted, Butterworth stressed that conclusions on possible rates of increase should not be based on comparisons by Area, as these estimates had large CVs and were subject to possible additional variance due to inter-survey shifts in distribution. Estimates based on sets of circumpolar surveys were more reliable, but CVs for the estimates in Appendix 5 had not yet been calculated, and the 'year' to which they referred was not clear because each set of estimates corresponded to a 6-year period. He did not think it appropriate to use them for estimating rates of increase as yet. Other questions raised concerned the scaling up procedure to adjust for incomplete area coverage, specifically whether the clumped nature of humpback whale distribution had been taken into account, and whether it would not be better to scale down to a common area rather than scaling up. Butterworth agreed that both might be more defensible procedures, although they were likely to lead to increased CVs.

When considering estimating trends from such data, several members mentioned the need to take so-called additional variance into account, and the suggestion was made that the effects of high-ice, low-ice years, for instance, might be investigated. Incorporating additional variance in this way might lead to an 'explanation' of variance and thus bring the associated CVs down. Butterworth agreed that other variables could be introduced into these datasets using a Generalised Linear Model (GLM) approach.

Findlay introduced SC/50/CAWS25, which was prepared in response to a request from last year's sub-committee on Southern Hemisphere humpback whales. Catches of humpback whales by modern whaling in the Southern Hemisphere were reviewed, along with the number of catcher vessels operating in each of a number of whaling grounds. Grounds included the Falkland Islands Dependencies, Antarctic pelagic waters (including the Ross Sea prior to 1930), the west and east coasts of southern Africa (Gabon to Madagascar), Kerguelen Island, Australia, New Zealand, Brazil and the west coast of South America. Data were obtained from both published and unpublished sources, but did not include the undeclared catches of humpback whales by either the Soviet fleets or the *Olympic Challenger*. Brief reviews of the history of operation on each ground were reported. Crude catch per unit effort (CPUE) indices were calculated as annual catch per catcher vessel for each ground. Most grounds showed marked declines in the initial 10 years of whaling and thereafter were generally of two types. In the first type declines in the catch levels in the initial years of whaling resulted in the closure of the ground, followed by some recovery of the stock. In the second type, catches declined and remained low until the cessation of humpback whaling in October 1963. Estimates of abundance and population trends from after 1963 show Southern Hemisphere populations to be undergoing some recovery in all areas where surveys have been undertaken.

The sub-committee thanked Findlay for preparing this review. Some discussion followed on how the Comprehensive Assessment of southern humpback whales should now proceed, given the uncertainties in the locations of many catches (particularly the previously undeclared Soviet catch). Last year, the sub-committee had proposed a number of options for dividing feeding ground catches into putative breeding 'stocks', and it was proposed that a small group under Findlay would review what catch data were available, consider whether last year's proposed catch divisions were still appropriate, and discuss how the CPUE data might be utilised in an assessment.

The sub-committee accepted the plan of action as proposed by this Group, as below. No changes to the stock division (Fig. 1) accepted in 1997 were proposed.

Modelling of the pre-exploitation size of stocks will be carried out as recently done for southern right whales (SC/50/Rep4). The model described in SC/50/Rep4 (the population model used in the *Catch Limit Algorithm* of the RMP; IWC, 1993) will be run for stocks where some recent population estimates have been determined (stocks C, D and the east Australian component of stock E). Low latitude catches of humpback whales reported in SC/50/CAWS25 can be assigned to these stocks except for those from the Kerguelen Islands. For the purposes of these analyses the undeclared Soviet catches for which no catch position data are available will be assigned on a *pro rata* basis. Catches from the Kerguelen Islands will be equally divided between C and D. These analyses are intended as preliminary; both the population model used and options for allocating catches can be refined in the light of initial results obtained.

6.3.2 Stock structure

Baker introduced Baker and Medrano Gonzalez (1998) in which the distribution and worldwide diversity of humpback whale mtDNA lineages was described, using published sequences from 514 individuals (Baker *et al.*, 1993; 1998; Medrano-Gonzalez *et al.*, 1995; Palsbøll *et al.*, 1995; Larsen *et al.*, 1996). The samples represented 20 regional habitats, forming eight putative stocks among the three oceanic populations. Although the datasets differed somewhat in the length and position of the DNA control region sequenced, an evaluation of patterns of variation across the combined length showed them to be comparable for a relative assessment of diversity and geographic structure. Overall mtDNA diversity was partitioned hierarchically into oceans, stocks within oceans and regions within stocks. The regional differentiation of mtDNA lineages was most marked between feeding grounds of the North Pacific and North Atlantic. Differentiation was weakest (although statistically significant) among the four wintering grounds of the Southern Hemisphere. Comparisons of haplotype and nucleotide statistics showed considerable differences in the explained variance and permutation probabilities at each hierarchical division. Further consideration is required to determine which approach is most appropriate for analysis of stock structure of interest to the IWC. A phylogenetic reconstruction of the control region sequences allowed classification of all 514 samples into one of three clades or ancestral linkages, first described by Baker *et al.* (1993).

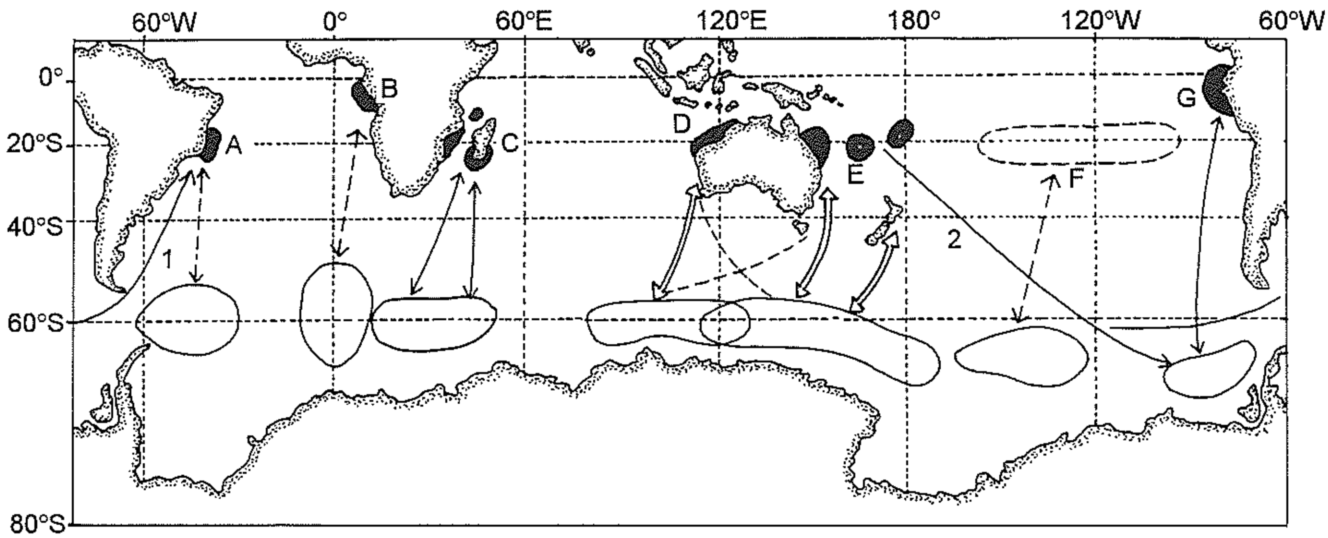

Fig. 1. Putative feeding grounds and migratory routes for Southern Hemisphere humpbacks (from *Rep. int. Whal. Commn* 48:181).

Each ocean is dominated by one clade, and, in the North Pacific and North Atlantic, a secondary clade seems to be the result of gene flow from the Southern Hemisphere. Only the Southern Hemisphere includes lineages from all three clades (although with differing regional frequencies). The patterns of clade distribution and lineage diversity in the North Pacific and North Atlantic appear to be influenced by an expansion of these populations into new feeding grounds following the retreat of the last ice age.

In response to a query why there was less differentiation among Southern Hemisphere localities than among regions within the North Atlantic or North Pacific, Baker replied that this might be because the analysis for the Southern Hemisphere was based on material from breeding grounds, whereas those for the North Atlantic and North Pacific were based on material from the feeding grounds. Pastene reported on a mtDNA analysis of feeding ground material from the Southern Hemisphere, in which only Area IV was differentiated from V, VI and I. A microsatellite analysis had failed to detect any significant difference between Areas IV, V and VI – Area I had not yet been examined.

Baker then introduced SC/50/CAWS35, describing a preliminary analysis of mtDNA variation and geographic structure of humpback whales from wintering grounds of Areas III, IV, V and VI and/or I. The analysis included previously published mtDNA sequences from Western Australia, East Australia, Tonga and Gorgona Island, Colombia (Baker *et al.*, 1998) and unpublished sequences from Madagascar (Antongil Bay), New Caledonia and coastal Colombia (Malaga Bay). The analysis was based on a consensus segment of 240bp of the control region from 176 individual whales. A total of 67 unique haplotypes was defined by variable sites within the consensus segment. A hierarchical analysis of molecular variance (AMOVA) also showed significant differences among four historical stocks or whaling management areas. However, an analysis of haplotype frequencies was not significant for stocks ($p = 0.059$), but showed more differences among pair-wise comparisons of wintering regions. Most pair-wise comparisons between wintering grounds were consistent with geographic distance or stock divisions in the haplotype analysis. Notable exceptions were the absence of difference between Madagascar and Western Australia, and the absence of difference between both these regions and New Caledonia. A larger set of samples is now available, representing several seasons, from Madagascar, Western Australia, New Caledonia, Tonga and Colombia. Further analyses of these samples are planned.

Concern was expressed about interpretation of some of the results; for instance, the non-significant difference between Madagascar and New Caledonia, compared to the significant difference between east and west coasts of Australia. Baker replied that this was probably largely the result of inadequate sample sizes. It was also pointed out that because of the high degree of variation shown in each region, large sample sizes might be needed to obtain adequate resolution. Pastene suggested that a larger segment of the control region needed to be analysed, and the possibility of inadvertent resampling of individuals on breeding grounds should be investigated. Clapham stressed the need to use a number of statistical techniques to analyse such data, because reliance on only one model might produce misleading results. It was also suggested that larger sample sizes might enable separate analyses by sex to be carried out, and the validity of the statistical comparisons depended greatly on how the samples were grouped when using an AMOVA design. Baker reported that microsatellite analysis also indicated a very high degree of individual variation in southern humpback whales.

In response to a query regarding how the genetic work could be advanced further, Baker said that there were some areas (notably both sides of the South Atlantic) where there was currently a lack of any genetic information, and there was a need for more samples from feeding areas. He was concerned that sampling in migratory corridors (rather than on breeding grounds) might produce misleading results, given experience in some areas of the North Pacific.

Pastene summarised genetic material collected by biopsy during JARPA (SC/50/O3). A total of 88 samples from humpback whales was now available, 7 from Area III, 47 from Area IV, 19 from Area V and 15 from Area VI. All except those collected in Areas III and IV last season have been analysed.

Ensor reported that biopsies had been collected from 10 humpback whales during the 1997/98 SOWER cruise (SC/50/Rep1). Eight of these had been from Area IIW and two from the recently described feeding aggregation on the border between Area II and III.

Mikhalev (SC/50/O18) reported on investigations, which had resulted in the discovery of several previously unreported recoveries of whale marks from the Soviet factory ship *Slava* in the Southern Hemisphere. For the period 1955-1966 a total of 51 recoveries had been found (including marks from both the Soviet and the Discovery marking schemes), of which 25 were from humpback whales: only six of the latter had been reported previously. The new information supports that obtained previously, in that migrations from Tonga, New Zealand and both coasts of Australia are linked to either Area IV or V. It was noted that these were probably only a small fraction of the number of recoveries actually made: in the 1959/60 season, for instance, it is known that 133 marks were recovered on either the *Slava* or *Sovietskaya Ukraina*, of which no further details existed. The need to obtain further information on not only mark recoveries but also marks fired under the Soviet scheme was stressed.

In response to a query, Mikhalev responded that he believed marking information might be available for about 1,000 marks fired under the Soviet scheme.

The sub-committee thanked Mikhalev for his efforts, and urged him and his colleagues to continue their invaluable work in retrieving catch and marking data from previous Soviet whaling operations.

Borodin requested that the following statement appear in the report. 'Last few years (IWC, 1997a, p.82, pp.137-8; IWC, 1998a, p.77) the Russian delegation made a statement about the necessity for independent experts with primary information of whaling (vessel logbooks, scientific reports, etc.) to present these materials on national level so that they may undergo an expert review. This has not been done. This year we repeat again our statement and the need [for] this statement to be included in reports'.

Recent information concerning humpback whales off Oman, and whether this population has any connection to the Southern Hemisphere, was provided by Baldwin (SC/50/CAWS21). In November 1997, 43 sightings of 72 humpback whales had been made in 22 days during an offshore seismic survey. Data on the general distribution and abundance of humpback whales in the region supported the notion that these whales were resident year-round in the northwest Indian Ocean, although their abundance off the coast of Oman seemed to decline in summer. The recent status of the species in the area, following the Soviet catching in 1966, was in doubt.

In discussion it was pointed out that the Soviet catching, although of brief duration, had been extremely intensive, with 25 catchers sweeping the area. Accordingly, although the opportunistic surveys reported by Baldwin were of longer duration than the few days spent off Oman by the Soviets, the recent effort was likely to have been considerably lower than during the whaling operations. Thus, the lower sighting rates reported by Baldwin may not necessarily indicate that the stock remains depleted.

The sub-committee recommended that dedicated surveys should be carried out to establish the status of humpback whales in the northwest Indian Ocean, and that these should include the collection of biopsy material from which the genetic relationships of this interesting stock could be investigated (particularly since genetic material was now available from Madagascar to the south).

6.3.3 Further information on catches

Pinedo introduced SC/50/CAWS30, which had been prepared in response to a request from last year's sub-committee on Southern Hemisphere humpback whales. She had contacted a number of major libraries in Brazil for information on local whaling in colonial times, but no information had been found. As a consequence she had relied heavily on published material, particularly two books and a document reproduction (Ellis, 1958; Ellis, 1969; Ellis, 1972), and had also personally contacted the author of these. Whaling had started in 1602 and until 1801 continued under a Portuguese monopoly. Although colonial whaling had declined in the 19th century, takes continued up to the end of the 19th and into the beginning of the 20th century. Catches were seasonal, occurring in winter and spring, and were most probably confined to within approximately 6.6 km of the coast. Cow-calf pairs seemed to be targeted. The species involved were usually not stated, but descriptions and circumstantial evidence suggest that the catch was mainly composed of right whales. A complete series of catch statistics does not exist but Ellis (1969) lists at least 2,664 whales taken between 1761 and 1819. This figure contrasts markedly with that given by Richards (1993) of 14,904 right whales killed by shore stations from 1772 to 1814, a discrepancy which was probably due to an under-representation of shore stations in Ellis (1969). Only three humpback whales are known to have been taken, in 1801. Modern whaling in Brazil started in 1910 and continued (intermittently) until 1974. Although catch statistics are not always complete, and sometimes contradictory if more than one source exists, it is estimated that at least 1,334 humpback whales were taken in the Brazilian fishery between 1910 and 1963.

The sub-committee thanked Pinedo for her work. In discussion, the existence of a Brazilian open-boat fishery taking humpback whales contemporary to the onset of modern whaling in Brazil was mentioned, and a query raised whether these catches had been included in SC/50/CAWS30. Pinedo replied that records of these catches were not found in the archives of government departments in Brazil, but further investigations could be made, once the reference of the original source of the information relative to that operation (mentioned in Tonnessen and Johnsen, 1982) became available.

6.3.4 Other

Two papers submitted to the sub-committee concerned the effects of noise on humpback whales (McCauley *et al.*, 1998a; 1998b). Due to time constraints, these were not discussed, but the topic was considered to be important and might perhaps be more appropriately discussed by the Environment sub-committee in future.

6.4 Future special meeting

Before a special meeting to conduct a Comprehensive Assessment of Southern Hemisphere humpback whales could be planned, action was needed on a number of outstanding items.

The sub-committee noted progress in a number of areas, as reported above. While work is still required to complete many of those tasks, little or no action has yet been possible, given the short interval between the annual meetings and for other reasons, on a number of other tasks recommended last year. The latter are listed below, with reference to last year's report in brackets.

(i) *Acquisition and entry of revised Soviet catch data* (item 9.1.1) - Secretariat - no new data have been acquired.
(ii) *Investigation of the availability of original Soviet scheme marking data* (item 9.1.1) - Secretariat - ongoing.
(iii) Creation and maintenance of a centralised directory of Southern Hemisphere humpback whale photo-identification catalogues (item 9.1.3.1) - Secretariat - action required.
(iv) *Collection of biopsy samples from three main strata: breeding ground, feeding ground, migratory corridor* (item 9.2.1) - national groups - some action, see Item 6.3.2.
(v) *Monitoring of abundance to continue or be initiated where no survey programme exists* (item 9.2.3) - national groups - no new survey data have been reported this year.
(vi) *Inclusion of humpback whales as targets for biopsy and photo-identification in future Antarctic survey expeditions in the South Georgia region* (item 9.2.3.2) - national groups - no action reported.
(vii) *Researchers in photo-identification programmes to evaluate the likelihood of obtaining estimates of biological parameters* (item 9.3.3) - national groups/individual scientists - no action reported.
(viii) *Comparison of currently observed increase rates to be considered in conjunction with a review of demographic parameters for Southern Hemisphere humpbacks and a comparison with information on increase rates and demographic parameters for North Atlantic and (North Pacific) populations* (item 9.3.3) – Scientific Committee - no action.
(ix) *Progress report on retrieval of detailed Soviet catch data* (item 9.4) - relevant scientists - no action reported.

The sub-committee decided to set up an intersessional working group under Clapham to consider Item (viii). They would report back to the sub-committee at next year's meeting.

As regards Item (vii), the sub-committee felt that the most appropriate approach would be to encourage individual members to consult with researchers concerned with photo-identification on humpback whales in their region for this information.

In light of these outstanding matters requiring action the sub-committee agreed that it would be in a better position at the next meeting to decide when an assessment might occur.

7. NORTH ATLANTIC HUMPBACK WHALES

7.1 Report on progress towards assessment

Smith presented an update on the status of information on the North Atlantic humpback whale (Appendix 6). Considerable progress had been made, including papers published, in press or in preparation on abundance, trends, population structure, migration and breeding grounds, and catch data. The most important papers from the YONAH project are expected to be available by the end of 1998. Many other analyses are substantially developed, but the likely time frame of their availability is unclear; these include some critical areas such as analyses of trends in abundance and clarification of population structure, especially as it refers to specific breeding grounds. Thus, while it might be possible to undertake the Comprehensive Assessment in 1999, there was likely to be a substantial amount of information that would still be unavailable at that time. It was therefore suggested that the assessment should be carried out in the year 2000.

In discussion, Smith stressed that while every effort would be made to construct as comprehensive a catch history for the North Atlantic as possible, it was likely that the total catch will never be known completely, and this would constrain what could or could not be done in the Comprehensive Assessment.

Apart from an incomplete catch history, two main gaps for the assessment were identified. These concerned a lack of information on the distribution and abundance of humpback whales in the waters of the southeast Caribbean (Windward Islands) and off the Cape Verde Islands, and their relationship to humpback whales in the rest of the North Atlantic. In regards to the former, Carlson presented a summary of the individual identification photographs available for humpback whales from the eastern Caribbean (SC/50/CAWS28). There were only nine photographs of humpback whales from the eastern Caribbean amongst the 5,000 odd in the North Atlantic humpback whale catalogue. Two of the nine had been matched, one with Puerto Rico and the other with Newfoundland, while there was a third possible resighting in Greenland. This sample is too small and spatially and temporally diffuse to draw any meaningful conclusions, and further photographs, biopsy samples and song recordings were required to address this question.

Clapham presented a summary of information on the status and stock origin of humpback whales in the Windward Islands (SC/50/CAWS11). Although the general pattern of a maternally-directed fidelity to high-latitude feeding grounds in summer, and a general mixing on the breeding grounds in the waters in the northern part of the Antillean chain in winter, had been established for the North Atlantic, relatively little effort had been directed on studying humpback whales further south. Densities in the region appeared to be low, despite this being a principal whaling ground in the 19th century. This was also the area in which the subsistence hunt at Bequia was operating. The apparent failure of humpback whales to recover in this region raises the questions (a) from which feeding grounds in the North Atlantic do these whales originate, and (b) are they genetically distinct from the humpback whales that use the breeding range to the north? The paper proposed: (1) a study of logbooks from 19th century whaling ships visiting the Windward Islands to determine the historical distribution of the species, and to assist in survey design for the current population; (2) vessel surveys using visual and acoustic techniques to provide a clearer picture of current distribution and abundance; and (3) individual identification of whales using genetic or photographic techniques to investigate stock linkages and migratory behaviour.

In discussion of the paper, Hester and Swartz commented that such a programme would have a greater chance of success if it was carried out in cooperation with regional governments.

The possible use of acoustic methods in facilitating censuses was discussed. Clark reported that acoustic data originating from the SOSUS fixed hydrophone arrays since 1993 had shown that detection rates for singing humpback whales in the southeast Caribbean in winter were about one-third to one-half of those in the high density areas. These rates corresponded to the numbers of individual singers tracked per day, and it was not clear how this related to the total numbers of humpback whales in the area. Clark also described recent fieldwork in Hawaii combining visual and acoustic methods, in which it had been possible to locate individual singers acoustically out to 5-6 n.miles, and then to direct a boat with a GPS on to the whale so that it could be photographed and biopsied on surfacing. Such a technique might be especially useful in low density areas such as the southeast Caribbean.

In regards to the situation of the Cape Verde wintering ground, or the eastern North Atlantic stock, Clark summarised acoustic information suggesting the presence of an eastern component. SOSUS data collected since 1996 had shown that singing humpback whales could be heard in the Norwegian Sea in winter, while others proceeded south past Ireland towards Spain. The number of animals involved was small, in the tens per day. This pattern had persisted for two years. The sub-committee noted that this remnant stock or population remained uncharacterised by photo-identification or genetic information.

The sub-committee recommended that the possibility of collaborative research on humpback whales in the southeast Caribbean be explored with national authorities in the area and the use of combined acoustic and visual methods be investigated to facilitate the collection of abundance and individual identification data.

Smith announced that the possibility of further research on humpback whales in the northeastern Atlantic was being considered, including a logbook survey in the Cape Verde Islands and an integration of all published information on humpback whales in the northeast Atlantic as a whole.

7.2 Action arising

Given the progress noted above, and the likely time frame for the availability of other analyses, the sub-committee recommended that a Comprehensive Assessment of North Atlantic humpback whales be carried out by the Scientific Committee in the year 2000.

It was pointed out that this population was subject to a small aboriginal take at Bequia in the West Indies (and had in the recent past been subject to an aboriginal hunt in Greenland). There was justification therefore in giving the Comprehensive Assessment of this stock some priority over other humpback whale stocks.

8. NORTH PACIFIC HUMPBACK WHALES

SC/50/CAWS31 provided a summary of the status of the North Pacific Humpback Whale Fluke Catalogue maintained by the National Marine Mammal Laboratory, Seattle USA. To date, over 24,000 photographs of humpback whale tails from all regions in the North Pacific from at least 16 different research groups have been accessioned into the catalogue. Based on recent efforts by all of the cooperating research groups to match photographs previously submitted to the catalogue with recently submitted photographs, 1,010 resights of individual whales from at least a five year period were reported. Further, 116 and 5 resights of individual whales were reported from periods spanning 15 and 20 years, respectively. In addition, the catalogue is currently being used to ascertain the extent to which calf mortality and the average reproductive interval can be estimated from the catalogue. For example, following the completion of a two-part workshop on estimating calf mortality in North Pacific humpback whales, analysis of data on 58 adult female whales with calves sighted in Hawaii that were subsequently sighted in Alaska in the same year was begun. Information on the fraction of these 58 females seen with calves following the breeding season in waters off Alaska will be used to estimate rates of calf mortality.

DeMaster reported that a paper recently completed by Calambokidis *et al.* (1997) provided abundance estimates for North Pacific humpback whales from the years 1991-1993. The estimates were based on mark-resight methodology. Estimates of basin-wide abundance and abundance for three stocks of North Pacific humpback whales were reported. Recognising some of the caveats identified by the authors in undertaking this analysis, the estimated number of humpback whales in the North Pacific between 1991 and 1993 was approximately 6,000.

The sub-committee welcomed these results, and encouraged the authors to submit papers or reports on their work.

9. SPERM WHALES

9.1 Report of the intersessional group

Brownell introduced the report of the intersessional sperm whale group that had been set up at last year's Scientific Committee meeting to review plans for a Comprehensive Assessment of sperm whales (Appendix 7). The group had agreed to recommend that the Comprehensive Assessment start with a focus on North Pacific sperm whales. The following studies were proposed:

(i) a review of mark-recapture data and joint US-Japanese genetic studies;
(ii) a preliminary abundance estimate for the western North Pacific, based on sightings;
(iii) a review of past abundance estimates and models;
(iv) a review of historical catch data;
(v) a review of sperm whale regulation in the North Pacific;
(vi) life history, social behaviour, ecosystem considerations and current anthropogenic mortality.

Brownell stated that the sub-committee might only be able to make progress initially with abundance estimation.

9.2 Action arising

The sub-committee briefly discussed the possibility of undertaking a Comprehensive Assessment of North Pacific sperm whales, as suggested in Appendix 7. It was agreed that before making any decision on this matter, the historical catch series needed to be reviewed, to see what problems existed and how they might be overcome. The matter was considered further under Item 9.5.

9.3 Abundance and trends

Nishiwaki introduced SC/50/CAWS9, in which estimates of current abundance and distribution of large male sperm whales in Antarctic Areas IV and V had been calculated using sightings data originating from JARPA surveys from 1989/90 to 1995/96. These covered the area from 60°S to the ice edge and from 70°E to 170°W. Sperm whales were widely distributed in Areas IV and V in each year. There was a high density area from 70°E to 100°E, and they were rarely found within Prydz Bay and the Ross Sea, there being no sighting south of 73°S in the Ross Sea. Abundance estimates for sperm whales in Area IV ranged from 2,946 to 4,289, and for Area V from 2,207 to 3,146 animals. These results are consistent with those from the second and third IDCR/SOWER Antarctic circumpolar surveys. However the possible effect of under-surveying of high-density areas, as noted for JARPA estimates of minke whales, was not considered in this paper. Estimates of abundance when corrected for animals missed on the trackline became 9,206–13,403 for Area IV and 6,897–9,838 in Area V: estimated biomass values (uncorrected for fluid loss during dissection) were 254,000–367,000 tonnes in Area IV and 189,000–270,000 tonnes in Area V.

In discussion it was noted that the corrected estimates used a $g(0)$ value of 0.32 obtained from simulation studies by Kasamatsu and Joyce (1995).

Butterworth introduced the results of analyses of sperm whale sightings from IDCR/SOWER cruises to the Antarctic between 1978/79 and 1995/96 (SC/50/CAWS37). These gave estimates of 5,461 (CV 0.44), 11,369 (CV 0.18) and 7,867 (CV 0.19) for the first, second and third (incomplete) circumpolar sets of surveys. It was noted that the estimated value for $f(0)$ (the inverse of the *eshw*) was very different for the first set of surveys (1.985 n.mile^{-1}) than for the latter two (0.989 and 0.825 n.mile^{-1} respectively). The reasons for this difference were unknown. In Appendix 5, he had updated these estimates to take into account the different area coverage between circumpolar sets, producing corrected values of 7,900, 13,000 and 14,300 whales respectively. These estimates only referred to the large male component of the population, and also assumed that $g(0)$ was 1; to this extent therefore they might be considered negatively biased. The apparent increasing trend was noted, but caution was expressed over its interpretation.

In relation to the above two papers, the sub-committee concluded that although it was highly unlikely that $g(0)$ for sperm whales was 1.0, it was not appropriate at this stage to adopt a lower value until the assumptions behind its calculation had been thoroughly examined. It was also probably not advisable to apply a $g(0)$ estimate from one geographical region to the species as a whole. These papers had illustrated two general problems with sightings surveys of sperm whales: the lack of a generally agreed estimate for $g(0)$ in this case, and the segregation by sex and size class of the species. Kato also expressed his concern over the estimation of mean school size in sperm whales, especially where there was a loose association of individuals/pods.

Paper SC/50/CAWS2 had been prepared in response to a request of the intersessional sperm whale group (Appendix 7), and analysed sightings data obtained from Japanese whale sighting vessels in the North Pacific between 1982 and

1996. In 341,199 n.miles of searching, a total of 1,412 sightings of 5,310 sperm whales had been made. Although surveys had taken place in 11 months of the year, effort had been concentrated in August and September, and most consistently allocated in the western half of the North Pacific. If analysis was confined to the area 20°-50° N, 130° E-180°, and data for 1994 and 1996 excluded because of low effort, a significant rate of increase (11% a year) was obtained. A line transect estimate for the western North Pacific (0°-50° N, 130°E–180°), uncorrected for $g(0)$ or loose associations of single animals, was 25,816 (CV 0.11). A correction for association increased the estimate to 32,676, and a correction for the value for $g(0)$ of 0.32 of Kasamatsu and Joyce (1995) increased it still further to 102,112 (CV 0.155).

In discussion, the opinion was expressed that if the data were sufficient, a more appropriate estimate of abundance for such a large region would be obtained by stratifying by area.

Brownell presented SC/50/CAWS20, in which a combined visual and acoustic survey for sperm whales was conducted in the eastern temperate North Pacific between March and June 1997. Sperm whales were detected acoustically using a towed hydrophone array, and 60 acoustic detections were made in 14,500km of searching. Mean group size was estimated by visual observation of 20 of the acoustically detected groups, which were found by directing the ship to the location from which the sounds came. Visual survey was carried out for 8,080 km, resulting in eight sightings (excluding acoustic detections that were seen visually later). The estimate of $f(0)$ used in the visually-based estimate of abundance was based on 281 sightings of sperm whales from previous surveys in the eastern Pacific. Because of the small number of sightings it had not been possible to integrate the visual and acoustic data to estimate detection probabilities. The acoustically based estimate of 39,200 (CV 0.60) sperm whales was not significantly different from the visual estimate of 24,000 (CV 0.46) whales. Acoustic techniques substantially increased the number of sperm whales detected on the survey by increasing the range of detection and allowing night-time survey. However the acoustic surveys could not replace visual methods for estimating group size.

Following this paper, questions were raised about how to estimate school sizes acoustically. Leaper referred to a paper by Gillespie (1997) which described a computer program for separating vocalisations from individual sperm whales which allows the number of vocalising whales to be counted. Alternative methods using estimated click rates per individual have also been used. Zeh commented from her experience of bowhead whale acoustic censuses that she was not optimistic that tracking individuals would be a feasible method of estimating group size, except perhaps for small schools. Zeh also noted that in the survey described in SC/50/CAWS20, schools detected acoustically were closed with for visual confirmation of group size. This could introduce a bias if, for instance, larger schools could be detected at greater distances, due to a more favourable signal/noise ratio. There may also be problems obtaining detection probabilities by integrating visual and acoustic cues, as the probability of seeing a whale at the surface may be negatively correlated with the probability of hearing it underwater. This can lead to overestimation of abundance because detection probabilities are underestimated.

Nevertheless the sub-committee recognised the potential value of acoustic techniques in estimating sperm whale abundance, and recommended that researchers active in the field cooperate and integrate their results to the greatest extent possible, and encouraged the submission of further papers on the topic to further Scientific Committee meetings.

Slooten introduced several documents concerning recent research on abundance estimation of sperm whales at the University of Otago, New Zealand (SC/50/CAWS39; Childerhouse and Dawson, 1998; Childerhouse *et al.*, 1998). Research on sperm whales at Kaikoura (42°S) has used mark-recapture and acoustic surveys to study distribution and abundance. Mark-recapture estimates are based on photographic identification data (Childerhouse *et al.*, 1995). Almost all sperm whales encountered at Kaikoura are single males, and all can be photographically identified. Photographs are graded on both photographic quality and distinctiveness. The stability of ID markings has been checked by treating tail flukes as if they are double tagged and looking at each side of each fluke independently (Childerhouse *et al.*, 1996). Photo-identification data have also been used to study seasonal changes in distribution and abundance. Of 135 identified individuals, about half (63) are seen repeatedly, during summer and winter (for up to 10 seasons). The other half (72 individuals) apparently transited through the area and have only been seen in one season. Mark-recapture models will be developed to take account of this population structure. There were significant differences in distribution, abundance and diving behaviour between summer and winter (SC/50/CAWS38; SC/50/CAWS39), which are apparently related to prey distribution (SC/50/CAWS38). Work is in progress to look at finer-scale changes in distribution and abundance by season, and correlations with environmental variables.

Acoustic surveys off Kaikoura have used directional and omnidirectional hydrophones. This work can be used to complement, or as an alternative to, the towed hydrophone array methods described in SC/50/CAWS20. Directional hydrophones are used from small vessels, including a 7m hard-hulled inflatable. This makes it possible to: (a) carry out small-scale work on distribution, abundance, movements and acoustic behaviour; (b) track individuals in order to study diving behaviour and acoustic behaviour; and (c) calibrate visual and acoustic surveys, and measure group size acoustically. A computer program has been developed to count the number of clicks in a sperm whale recording. Work is continuing to calibrate and ground-truth acoustic surveys by recording individual whales for complete dive cycles, estimating the click rate per individual, and estimating the range of the directional and omnidirectional hydrophones. Stereophotography (Dawson *et al.*, 1995) can be used to answer questions about movements and population structure. For example, in Kaikoura some of the largest individuals are resident in the area and there is no sign that they leave at the onset of the breeding season (SC/50/CAWS39).

On the subject of photo-identification, the sub-committee stressed the importance of evaluating photographs separately for quality and distinctiveness. Quantitative evaluation of these criteria was needed; different matchers should be compared in their scores, for instance, and possible changes in these criteria with time investigated. It was suggested that a compilation of photo-identification efforts on sperm whales (as done for humpback whales, for instance) should be considered, and this was referred to the intersessional group planning the sperm whale stock assessment.

It was agreed that a major topic of the Comprehensive Assessment should be a discussion of the best method of assessing sperm whale abundance.

9.4 Stock structure

Brownell spoke on a progress report on genetic data for North Pacific sperm whales (SC/50/CAWS19). The mtDNA control region and six microsatellites were being investigated in historical samples from the Japanese whaling industry and in contemporary samples from biopsies, strandings, etc. Analyses at the Southwest Fisheries Centre in the USA are concentrating on the eastern North Pacific - preliminary results indicate a striking subdivision between samples taken within about 300km of the coast and those offshore as far east as Hawaii. However this result had to be interpreted with caution because the offshore samples were collected 20 years earlier than the coastal samples, and nuclear gene frequencies may change quite rapidly because of sperm whale social structure and the likely effects of relative male depletion. Recommendations were that: (a) an empirical investigation of shifts in gene frequency through time should be made using historical samples from the Japanese whaling industry; (b) samples from whole groups of sperm whales should be investigated for social structure; and (c) future sampling should concentrate on taking fewer samples from more schools, rather than multiple sampling of a few schools.

As regards (b), Kato reported that the only samples remaining from Japanese Special Permit catches of whole schools might be teeth and he enquired whether these could be used for genetic analysis. Baker replied that teeth were good candidates for genetic work, even after moderate heating that might have been necessary for cleaning. It was important to be sure, however, that one was dealing with unique individuals. The sub-committee recommended that the use of sperm whale teeth for genetic analysis be examined further, and that the collection of material from mass strandings of sperm whales should be strongly encouraged.

9.5 Catches

The sub-committee welcomed document SC/50/CAWS24 on density-dependent habitat selection and the modelling of sperm whale exploitation. It was appreciated that this was an important paper, especially its conclusion that the movement of sperm whales in response to greater resource availability may make CPUE a very poor measure of local depletion, and the inferences for estimating the size of stocks from sightings surveys. However due to a lack of time the sub-committee did not discuss its contents in detail.

Mikhalev (SC/50/CAWS40) described Soviet catching of sperm whales in the Arabian Sea and biological information from the catch. Two Soviet expeditions took a total of 954 sperm whales including 750 females over four seasons (1963-66), but only reported a catch of 424 whales including 75 females to the Bureau of International Whaling Statistics. The distribution of catches was very similar to that for 19th century whaling. The author concluded that evidence (high incidence of ambergris, absence of oval scarring) indicated that this was a discrete population separated from the rest of the Indian Ocean.

In response to queries regarding his conclusion that sperm whales have a gestation period of less than one year, Mikhalev replied that he believed the simultaneous presence of groups of large and small foetuses in the data pointed to a supplementary period of conceptions. In response to other queries he responded that although extensive marking of sperm whales had occurred in the area, there had been no recoveries in the data he had available. Little biological material, apart from a few small foetuses, remained from these catches.

Yagi questioned the accuracy of the data presented, asking whether it had been peer-reviewed or made available to other scientists. Mikhalev responded that the information on past USSR catches had been collated by Zemsky, Berzin, Tormosov and himself, each of whom (from different laboratories) had sailed with one or other of the four Soviet fleets that had operated in the Southern Hemisphere, and must be considered the foremost experts in the field. He in fact had personally witnessed the sperm whaling in the Arabian Sea.

Brownell introduced a summary of information on USSR pelagic catches of sperm whales in the North Pacific between 1949 and 1979 (SC/50/CAWS27). Yearly fleet summaries for some seasons were provided by the late Dr A.A. Berzin to the authors, relating to the *Vladivostok* fleet during the period 1963-1978 and the *Danij Vostok* fleet during the period 1963-1979. A comparison with official catch statistics submitted to BIWS by the Soviet authorities revealed serious inconsistencies. The total USSR catches for six years (1966, 1967, 1970, 1971, 1972 and 1973), for instance, was officially declared as 37,275 whales, whereas the Berzin data indicated that 66,950 sperm whales were actually caught (or 1.8 times the official catch). Furthermore, the Berzin data revealed that in the years 1966, 1967, 1970 and 1971, the true catch of males was 1.3 times, but the female catch 9.6 times, greater than the official records for these two expeditions. The authors believed that similar under-reporting of sperm whale catches occurred on other Soviet whaling expeditions in the North Pacific, at least until 1972, when the International Observer Scheme (IOS) came into effect. They estimated that about 180,000 sperm whales may have been taken by Soviet whaling expeditions between 1949 and 1979, or about 60% higher than the officially reported catch.

In discussion, Brownell cautioned against assuming that the IOS was completely effective in stopping under-reporting of sperm whale catches in the North Pacific, as experience from one Soviet factory ship in the Southern Hemisphere was that some under-reporting continued after the IOS was introduced. In response to queries he stated that there was no information on the locations of the undeclared catches, and he did not know if any biological data were available for these whales.

Kasuya then introduced SC/50/CAWS10, in which he stated there was some evidence of statistical manipulation in the Japanese coastal sperm whale fishery. Official length composition data frequently featured an unrealistically large number of individuals at or just above the minimum length, compared to the number just below that length. The sex ratio in samples of whales examined by biologists (and an International Observer) differed greatly from that in the official statistics, with females being markedly under-represented in official statistics compared to the samples examined in ten seasons between 1959 and 1985. A catcher-boat log from 1959-61, when a Japanese domestic quota for sperm whales had just been introduced, differed from official figures for the numbers of whales killed by the company concerned; towards the end of each season, the number of sperm whale kills listed in the log exceeded the total declared for that month by the company concerned. The author concluded that the extent of such discrepancies was unknown, and was likely to differ greatly with month, year and company concerned, but was probably sufficient to render the catch statistics from coastal sperm whaling unreliable for the purposes of the Comprehensive Assessment. He stressed the need for further effort to discover independent sources of statistical information.

Okamoto and Moronuki stated that it was the policy of the Japanese Government to provide the most accurate statistics possible to the IWC, and that they were not convinced that the information provided in SC/50/CAWS10 was any more reliable, given that it referred to some 40 years ago, nor that it was necessarily representative of the whole time series of catches. At this stage they considered that it was essential that these allegations should be thoroughly investigated before any conclusions were drawn as to the reliability of the data. Ohsumi pointed out that some features of the official statistics were similar to those seen in statistics of other nations taking sperm whales, and that for the purposes of the Comprehensive Assessment it was necessary to recognise when such data were inaccurate and to make appropriate adjustments.

A number of speakers agreed with the latter sentiment, and in particular that if there was to be progress with the Comprehensive Assessment of this stock then efforts should be directed at attempting to compile as accurate a catch series as possible. If exact figures could not be found, then realistic upper bounds should be sought to express the range of uncertainty. Brownell noted that the problem of sperm whale catches being recorded as Baird's beaked whales in the small-type whaling operations in Japanese waters was discussed in the Scientific Committee as early as 1976 (Balcomb and Goebel, 1977), and more recently by Kasuya *et al.* (1997). However no action had been taken to correct these statistics. A small group under Ohsumi was therefore set up to work intersessionally on developing a catch series that could be used in the Comprehensive Assessment. The exact terms of reference of the group would be developed in consultations between Ohsumi and Brownell.

Ohsumi then presented his review of the history of Japanese regulatory measures for sperm whaling in the North Pacific (SC/50/CAWS12). This had been prepared in response to a request from the intersessional group on the Comprehensive Assessment of sperm whales under Brownell. Regulatory measures were introduced as early as 1909, and included in turn, limitations on effort, catch (by whaling classification), minimum (and later maximum) size, catch of lactating females, season, and whaling ground.

The sub-committee welcomed this paper, and suggested that similar compilations of national regulations and restrictions (including enforcement) should be prepared as part of future Comprehensive Assessments.

9.6 Other

The presence of sperm whales off the coast of Oman was confirmed by six sightings between 1994 and 1997, including single animals and groups of up to 24-50 animals (SC/50/CAWS22). Three of these sightings occurred in the Gulf of Oman and three in the Arabian Sea. A further sighting of 4-6 sperm whales, including a large male, was made off the United Arab Emirates in July 1995.

Interactions between sperm whales and trawlers were recorded in the northwest Atlantic, with sighting rates being about 30 times greater when the net was being hauled than at other times (SC/50/O16). It appeared likely that the whales were all males and feeding on fish escaping from the net.

10. SOUTHERN HEMISPHERE MINKE WHALES

Fujise described progress on work to address outstanding issues regarding JARPA that had been raised at last year's meeting (Appendix 8). This included developing methods to correct bias in abundance estimates, stock definition, statistical analysis of mtDNA, a pilot study on nuclear DNA, availability of low-latitude genetic material, analysis of morphometrics, examination of stock boundaries between Areas IV and V, a segregation study, recalculations of biological parameters by biological stock, a mesoscale survey plan for ecosystem and environmental change. In addition, the Scientific Committee had discussed the availability of samples from past commercial whaling for stock identification analysis and the problem of representativeness of samples. Results of some of this work are discussed below.

Although the interval since the last meeting had been unusually short, the sub-committee felt it was helpful to receive this progress report, and looked forward to more detailed responses at the next Scientific Committee meeting.

10.1 1997/98 Antarctic cruise results

Ensor introduced SC/50/Rep1, the cruise report of the 1997/98 SOWER Antarctic cruise. The Japanese Government had supplied two research vessels, the *Shonan Maru* and the *Shonan Maru No. 2*, and for the first time four researchers were carried on each vessel. The target area to be surveyed was Area IIW (between longitudes 60° and 30°W) and south of 60°S. This was the third survey of Area II, the previous cruises being in 1981/82 and 1986/87. The ships left Punta Arenas on 14 January and arrived at Cape Town on 26 February 1998. Two days were reserved for blue whale research. A total of 3,008 n.miles was surveyed on effort in the research area, and 200 sightings of 422 minke whales were made. Survey coverage was affected by the ice edge, which reached the normal northern boundary of the research area in places, forcing the northern boundary to be moved to 58°S. Sufficient progress was made to enable extension of the coverage westwards to 25°W. Experiments conducted included estimated distance and angle, and biopsies were taken from 6 blue, 10 humpback, 5 southern right, 3 sei, 3 killer whales and 3 short-beaked common dolphins. South of the main ice edge, satellite imagery indicated a large (approximately 100,000 n.mile^2) area of open water in the southern Weddell Sea which the survey vessels could not enter because of an ice barrier. This might have accounted for the number of minke whales seen being less than expected, as they were presumably able to pass under the ice and into this ice-free area.

Kato expressed his thanks to Ensor and his colleagues for their leadership and hard work under difficult conditions. He pointed out that the survey had also encountered a large number of fin whales (39 sightings of 204 animals), but relatively low minke whale sighting rates. He asked whether this could be correlated with the unusual ice conditions. Ensor replied that the fin whales were mainly observed north of the usual survey area, in relatively warm water; therefore the detection of fin whales appeared not to be influenced by the unusual ice conditions. However, the lower minke sighting rate might have been due to minkes being in the large open water area that could not be surveyed.

The sub-committee expressed its thanks to the Japanese Government for the generous provision of these vessels, and to Ensor and the other researchers for their efforts.

Nishiwaki reported on the results of the 1997/98 JARPA survey (SC/50/CAWS8). This had been conducted in Area IV and the eastern part of Area III from 17 December 1997 to 14 March 1998. One dedicated sighting vessel and three sighting/sampling vessels were engaged in a sightings survey in closing mode. The sighting vessel covered 5,136 n.miles and made 127 primary sightings of 243 minke whales, while the three sighting/sampling vessels searched a total of 16,462 n.miles and made 545 primary sightings of 1,130 minke whales. A total of 526 minke whales was targeted for sampling, of which 438 were caught (110 from Area III and 328 from Area IV). The proportion of sexually mature animals was very low amongst the females (22.7%) in Area IV, and immature females dominated in the southern stratum. It was suspected that most of the mature females had moved into ice-free waters inside the pack-ice edge where the research vessel could not enter. It was suggested that one of the probable reasons for the character of the present survey results was the different shape of the ice edge.

In discussion, the question of the implications of the apparent environmental effect on the observed maturity rate in females was raised, particularly as it related to the success of the JARPA programme in obtaining representative samples. Nishiwaki replied that it was not known whether the trend would continue, and further study was needed to compare the data with previous results.

10.2 Subspecies and stocks

Field characters for distinguishing between the two forms of southern minke whale were described and illustrated in SC/50/CAWS15. This was important if abundance estimates from sightings surveys were to be correctly allocated.

The results of RFLP analysis of the mitochondrial DNA (mtDNA) in minke whales from Areas V and VI sampled during the JARPA survey of the 1996/97 austral summer season were presented in SC/50/CAWS4. Samples were divided into three longitudinal sectors: Area V Western (130°E-160°E), Area V Eastern (160°E-170°W) and Area VI Western (170°W-140°W) and two time periods, early and late in the survey season. A total of 361 whales was examined (VW-late $n=98$; VE-early $n=$ 67; VE-late $n=105$; VIW-early $n=91$). For comparison the group VIW-early of the 1985/86 commercial season was used ($n=134$). Quantification of the mtDNA differentiation among area/time groups was carried out using the Analysis of Molecular Variance (AMOVA). No significant differences were found among the area/time groups of the 1996/97 survey. The combined sample of the 1996/97 survey showed significant differences with a standard sample of the 'western stock' but not with a sample of the 'core stock'. The same results were found when each of the area/time groups of the 1996/97 survey and the group VIW early 1985/86 were compared with the standard samples. A comparison among survey seasons for different area/time groups suggested that yearly variation seems to occur in Area IIIE and Area IVW.

The sub-committee noted that this study confirmed that the 'western' stock was different from the others studied, which were all similar.

A preliminary examination of mitochondrial DNA heterogeneity in Antarctic minke whales considering temporal, longitudinal and latitudinal (distance from the ice-edge) factors was presented in SC/50/CAWS7. A total of 563 samples from Area IV taken during the 1989/90 and 1991/92 JARPA surveys was used in this exercise. AMOVA was used to test for: (a) the latitudinal factor in total Area IV (dividing offshore and ice-edge samples by a line at 60 miles from the ice edge); (b) the longitudinal (Area IV western and eastern) and latitudinal factors; and (c) the latitudinal, longitudinal and temporal factors (early and late period in the survey season). The only source of mtDNA heterogeneity was attributed to minke whales from the western part of Area IV taken in offshore areas in the early period of the survey season.

The sub-committee noted that this study concluded that the differences in the 'western' stock were attributable to an early, offshore component, and that because the commercial catch had been mainly near the ice edge, the analysis of past commercial catches would not be particularly useful for stock identification.

10.3 Abundance and trends

Polacheck presented SC/50/CAWS32, which examined VPA analyses of Southern Hemisphere minke whales in Areas IV and V by Butterworth *et al.* (1997; 1999). Butterworth *et al.* (1999) had concluded from their analyses that there was an increasing trend in recruitment in this stock prior to the period of exploitation. SC/50/CAWS32 investigated the effect of changing two key assumptions in the VPA formulation of Butterworth *et al.* (1999), the assumptions with respect to selectivity and separability among the older age classes during the period of the commercial catches. This investigation was carried out by replacing these assumptions with the assumption that there was no temporal trend in recruitment prior to exploitation and examining whether the data on current abundance could be fit under this assumption and whether the resulting apparent selectivities for the commercial catches were plausible. If the assumption of no temporal trend proved to be inconsistent with current abundance data or if it led to implausible selectivity curves, this would support the conclusions of Butterworth *et al.* (1999).

SC/50/CAWS32 concluded that constant pre-exploitation recruitment was consistent with the basic input data and population dynamics model of Butterworth *et al.* (1999). A lack of pre-exploitation recruitment trend implied a dome-shaped selectivity curve for the commercial catches with a decrease after age 17-26. The results of Butterworth *et al.* (1999) also implied a dome shape and a decrease in catch at older ages. However, the peak in the selectivity curves in Butterworth *et al.* (1999) occurred at somewhat older ages (23-29). SC/50/CAWS32 discussed factors affecting realized selectivities that could have led to the estimated selectivity curves. These included the possibility that older animals found refuge in portions of Areas IV and V where there was little whaling effort or in the pack ice where whalers could not follow.

SC/50/CAWS32 concluded that the VPA modelling framework, by itself and given the available data, appeared unable to resolve the issue of the pre-exploitation trends in recruitment. It concluded that the estimates were critically dependent upon assumptions either about trends in past recruitment or selectivities and separability in the commercial catch. Within the VPA context, it was concluded that a resolution would require convincing external evidence favouring a specific selectivity pattern. Polacheck suggested that a way forward would be a more detailed examination of the spatial/temporal pattern of the age compositional data from the catches than had yet been carried out and more complete tests of sensitivity to assumptions than were reported in Butterworth *et al.* (1999).

Butterworth responded that the selectivity assumptions in Butterworth *et al.* (1999) had been motivated on two independent grounds, biological and statistical. On the biological front, increasing selectivity with age was suggested by whalers' desire to take larger, hence older, animals and the fact that whaling took place close to the ice edge where older animals tended to predominate. He drew attention to table 4 of Butterworth *et al.* (1999), which showed an increasing trend in the age of animals caught in Area IV by degree latitude from 61° to 66°S. He noted, in response to suggestions in SC/50/CAWS32 that differential male/female availability might be confounding the results, that Butterworth *et al.* (1999) had shown that key results were essentially unchanged when analyses were conducted on a sex-disaggregated basis. He considered that the possibilities suggested by Polacheck to explain the age-selectivity curves resulting from the assumption of no trend in recruitment prior to exploitation were inadequate to explain the large fraction of otherwise takeable whales implied to be unavailable by these curves.

On the statistical front, Butterworth noted that the conclusions of Butterworth *et al.* (1999) regarding the historic increase in recruitment were unchanged when the slope of the commercial selectivity at age from ages 22 to 30 was treated as an estimable parameter. He agreed with Polacheck that this analysis was conditional on the assumption that the maximum in commercial selectivity with age would occur beyond age 21. He believed that other runs of the model, not reported in Butterworth *et al.* (1999), had led to rejection of alternative assumptions regarding that maximum age on the basis of likelihood ratio tests. However, the relevant outputs would have to be checked, and that was not possible in the time before the sub-committee would conclude its work. Furthermore, the analyses of SC/50/CAWS32 made no allowance for any pattern in selectivity in the commercial catch as is conventional in the application of VPA to fisheries, and hence ignored the information content of these data with respect to the historic recruitment trend.

Hatanaka noted that the low selectivity for older ages in SC/50/CAWS32 is inconsistent with the actual situation. He anticipated that these analyses using age data can elucidate the real trend of recruitment, and emphasised that such valuable data are obtained only by lethal sampling.

Ohsumi noted that the assumption of SC/50/CAWS32 that there was no temporal trend in recruitment prior to exploitation was contradicted not only by the analyses of Butterworth *et al.* (1999) but also by analyses of Kato (1987), Kato and Sakuramoto (1991), Thomson *et al.* (1997) and Butterworth *et al.* (1997) that showed a decline in age at sexual maturity and by anecdotal reports from whalers. Polacheck reiterated that his results do not indicate that there was no trend but rather that the VPA modelling framework without selectivity assumptions similar to those in Butterworth *et al.* (1999) is unable to resolve the question. He noted that if data on encounter rates over time were available, an analysis incorporating these data into the VPA framework might provide evidence for a trend. Polacheck also noted that the same data used in Butterworth *et al.* (1999) to indicate a latitudinal trend in age near the ice edge also showed an equally high mean age between 59° and 61°S as at the ice edge. Polacheck further noted that the role and dependence on the selectivity assumptions in Butterworth *et al.* (1999) were substantially different than in most conventional fisheries applications. This is because of the low cumulative fishing mortality rates and the small amount of external information available for fitting the VPA model in this case.

Smith noted that new information presented under Item 10.1 supported the possibility of animals being south of the pack ice edge. Large areas of open water are noted to have existed during the periods of the SOWER and JARPA surveys, unavailable for sampling. He also noted that the factory vessels apparently tended to be 5-20 n.miles north of the ice edge (de la Mare, 1997). Thus the possibility of age selectivity within 60 n.miles of the ice edge needed to be further explored. This general issue also raises the possibility that JARPA age samples are not representative for older animals, as has previously been shown for younger animals.

The sub-committee agreed that, although some analyses of age and sex distributions of minke whales as a function of latitude (Ohsumi and Masaki, 1975; Kato, 1982; 1983; Kato *et al.*, 1991) had been conducted, the accumulating JARPA data permitted the examination of age and sex gradients approaching the ice edge on a finer scale (e.g. within 60 n.miles) than had been done. Longitudinal effects in these distributions could also be further examined. It was agreed that conducting such analyses should be added to the list of tasks identified for JARPA. These analyses might shed some light on what assumptions regarding selectivity of the commercial catch are most reasonable.

The sub-committee also agreed that additional sensitivity tests which encompassed a wide range of selectivity patterns might help to resolve this issue. Since there was no time to complete and consider these, the sub-committee was unable to reach agreement at this meeting regarding whether or not the selectivity assumptions of Butterworth *et al.* (1999) were supported.

Working papers elaborating on and providing a rationale for the comments summarised above were prepared by Butterworth, Punt and Polacheck. These are included in Appendices 9-11.

In SC/50/CAWS34 minke school density is estimated from the first six IWC/IDCR independent observer (IO) surveys from 1985/86 to 1990/91, using methods which model heterogeneity due to covariates such as school size and sea state in addition to perpendicular distance. Incorporating these covariates reduces bias in estimated density by about 15% compared to the case in which the IO data are analysed using only perpendicular distance. However, comparison with standard line transect results indicates that the estimates of density obtained from the analysis of IO data remain substantially negatively biased even when heterogeneity due to school size and sea state is modelled. The IO analysis methods are vulnerable to bias from heterogeneity in school surfacing patterns if both platforms search the same region of sea simultaneously. Plots of first sighting distances ahead of the vessel of sightings by the two independent platforms show that they do search the same region at the same time, and this is believed to be the primary source of bias in the IO analysis. The authors conclude that if unbiased estimates of density are to be obtained from IWC Antarctic surveys in the future without assuming certain detection on the trackline, it is important to separate the regions that the two independent platforms search. In particular, consideration should be given to using the search procedure suggested by Buckland and Turnock (1992).

In discussion, Butterworth drew attention to the fact that the implications of this paper were that the design of IO experiments on the SOWER cruises needs to be reconsidered. The sub-committee agreed to refer this issue to the proposed SOWER planning meeting in Tokyo, but it was suggested that an immediate and comprehensive change in procedure may be undesirable, in that it could cause problems of comparability with previous estimates. The Buckland-Turnock Method might be used experimentally for part of the IO mode survey.

10.4 Other

SC/50/O3 described several research projects conducted on Antarctic minke whales at the Institute of Cetacean Research (ICR). Age composition and reproductive status of the minke whales sampled are being investigated. Genetic variation at the mitochondrial and nuclear DNA (microsatellites) levels is being examined to investigate stock structure in Areas IV and V. Methods of correction of sampling bias are being explored and a revision of the abundance estimation under JARPA is being carried out. Other research underway included analysis of stomach contents, accumulation of heavy metals and organochlorines as well as several physiological studies.

Seven strandings of minke whales along the São Paulo State coast of Brazil between 1986 and 1987 included at least three of the dwarf form and two of the ordinary (dark shoulder) form (SC/50/O5).

11. OTHER SPECIES AND/OR STOCKS

SC/50/CAWS6 and 13 on Bryde's whales were considered by the RMP sub-committee. Information on a number of species off Brazil in SC/50/O5 was welcomed but was not discussed due to lack of time.

12. OTHER ISSUES

12.1 Future SOWER cruises

12.1.1 Report of intersessional group

The report of this group was considered by the small group under Kato (Item 12.1.2).

12.1.2 Planning for 1998/99 cruise

A small group under Kato was formed to consider this Item.

The sub-committee recommended that the 1998/99 cruise should take place principally in Area IV south of 60°S, but with the possibility of including sections of eastern Area III where blue whale concentrations might be found. The cruise would include at least 11 days of dedicated time for blue whale research. The sub-committee also recommended that there should be a planning meeting for this cruise in Tokyo, and that funds should be provided for the attendance of the cruise-leader, a sightings specialist and an acoustics specialist. Details were considered and will be reported to the full committee.

12.2 Acoustics – report of intersessional correspondence group

Swartz reported on progress made by this group since the last meeting (SC/50/O14).

The sub-committee endorsed the proposal that a library of whale sounds be compiled, with a view to archiving representative samples and making copies available to interested researchers: the preferred format was digital, for ease of exchange. The working group was encouraged to continue its work during the coming year and to expand the scope of the acoustic methods considered.

With regard to recordings of blue whales (Item 4.2.2 and Appendix 2), the sub-committee recommended that all blue whale recordings from the SOWER cruises should be gathered in one place and put in a format that makes them accessible to researchers. It was agreed that a working group under Clark would be set up to coordinate the process, which should involve all the stake-holders in the blue whale recordings made to date. The aim would be to provide a properly archived and annotated series of sounds, the analysis of which would be presented at the next IWC meeting. It was estimated that a sum of $3,000 would be required to cover the costs of analysis, and a total of $3,000 for editing and archiving the sounds onto CD ROM.

12.3 Mathematically-based techniques for recognition analysis

The sub-committee was disappointed that no progress had been made on this topic since the last meeting, although they recognised that there had been problems in getting the right people to this meeting as invited participants.

The sub-committee was informed that the computerised right whale matching programme developed by Hiby under an original IWC (and later IFAW) contract was now complete, and had been demonstrated at the right whale workshop. Hiby was now investigating a similar possible system for humpback whale flukes.

12.4 Biopsy sampling – collection of behavioural data

Clapham reported on the results of an intersessional working group. A draft data form was designed which standardised collection of the necessary information. This was now submitted to the Scientific Committee for comment.

In discussion it was stressed that the form was mainly intended for genetics analysts who required associated behavioural information, and that other researchers were free to modify it to suit their species/area of interest. However the form contained the basic information required, and while items could be added, none should be deleted.

The sub-committee recommended that the basic form should be adopted (once comments had been incorporated) and that consideration should then be given to making the form available electronically through the Secretariat.

13. PRIORITIES AND DIRECTIONS FOR FUTURE SCIENTIFIC COMMITTEE WORK (LONG TERM)

Future priority items are presented in Table 1.

The sub-committee noted that this list did not preclude papers on other subjects appropriate to the sub-committee's terms of reference being submitted in any year, but these might only be discussed in full if their subject matter was pertinent to a priority topic at that meeting.

The Southern Hemisphere humpback assessment planned for 1999 would only be preliminary given outstanding issues of catch allocation and stock identity. These problems were unlikely to be solved in the immediate future, but the results of the preliminary assessments might help establish how critical the uncertainties were in each case.

Brownell noted the problems related to stock structure have been a major problem for all assessments in this committee since it started. If the committee was interested in the Comprehensive Assessment of North Pacific sperm whales, it should start work as soon as possible. To start this work as soon as possible, it was necessary to pool the North Pacific sperm whale samples from the United States and Japanese collections. The people and funding were available to start work on this project immediately.

Table 1

Future priority items. For detailed descriptions of the work proposed see the indicated Agenda Items. Items are not prioritised within each year. This schedule will be reviewed and revised each year.

Year	Item
1999	Southern Hemisphere blue whales
	Differentiating forms (Item 4.2.2)
	Abundance estimates (Item 4.2.1)
	Western North Atlantic right whales
	Abundance, trends, and vital rates (intersessional meeting – Item 5.2)
	Southern Hemisphere Humpback Whales
	Preliminary stock assessments (Item 6.3.1)[1]
	Comparative data from northern stocks (intersessional group – Item 6.4)
	Southern Hemisphere minke whales
	Recruitment trends, (VPA analysis) (Item 10.3)
	Abundance estimation
	(IO approaches, GAM-based estimates) (Item 10.3)
2000	Southern Hemisphere blue whales
	Review of catch and survey data to identify geographic areas of concentration for future study (Item 4.2.1)
	North Atlantic humpback whales
	Comprehensive Assessment (Item 7.1)
	North Pacific sperm whales
	Abundance estimation methods (Item 9.3)
	Southern Hemisphere minke whales
	Abundance estimates (Item 10.3)
2001	Southern Hemisphere humpback whales
	Stock structure (Item 6.3.2)
	North Pacific sperm whales
	Stock structure (Item 9.4)
	Southern Hemisphere minke whales
	Stock structure (Item 10.2)
After 2001	Southern Hemisphere blue whales
	Comprehensive Assessment
	Southern Hemisphere humpback whales
	Comprehensive Assessment
	North Pacific humpback whales
	Comprehensive Assessment
	North Pacific sperm whales
	Modelling - catch history
	Multi-species ecosystem considerations
	North Pacific
	Southern Hemisphere

[1] See text.

Ohsumi noted that large amounts of data have accumulated on various species from which it might be possible to examine multi-species problems, and there was a need to prepare for a future examination.

14. ADOPTION OF REPORT

The report was adopted on 6th May 1998.

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Appendix 1

AGENDA

1. Convenor's opening remarks, election of Chair, appointment of rapporteurs
2. Adoption of Agenda
3. Review of available documents
4. Southern Hemisphere blue whales
   - 4.1 Reports of the SOWER cruises
   - 4.2 Progress towards assessment
     - 4.2.1 Abundance and trends
     - 4.2.2 Subspecies and stocks
     - 4.2.3 Other
5. Right whales
   - 5.1 Report of the Cape Town Workshop
   - 5.2 Action arising
   - 5.3 Other
6. Southern Hemisphere humpback whales
   - 6.1 Progress in catch and marking data coding
   - 6.2 Establishment of Southern Hemisphere directory and Antarctic catalogue
   - 6.3 Progress towards assessment
     - 6.3.1 Abundance and trends
     - 6.3.2 Stock structure
     - 6.3.3 Further information on catches
     - 6.3.4 Other
   - 6.4 Future special meeting
7. North Atlantic humpback whales
   - 7.1 Report on progress towards assessment
   - 7.2 Action arising
8. North Pacific humpback whales
9. Sperm whales
   - 9.1 Report of the intersessional group (Brownell)
   - 9.2 Action arising
   - 9.3 Abundance and trends
   - 9.4 Stock structure
   - 9.5 Catches
   - 9.6 Other
10. Southern Hemisphere minke whales
    - 10.1 1997/98 Antarctic cruise results
    - 10.2 Subspecies and stocks
    - 10.3 Abundance and trends
    - 10.4 Other
11. Other species and/or stocks
12. Other issues
    - 12.1 Future SOWER cruises
      - 12.1.1 Report of intersessional group

12.1.2 Planning for 1998/99 cruise
12.2 Acoustics – report of intersessional correspondence group
12.3 Mathematically-based techniques for recognition analysis
12.4 Biopsy sampling – collection of behavioural data – report of intersessional group
13. Priorities and directions for future Scientific Committee work (longer term)
14. Publication of documents
15. Adoption of report

Appendix 2

SOUTHERN OCEAN ACOUSTIC RECORDINGS

Clark, Bannister, Findlay

Since 1995 there has been a deliberate effort as part of the SOWER program to explore field techniques for differentiating between pygmy and 'true' blue whales. This has resulted in a collection of acoustic recordings, some of which contain blue whale sounds (Ljungblad *et al.*, 1996; 1997; SC/50/CAWS29). Members of the sub-committee expressed an interest in knowing more about the status of the recording collection and the analyses of these data.

The total number of hours of tape recordings could not be determined at this time, but there is in the order of several hundreds of hours, not tens or thousands. Analysis and review of existing material has been done on an informal and voluntary basis to provide some preliminary results on the whale sounds. Ljungblad has reviewed many of the recordings from instances when tape logbooks from the ship on which he was working indicate that whales were vocally active. Sections of tape collected during the 1996/97 and 1997/98 recording efforts which were known to contain sounds, were copied and provided to Clark for preliminary analysis. For the 1997/98 effort this did not include material from Area II. For the 1996/97 analysis effort, Clark took the material sent to him and converted it onto CD-ROM, a medium that provided much more efficient access and analysis. Some of these CD-ROM data files were then provided back to Ljungblad. Significant portions of the available recordings have not been fully reviewed or analyzed for whale sounds.

As further recording efforts take place, and more becomes known about regional and subspecies characteristics of blue whale sounds, the value of organization and documentation of the recordings increases. Given the initial, though limited, success at collecting material (i.e., small number of samples of blue whale recordings in the Southern Oceans), and the early indications that sounds from true blue whales recorded in Area II are different from pygmy blue whales off Madagascar, it is important to: (a) properly archive all original recordings; (b) fully analyze all existing recordings in a consistent manner; and (c) properly copy all original recordings onto at least one standard format so that these data are available to IWC Scientific Committee scientists and other researchers worldwide. At the very least, the archival process includes collating all data associated with a recording (e.g., recording parameters, environmental conditions, behavioral observations).

We recommend that an acceptable natural sound library (e.g., BBC, LNS) serve as the repository for the original recordings. Clark offered to discuss this matter with the curator of the Cornell Library of Natural Sounds (LNS), which presently serves as the largest and most active sound library in the world. Clark further offered that the Cornell Bioacoustics Research Program would be willing to convert all appropriate material onto a common digital medium (e.g., CD-ROM readable on Macs, PCs and UNIX), and work with Don Ljungblad (and any others wishing to be involved) to complete the analysis of the acoustic data set in time for next year's meeting. This Bioacoustics effort to convert and analyze the recordings would require some modest support but until a full inventory of material is known, the level of support cannot be determined.

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Appendix 3

RIGHT WHALES - REPORT OF THE CAPE TOWN WORKSHOP – CHAIRMAN'S SUMMARY

Last year, the Commission (IWC, 1997a, item 11.8.2) endorsed the Scientific Committee's recommendation (IWC, 1997b, item 10.3) for a special intersessional meeting on right whales, to be held in early 1998 in Cape Town, South Africa. Details of the proposal were formulated in last year's report, annex H, appendix 4.

The last scientific review of right whales was in 1983 (Brownell *et al.*, 1986). Since then, much new material has become available from studies of the northwest Atlantic right whale population, and from at least four Southern Hemisphere populations (Argentina, Australia, New Zealand, South Africa), based on photo-identification programmes, genetic and pollution studies. Information is now also available on previously unreported Southern Hemisphere pelagic catches. Some Southern Hemisphere populations are now increasing, but this has not been apparent for any Northern Hemisphere population. The status of northwest Atlantic right whales, with a population of perhaps only 300 animals, has been one of the most serious recent conservation issues facing any single large whale population. An attempt to explain that contrast was seen as a major focus of the special meeting.

As planned, a two-day public Symposium was followed by a six-day Workshop, in and south of Cape Town on 16-17 March and 19-25 March 1998, respectively. Workshop participants attended by invitation. The forty participants were drawn from eight nations, including national delegates and invited participants, and from the IWC Secretariat; there was equal representation from the Northern and Southern Hemispheres. The Workshop report was presented to the main Scientific Committee as SC/50/Rep4.

The Workshop addressed five main areas of interest:

(1) a detailed worldwide review of current information on right whale systematics, stock identity, historical and modern catches, biological parameters and estimates of abundance and trends, all based on information provided at the meeting, and leading to a population modelling exercise for the southern hemisphere;
(2) a worldwide comparison of population status;
(3) a detailed review of factors potentially affecting recovery;
(4) consideration of issues relating to whalewatching;
(5) conclusions on the implications of all the above for management, and on future research.

1. Worldwide review of current information (SC/50/Rep4, items 6-10)

Systematics (item 6)

The current classification of right whales is based, uniquely for large whales, on a taxonomic distinction between Northern and Southern Hemispheres (the northern right whale, *Eubalaena glacialis*, and the southern right whale, *E. australis*), and depends upon a single skull character. No study to date has examined other characters (morphological or molecular) to assess the validity of the traditional, morphological, classification. There is a lack of sampling from throughout the species' range, with little or no information on North Pacific *E. glacialis*, and genetic information on *E. australis* only from one or two populations or geographic regions. North Pacific right whales have either been classified as a subspecies of their North Atlantic counterpart, or described as full species; both North Atlantic and North Pacific right whales have been considered taxonomically distinct from Southern Hemisphere animals.

An examination of mitochondrial DNA material from three ocean basin forms of right whales (North Atlantic, North Pacific, Southern Oceans) gave results inconsistent with current taxonomy, supporting independent taxonomic status for all three forms (Rosenbaum *et al.*, 1998). The Workshop **recommended** that additional samples from those areas and some available from the South Pacific, plus additional historic and current North Pacific material, should be used in further analyses, and that the question of right whale taxonomic status be reconsidered by the Scientific Committee following publication of the results. In the meantime, assessments could continue on the basis of the results available at the meeting.

Stock identity: distribution and population separation (item 7)

The Workshop agreed it would attempt to identify present and past breeding (i.e. mating) and calving grounds as the basic 'management unit', together with associated feeding areas.

For each of five main regions (North Atlantic; North Pacific; South Atlantic and Indian Ocean coast of South Africa; Australia/New Zealand and Indian Ocean; Southern Hemisphere – general), the Workshop reviewed information on a series of topics, including distribution and seasonality on calving and feeding grounds, movements and genetic information. For some regions, information was included on historic catches, morphology and parasites. The results were synthesised for each region independently. Those relating to seasonal abundance were tabulated in detail for each of four regions (SC/50/Rep4, annex D, tables 1-4) in terms of both relative and absolute abundance.

The results for each region, as contained in the specific Synthesis section for each, can be summarised as follows.

A. NORTH ATLANTIC (ITEM 7.1.5)

Only animals found in the western North Atlantic can be considered a functioning extant unit. For practical purposes, that area can be considered a single 'management unit', from genetic evidence probably corresponding to a true biological population. Animals in the eastern North Atlantic may be considered as a 'relict' population or populations.

B. NORTH PACIFIC (ITEM 7.2.4)

Whether two or more stocks exist is still problematical. Only animals in the western area can be considered a functional extant unit. From their different catch and recovery histories it seems there were once at least two stocks, at least on the feeding grounds. Right whales summering in the Okhotsk Sea have been considered to be a separate population, wintering in the Sea of Japan and possibly the East China Sea, although it seems unlikely that animals found in such close proximity, notably in the Kuril Islands and Okhotsk Sea, would belong to separate stocks.

C. SOUTH ATLANTIC AND INDIAN OCEAN COAST OF SOUTH AFRICA (ITEM 7.3.6)

Three calving grounds in the South Atlantic (Brazil, Argentina, South Africa) from up to a possible six in the past, are now substantially populated. From genetic, morphological and possibly parasite data, calving grounds off Brazil and Argentina should be considered as separate management units, but with a small amount of movement between them. Of five suggested South Atlantic feeding grounds, links (from photo-identification) have only been established between Argentina and the South Georgia area, and between South Africa and 'south of 50°S'.

D. AUSTRALIA/NEW ZEALAND AND INDIAN OCEAN EXCLUDING EAST AFRICA (ITEM 7.4.5)

Animals wintering on the Australian coast are considered a single management unit, probably comprising a true biological population. There is now evidence for more extensive movements into colder waters (as far as 65°S) than previously believed. Around New Zealand, the great majority are found in the Auckland-Campbell Islands area, and should be referred to as the New Zealand sub-Antarctic population, separate both from a New Zealand-Kermadec management unit and the Australian unit.

In the Indian Ocean, records of 19th century catching positions (Townsend, 1935) suggest a separate Central Indian Ocean management unit, with the possibility of another unit further to the west, near the Crozet Islands, although there is little evidence of animals there currently.

A number of specific recommendations arose out of the stock identity review, i.e. on collection and analysis of biopsy samples, the number, timing and localities for additional samples (see item 7.5 and table 1), and on analysis of stable isotopes from baleen, as well as recommendations relating to population structure, choice of genetic markers, genetic data analysis and reporting (item 7.6).

Historical and modern catches (item 8)

Pre-modern data (i.e. pre-1900) were reviewed for the North Atlantic, North Pacific and Southern Hemisphere, with sub-division by ocean in the latter. Given the lack of actual catch data, the kill has had largely to be obtained from oil or baleen production statistics; it is therefore estimated rather than known. Different assumptions and procedures have been used in past estimates. The same is true for adjustment for hunting loss; depending on the fishery the adjustment ranges from 1.2 to 1.5 times the landed catch.

In the North Atlantic (item 8.1.1), catching occurred from at least the 11th Century, in Basque coastal and pelagic whaling. While dozens of whales were taken in the Bay of Biscay each year until 1650, the pelagic catch elsewhere has, for example, been estimated at between some 25,000 to 40,000 right whales off Labrador in the 80-year period 1530-1610. The stocks had been severely reduced before Yankee whaling began in the mid 18th Century. Shore whaling along the US east coast began in the mid 17th Century, peaking in around 1680-1730, but continuing with variable effort and total known catches only in the hundreds, until as recently as 1924. In the period 1855-1897, Yankee whalers in the North Atlantic took about 186 animals.

In the North Pacific (item 8.1.2), the Japanese net fishery took right whales from the late 17th Century. Before 1850, no more than about 100 animals were taken per year, with a decline thereafter. Few animals were taken from shore off the North American coast. Right whale pelagic whaling began in the Sea of Japan in the 1820s, on the central and eastern North Pacific 'Northwest' (Kodiak) grounds in 1835 and in the Okhotsk Sea in 1845. About 14,500 were taken as a total by American pelagic whalers in the North Pacific in 1835-1904, with 90% taken in 1840-59, although they cannot be allocated to grounds. No allowance can be made in North Pacific catches for hunting loss, nor for catches by other nationalities.

For the Southern Hemisphere (item 8.1.3), while shore-based catches can be allocated by management unit, based mainly on winter calving grounds, pelagic catches cannot be allocated as easily. Annex L details available information by decade and area. For shore-based whaling, catches are grouped by coastal wintering area; for those offshore, allocations are made to coastal wintering areas where possible ('bay whaling') or otherwise to ocean basin.

Pelagic catches in the South Atlantic (annex L, table 1) began in the 1770s, peaked in the 1840s, and continued at reduced levels until the early 1900s. A kill of 48,034 is recorded for the South Atlantic up to 1900. In the South Pacific, the pattern was similar (annex L, table 2), but began later (at Australian shore stations from 1805 and from American pelagic vessels from about 1815), peaking in the 1830s and dwindling thereafter. Data on a kill of 37,196 whales up to 1900 are given in annex L, table 2. In the Indian Ocean (annex L, table 3), a total of 12,605 kills up to 1900 is recorded, from the 1830s; they peaked within only a few years, in about 1835-44, and dwindled thereafter.

Details of the relatively small numbers taken in the 'modern' whaling era (post-1900) were provided (item 8.2). In the North Atlantic, a kill of some 100 animals in 1906-10 off the western British Isles seems to have had a catastrophic effect on the eastern North Atlantic population. In the North Pacific there was commercial whaling between 1911 and 1946, and catches for scientific research from the 1950s to the 1970s. Illegal Soviet catches in 1958-64 took some 200 animals, and there is some evidence of 'hundreds' being taken illegally in the Okhotsk Sea and of additional unreported takes near the Kuril Islands.

For the Southern Hemisphere, relatively few catches were reported from 1900 (item 8.2.3), but particularly significant are large unreported illegal Soviet catches from 1951/52-1971/72, totalling at least 3,349. The largest documented catches were off Patagonia (1,335), the southeast Atlantic (704), the southwest Pacific (372) and near the Crozet Islands in the south west Indian Ocean (309). Tables 1-3 in annex L record a total kill of 4,892 animals post-1900 in the Southern Hemisphere, with 3,397 in the South Atlantic, 943 in the South Pacific and 552 in the Indian Ocean.

The total Southern Hemisphere kill reported in annex L is 88,727 animals: 37,341 in the South Atlantic; 38,139 in the South Pacific; and 13,157 in the Indian Ocean (but see below for adjustments to allow for some catches being subsumed within other estimates for another area).

Biological parameters (item 9)

While agreeing that it was important to try to standardise data collection and data field types to permit comparisons within and between datasets, the Workshop did not attempt a Comprehensive Assessment of methodology and techniques but addressed three particularly important categories: photo-identification; biopsy; and necropsy.

Item 9.1.1 focused on coding the quality/detail of photographed sightings for quantitative comparison of matches within and between catalogues. Five assessment categories were agreed. A set (10 or so photographs) should be made available for comparison between research groups. The Workshop recognised the value of long-term photo-identification studies (Hammond *et al.*, 1990) in providing essential data for assessing and monitoring the status of right whale populations. It **recommended** the continuation of existing programmes and the establishment of new programmes where appropriate.

Given the value of the historical information contained in the various photo-identification catalogues, it also **recommended** that the images in the catalogues be digitised and archived in a secure way (and see IWC, 1990, pp.9-10).

A range of biopsy sampling topics relevant for both genetic and organochemical/biochemical analyses was reviewed (item 9.1.2). Methodology, numbers and locations of samples from different geographical areas were summarised (annex E). Technical matters addressed included: sterilisation of biopsy tips; the reaction of animals to biopsy; and the potential of alternative methods, e.g. use of sloughed skin, scrub scrapers and hand scrapes. It was noted that none of the latter would provide blubber samples, and their small size might restrict some DNA analyses. Calves typically show less reaction to the darting than the mother, and it was agreed that there is considerable scientific merit in obtaining samples from calves. The Workshop **recommended** that where possible such samples should be obtained from calves.

Researchers were reminded to ensure adequate time for obtaining the necessary permits for acquisition, import and export of samples. The Workshop **recommended** that IWC member nations should be asked to facilitate transfer of skin/blubber biopsy samples between research institutions in different countries to assist collaborative analyses, and that the IWC Secretariat approach the CITES Secretariat to determine the best way to facilitate the exchange of such material.

The Workshop **recommended** that where possible, necropsies should be conducted to determine the cause of death (Best *et al.*, 1998; Knowlton and Kraus, 1998) and to provide biological samples relevant to studies of the recovery of right whale populations. Protocols and minimum collection needs were detailed (item 9.1.3). The Workshop recognised a number of important ongoing studies that could be addressed further through necropsy data (annex F).

Data and methodologies for obtaining estimates of biological parameters were examined in the context of the underlying assumptions in the models used, and their likely reliability. Several points applicable to all the analyses used in the Workshop were noted. The underlying assumptions in the estimation methods presented, their biological significance, and the effects of their violation, were tabulated in detail (table 2). **Recommendations** and conclusions were presented (item 9.2). Attention was drawn to Caswell *et al.* (1998), a study of declining probability of survival in North Atlantic right whales, where of all the potential biases arising from possible violation of the tabulated assumptions that related to probable differences in parameter values by sex and age, potentially introduced the most serious bias into the results. A **recommendation** was made for the authors to take account of such factors in continuing to develop their methodology, together with a number of other **recommendations** relevant in this context.

A tabulation was provided of maximum lengths and ranges of calf size (table 3). Available information on longevity, age structure and growth rates, as well as for mortality rates and survivorship, was summarised for each major region (items 9.2.1, 9.2.2). The longest active reproductive life span identified so far is of a North Atlantic animal fortuitously identified in 1935 and rephotographed over 60 years later. A female photographed with a calf in 1967 was also seen with a calf 29 years later.

Given the possibility that survival rates have declined in recent years in the western North Atlantic population, the Workshop **recommended** that the results of the additional recommended work related to the methodology in Caswell *et al.* (1998) be presented to the Committee as soon as possible.

Information was also presented on reproductive parameters, i.e. age at sexual maturity, pregnancy rate and calf production and reproductive cycle/seasonality (item 9.2.3). The mean calving interval in the western North Atlantic was estimated as 3.67 (SE 0.11), but the Workshop noted an increase over time in recent years (Kraus *et al.*, 1998), with a significant increase ($p < 0.001$) in 1985-97 from 3.33 to 5.36 years. Kenney (1998) reported that calving rate changes could be correlated statistically with the Southern Oscillation Index; with an intense El Niño in 1998, a low calving rate could be expected in 1999.

Southern Hemisphere mean calving interval estimates included 3.35 years (SE 0.05) for Argentina, 3.12 years (95% CI 3.05, 3.17) for South Africa, and 3.64 years (SE 0.13) for Australia. Differences in the probability distribution of calving interval in Argentina and South Africa, with more three year intervals and fewer five year intervals in the former, could not be explained.

Estimates of abundance and trends (item 10)

For the western North Atlantic, one Workshop participant commented that population simulations suggest some recovery following protection in 1935, and that this slow recovery seemed to have continued at least until the 1980s (Reeves *et al.*, 1992).

Population size estimates based on a six-year running total of catalogued animals (see item 9.2) had been used to obtain an annual rate of increase (range –0.039 to +0.031) for each year 1987-1996 (Kraus, 1997). A regression estimate of 0.01 (SE 0.0232), using all the data, was probably negatively biased.

Three alternative methodologies to obtain estimates of the rate of increase were summarised (annex G). The first gave an estimate of 0.0159 (CI –0.0246, 0.0564) with the caveat that it is likely to underestimate the increase rate for the 1980s because the calving interval has increased significantly in recent years. The second used data from parous females, giving an increase between 1985 and 1997 (0.035, 95%CI 0.024–0.045) but with an apparent long-term oscillation in recruitment. The third (based on the approach of Caswell *et al.*, 1998) suggested an upper bound of 0.043. Although actual growth rates are likely to be considerably less than that, the figure illustrates that the growth rate of this stock is both low and substantially less than that of southern right whale populations, reported below.

Given the methodological concerns already expressed (item 9.2), the Workshop believed it could not reach any firm conclusions on recent population trends for the western North Atlantic stock. Given concerns over its status (see item 11, below) the Workshop **recommended** that as a matter of urgency further work should be carried out to provide quantitative information on population trends. For example, more complex models (which allow for parameters such as calving rate to vary with time) should be explored to test for any possible changes in trend. In addition, the use of stochastic models should be explored: stochasticity is particularly important in considering small populations. The Workshop also noted indications of a recent decrease in growth rates, as suggested by a statistically significant calving interval increase and three years' poor calf production (Kraus *et al.*, 1998). There were further concerns over a possible major change in the feeding grounds, as well as over recent increases in reported ship strikes and potentially fatal entanglements.

No information was available for the North Pacific. The workshop **recommended** that given its concerns over status (item 11), studies to assess population trends be implemented as a matter of urgency.

For the Southern Hemisphere, both in relation to population trends and abundance (item 11), the 11 management units already agreed (item 7) were used, i.e. sub-Antarctic New Zealand, Australia, Central Indian Ocean, Mozambique, South Africa, Namibia, Tristan da Cunha, Brazil, Argentina, Chile/Peru and mainland New Zealand/Kermadec. Current best estimates of certain demographic parameters and population sizes for each of these regions were summarised (table 4). Major results accepted by the meeting included:

(a) Argentina - increase rate 0.071(SE 0.8%), 1971-90; population size (reproductive females) 330 (95% CI 274-386), 1990;
(b) Australia - increase rate 0.0825 (95% CI 0.510-0.1140), 1983-97; population size (reproductive females) 73, 1995;
(c) South Africa - 0.072, 1969-87; population size (reproductive females) 613, 1996.

Detailed comments on these and other estimates, and the rationale for their acceptance, were given in items 10.1 and 10.2.

The Workshop agreed that it would be possible to attempt to obtain estimates of initial abundance for the Southern Hemisphere only if the whole hemisphere was combined. It could be attempted for specific breeding populations but that would need assignment of historical catches to each population - an extremely difficult task, not achievable at the meeting. A modelling approach was used (item 10.3.1), as in the *Catch Limit Algorithm* of the RMP; in conventional Committee stock assessment terms the approach was one of 'Hitting with fixed MSYR'. An average population increase rate of $r = 0.075$ was adopted; for comparative purposes rates of $r = 0$ (equivalent to estimating K by simply summing all historical catches plus the current population size estimate) and $r = 0.04$ were also used. In that way the extent to which the population's surplus production had been able to compensate for the effect of reductions through whaling could be assessed. Other parameter values adopted, to calculate the juvenile/adult ratio, were the annual average survival rate, s, = 0.98 p.a., and average age at first parturition, t_m, = 9 years.

Current population size was set at year 1997, with adjustments where necessary to the adult female population estimates available, using the assumed annual growth rate of 0.075. The estimate obtained, 1,607 adult females, was both negatively and positively biased, for reasons detailed (item 10.3.2). The calf/juvenile: adult ratio was estimated to be relatively high, at 1.4:1 - a consequence of the relatively high population growth rate (in the western North Atlantic, calves and juveniles account for only 26-31% of the population).

The 1997 total population size estimates for each area were then summed, giving a total of 7,571 whales for use in the population model. Noting the coarseness of many of the assumptions used to arrive at this figure, the Workshop emphasised that the current best estimate of the total number of right whales in the Southern Hemisphere is preferably expressed as 'about 7,000'.

Historical catch data used in the model were revised from those already considered (item 8) to account for some indicated catches being subsumed within estimates for another area. They were also modified to allow for struck and lost animals (at rates of 1.2-1.5 times the landed catch, depending on the fishery; IWC, 1986, p.31). Three catch histories were developed (table 6) - 'base case' (using an average loss rate of 1.35), and 'high' and 'low' cases (using the two extremes of struck and lost rates, and assumptions of 'none' and 'all' for instances of catch duplication). The catch per decade data (annex L) were converted to annual estimates assuming an even catch distribution per ten-year period.

The modelling results (fig. 5) gave an initial population size of about 160,000 for $r = 0$, but about 60,000 for $r = 0.075$. Estimated population trajectories for $r = 0.075$ for each of the three catch scenarios (fig. 6) showed marked changes only in the early part, suggesting a possible range for initial population size of 55,000-70,000 whales. An expanded version of the 'base case' trajectory (fig. 7) from 1880 illustrated: (i) the rapid depletion of the stock following the substantial catches of the early-mid 1800s; (ii) the almost complete lack of any sign of a recovery after 1850, for almost 100 years, followed by a gradual recovery after protection in 1935; and (iii) the effect of the illegal Soviet catches of the 1960s in delaying further recovery by about 20 years.

The trajectory also indicated that the entire Southern Hemisphere population reached a low point of about 300 animals in 1920, corresponding to an adult female population of about only 60 individuals. However, if there had been depensation effects (not allowed for in the current model), the minimum number in 1920 would have been higher than 300. The Workshop noted continuing uncertainties over both the historical catch series and the current projection and that the aggregation of different breeding populations might have distorted impressions of lowest sizes; the exact numbers generated by the model should thus be treated with caution.

In summary, the modelling exercise confirmed that the Southern Hemisphere population of right whales is still heavily depleted, perhaps at about 10% of its initial size. The model used suggested that the current growth rate should continue for some time before onset of any marked density dependent reduction, implying that the population as a whole should continue to grow with a doubling time of about 10 years for at least the next decade.

The Workshop recognised that the above exercise was merely an initial attempt to determine the population trajectories and initial population sizes for southern right whales. It **recommended** that at least three modifications of the analysis should be attempted in the future, as listed in item 10.3.4.

2. Worldwide comparison of population status (item 11)

The workshop noted that several Southern Hemisphere populations (those off Argentina, Australia and South Africa) are increasing at annual rates of *ca* 7-8%. The New Zealand sub-Antarctic population has increased (at least at the Auckland Islands) since the 1940s, but systematic research has not been undertaken for long enough to estimate whether it is currently increasing. Other areas where major whaling operations were conducted show no sign of recovery although recent information is either absent or incomplete. The Workshop **recommended** that research be undertaken to determine the current status of right whales there.

For the three best known Southern Hemisphere areas, the current estimated total abundance was about 7,000 (item 10). Should those populations continue to grow at 7-8% they would double in ten years. There have been no catches in the Southern Hemisphere since the early 1970s and there is no evidence that human-related mortality is affecting population recovery.

In the North Pacific, the situation differs greatly between the western and eastern populations. Sightings survey estimates for the summer feeding ground indicated an abundance of around 900 (95% CI 404; 2,108) in the Sea of Okhotsk. However, for the situation in the eastern North Pacific, there was considerable concern. Over the past forty years, most sightings have been of single whales; there have been encouraging sightings of small groups recently, but no confirmed sightings of calves this century and there were large illegal Soviet catches in the early 1960s. The workshop **recommended** that research effort to improve understanding of population status and possible human-related problems should be greatly expanded as a matter of urgency.

The situation in the North Atlantic gave the Workshop great cause for concern. The eastern North Atlantic population probably numbers only in the low tens of animals; its future remains questionable. For the western North Atlantic population, the Workshop expressed considerable concern. Whereas it may have increased since protection in 1935 (e.g. see Reeves *et al*., 1992) and may have been still increasing at a modest rate (about 2.5%) in the 1980s (Knowlton *et al*., 1994), more recent data (near-failure of calf production from 1993-95, increased calving interval, and a relatively large number of human-induced mortalities) suggest that this modest recovery rate (by comparison with the Southern Hemisphere) may not have continued in the 1990s. North Atlantic parous females show an increase between 1985 and 1997 but with an apparent long-term oscillation in recruitment (annex G). These features, together with the lack of significant increase in calving rates, support the need for age-structured models to account for the complexity of this population's dynamics. It was unclear whether the population is now declining, stationary or increasing, and the best estimate of current population size is only 300 animals (see item 10). The Workshop **recommended** that, as a matter of urgency, increased efforts be undertaken to determine the recent trajectory of this population.

The Workshop noted the high rate of known entanglement and ship strikes in the western North Atlantic; not all dead whales are recorded especially when they die, or are killed, offshore. The western north Atlantic population also shows a significantly depressed calving interval and fecundity compared with the Southern hemisphere. The Workshop agreed that inbreeding, organic chemical exposure and nutritional factors need further study (see item 12). It **recommended** that comparative studies should be undertaken to try to determine factors that may explain the difference between Northern and Southern hemisphere reproductive parameters.

The Workshop concluded that any human related mortality could be detrimental to the long-term survival of the western North Atlantic population. Efforts to reduce human-induced mortality are of the greatest urgency if the chances of the western North Atlantic population recovering are to be maximised. The Workshop drew the Commission's attention to its recommendations on Management Implications under item 14.

3. Factors potentially affecting recovery (item 12)

The workshop discussed a number of aspects in this context in detail: genetic diversity and genetic problems in small populations (inbreeding depression) (item 12.1); trophic relationships and body condition (item 12.2); anthropogenic factors (item 12.3); and health and pathology (item 12.4). Detailed **recommendations** were provided for each and those of greatest significance for management were reviewed for appropriate priority under item 14.

4. Whalewatching (item 13, annex J)

A Working Group established by the Workshop considered relevant issues, i.e. positive and negative aspects; legislation; regulations and guidelines; and management regulations. Its recommendations were discussed under item 14.

5a. Management implications (item 14)

The Workshop discussions resulted in a number of recommendations requiring management action to attempt to reduce or eliminate non-natural mortality of right whales and habitat disturbance. These are particularly important for those stocks for which the Workshop expressed concern over status.

Mortality

The Workshop identified ship strikes and incidental entanglements in fishing gear as the most significant cause of human-induced mortality of right whales (item 12)

With respect to ship strikes (item 12.3.3), given the serious concern over the status of western North Atlantic right whales (item 11), the Workshop **strongly recommended** that the Committee urges the Commission to make every effort to encourage the adoption by relevant governments of the specific recommendations in annex I.

More generally, the Workshop (item 12.3.2) **recommended** that the Committee requests the Commission to:

(1) urge its member nations to;
   (a) initiate or expand preventative measures including Notices to Mariners, notifications on charts and informational brochures to other areas where right whales and high levels of shipping overlap; and
   (b) develop mitigating options, areas to be avoided, early warning systems, sonar detection of whales, acoustic deterrents, and the shifting of shipping lanes and reductions in ship speed;
(2) seek cooperation from the International Maritime Organisation to provide protection for right whales, including but not limited to mandatory ship reporting and ship routing, especially where commercial vessels are entering calving, breeding or feeding areas.

With respect to entanglements (item 12.3.2), the workshop **recommended** that the Committee requests the Commission to urge member governments to ensure that:

(1) research continues on methods to reduce right whale entanglements in fishing gear;
(2) entanglement rates and the success of steps to reduce entanglement are determined and monitored (e.g. through periodic analysis of scarring rates and levels of severe entanglement in photo-identification databases);

(3) if the above monitoring indicates that protective measures are insufficient, they are upgraded as appropriate;
(4) disentanglement programmes (including training from experienced persons) are established where appropriate;
(5) consideration is given to the prohibition of any gear that might entangle right whales in high use habitats, and especially in calving, breeding or feeding areas and sanctuaries.

Disturbance and habitat
The Workshop **recommended** that the Committee requests the Commission to urge local, regional and national authorities responsible for right whale habitats to develop contingency plans for oil and chemical spills, where these do not exist (item 12.3.1).

It also made specific recommendations on habitat-related issues requiring management action by individual governments (item 12.3.5). It **recommended** that the Committee requests the Commission to ask the relevant governments to take the necessary action.

Facilitation of research
The Workshop **recommended** that the Committee requests the Commission to urge member governments to provide funding for the identified research items (item 15). In addition it draws attention to the following **recommendations** requiring action but not funding:

SAMPLE COLLECTION
The Workshop made a number of research recommendations concerning collection of biopsy samples. It **recommended** that the Scientific Committee requests the Commission to urge member governments to facilitate the issue of national permits to collect sufficient biopsy samples from adult and calf right whales to address the research recommendations identified in its report (items 7 and 9).

NECROPSIES
The Workshop noted the need for detailed necropsies of right whales, particularly for those populations for which there is concern over status. It **recommended** that the Committee urges the Commission to request that member governments ensure that appropriate programmes are initiated and, where necessary, permits granted to enable the work to take place (item 9.1.3).

SURVEYS IN TERRITORIAL WATERS
The Workshop identified the need for a further research cruise to assess the abundance of right whales in the western North Pacific. It **recommended** that the Committee requests the Commission to urge relevant member nations to cooperate in this exercise and in particular that the Russian Federation is urged to grant permission for vessels to survey within 12 n.miles of Okhotsk Sea coast (see item 10.2).

WHALEWATCHING
The Workshop endorsed the Commission's general principles for whalewatching (IWC, 1997b, p.105) and recommended that they be applied to all whalewatching activities involving right whales. It was agreed that it was critical to: (1) manage the development of new and fledgling whalewatching operations to minimise the risk of adverse affects; and (2) take appropriate regulatory measures in areas where directed research demonstrates negative impacts on whales from established whalewatching activities.

The Workshop agreed that special protected areas provide a framework for the implementation of site-specific regulations for whalewatching and that such areas are important in conserving coastal habitats. It therefore **recommended** that studies be undertaken to assess the establishment of special protected areas in areas of known right whale concentration (e.g. the Central-South Coast of Santa Catarina, Brazil).

5b. Future research (item 15)
During its discussions of the various agenda items, the workshop made a number of recommendations for future research (table 9). It re-iterated the value it attaches to all those recommendations. However, as at previous IWC workshops, it recognised the need to assign some priority to research items in the context of IWC interest. In particular, this applies to questions associated with the 'trend and condition of whale stocks' and 'measures for the[ir] conservation' (Article IV of the Convention). This was reaffirmed in the terms of reference for the meeting (item 1.2).

Trends and status
The Workshop confirmed the view already expressed by the Committee on several previous occasions (IWC, 1990) of the extreme importance of maintaining research effort when investigating trends in both abundance and in biological parameters. It therefore stressed that high priority should be given to the continuation of both demographic photo-identification studies (item 9) and surveys designed to improve knowledge of absolute abundance and current trends (item 10). Similarly, high priority should be given to the processing and analysis of such data. This is particularly important for the western North Atlantic where there are serious concerns over the status of the stock (item 11).

It also noted the need to initiate and improve such studies in areas of identified concentrations where they are either absent or in their infancy. High priority should be given to those areas where it is believed there is most chance of success.

To interpret data on trends and abundance it is important to determine appropriate management units. In this context, high priority should be given to stock identification studies that will answer questions believed to be hindering the ability to address important conservation questions (see item 7). Genetic sampling programmes should be initiated where needed, and maintained in areas where increased sample sizes are needed for statistical validity.

Conservation measures (item 15.2)
The workshop agreed that **high priority** should be given to research that will lead directly to improved methods of reducing anthropogenic mortality (e.g. reducing ship strikes and fishing gear entanglements) for stocks for which there is concern over survival (see item 11).

Priority should also be given to research into environmental factors that affect the fecundity and mortality rates of right whale populations (e.g. food limitation, pollution, item 12). Such research should ultimately lead to improved recommendations for appropriate and effective management action. Comparative studies between stocks that are recovering and stocks that do not appear to be (item 10) may be particularly valuable in this context. Studies that improve information on feeding grounds in the Southern Hemisphere will facilitate such comparisons.

From the genetic standpoint, two questions are of high priority:

(1) what are the implications of the low haplotype diversity detected in certain populations; and
(2) is the effective population size of right whales significantly lower than the abundance estimates?

Other items

Under 'Other Business' (item 17) the Workshop agreed that a proposal for the creation of a global right whale catalogue should be included in the context of a broader proposal for a Southern Hemisphere right whale consortium (annex K). Some concerns were expressed over the scientific rationale behind the project. The Workshop recognised that creation of a framework for collaborative research, similar to that in the North Atlantic Right Whale Consortium, could provide similar benefits, as well as serving as a vehicle for identifying and seeking support for right whale research worldwide. Its objectives were detailed in item 17.

The Workshop **agreed** that there was merit in the proposal and **recommended** that the Scientific Committee approves the principle of establishing a Southern Hemisphere Right Whale Consortium, for recommendation to the Commission. Subject to such approval, a Steering Committee, comprising representatives of each Southern Hemisphere nation currently involved in right whale research, should be established to develop the details of the proposal. Funding should be sought from, *inter alia*, the Commission, national governments and other sponsors to convene a meeting of interested parties, with appropriate terms of reference, to formally establish the Consortium.

In conclusion, the Workshop particularly wished to record its appreciation to the local convenor, Dr P. Best, and his associates; to the meeting sponsors - MTN Cape Whale Route, and The Two Oceans Aquarium, Cape Town; and to Mondi (SA), Price Forbes and The Monkey Valley Beach Resort.

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Appendix 4

CURATION OF INDIVIDUAL IDENTIFICATION PHOTOGRAPHS FOR HUMPBACK WHALES FROM THE ANTARCTIC: A RESEARCH PROPOSAL TO THE SCIENTIFIC COMMITTEE, INTERNATIONAL WHALING COMMISSION

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Description of project

College of the Atlantic (COA) has maintained a collection of humpback whale identification photographs from the Antarctic since 1987. This proposal seeks support from the IWC for: (1) expansion of this collaborative effort in the form of submission of identification photographs from members of the Commission and other researchers working in the Antarctic, and (2) resources for curation of these images.

Background

Personnel at College of the Atlantic have coordinated the development and testing of the photographic identification method for humpback whales, and pioneered development of the collaborative network throughout the North Atlantic region for compiling fluke photographs from different regions into a catalogue and master database. Two substantial collections of photographically identified humpback whales from the North Atlantic are housed at COA: the North Atlantic Humpback Whale Catalog (NAHWC) and the Years of the North Atlantic Humpback Whale (YoNAH) collection. The NAHWC contains approximately 16,000 photographs of over 5,000 individuals primarily collected since 1976. Project YoNAH, a three-year international collaborative project, was initiated to collect photographs from individual humpback whales using protocols designed to eliminate biases inherent in opportunistically collected photographs, and to expand sample size to improve precision of population estimates. COA has conducted all photographic analysis and cataloguing for the project. The YoNAH collection includes approximately 5,000 images of 3,000 individuals. In addition, COA is developing and housing the completed YoNAH database used for analysis and the YoNAH archive.

Current status of Antarctic Catalog

The Antarctic Humpback Whale Catalog maintained by COA was created in 1987. It currently contains fluke photographs of 270 humpback whales from the Antarctic collected between 1981 and 1997, primarily from the region of the Antarctic Peninsula. In addition, the collection contains photographs from breeding and calving grounds in Brazil, Colombia, Ecuador, New Zealand and Australia. The effort is highly collaborative. Photographs have been contributed by 80 individuals or research groups.

Plan of research

The catalogue currently relies primarily on photographs of the tail flukes, with dorsal fin photographs included where available as part of the same catalogue and database. This proposal calls for expanded use of dorsal fin and flank photographs. This would require the creation of two additional collections of photographs, one for left dorsals, the other for right dorsals. These collections could be used independently or jointly depending on the analytical requirements.

Relational databases will be used to store all associated field data and to coordinate data from the three collections. All images will be scanned and archived digitally, and linked to the database for ease of access and retrieval. The database will allow each image to be tracked to the appropriate field sighting data.

Reports will be issued to contributors when comparison of their submissions is completed. Reports will include the data for each photograph as it is contained in the database to allow for error checking, and the associated catalogue numbers assigned to each photograph. Reports will also include a sighting history for each individual previously sighted. A summary of catalogue activity will be issued annually to the Scientific Committee prior to the annual meeting.

Budget 1998/1999

This proposal seeks funds for comparing photographs and preparing and managing the resulting data (see Table 1). The infrastructure (computers, software, etc.) is in place to support the analysis and skilled personnel are available to undertake the analysis.

Table 1

Budget required. All costs in US$.

	COA	IFAW	Requested from IWC
Photographic comparison 400 hrs @ $10/hr	3,000		1,000
Project and database management			
Catalogue and database set-up, 80 hrs @ $15/hr			
Maintenance and reporting, 120 hrs @ $12/hr			1,200
Administration, 80 hrs @ $15/hr	1,200		1,440
External supervision, 80 hrs @ $15/hr		1,200	
Darkroom, photographic processing			500
Phone, fax supplies			200
Fringe (26% of project and database management salary)			686
Total	4,200	1,200	5,026

REPORT FROM WORKING GROUP ON SOUTHERN HEMISPHERE CENTRALISED DIRECTORY FOR HUMPBACK WHALE PHOTOGRAPHS AND ANTARCTIC HUMPBACK WHALE CATALOGUE

Best, Carlson, Gambell, Pastene

Centralised directory

Once information on photographic material is received, the Secretariat could, this year, establish a centralised directory for Southern Hemisphere humpback whale photographs as outlined last year in IWC (1998). The directory would take at least two weeks of the computing staffs' time and therefore would be prioritised accordingly with other work recommended.

Progress on the Antarctic Catalog

Photographs of Antarctic humpback whales taken during the JARPA/SOWER surveys between 1989/90 and 1995/96 have been evaluated and scored for 'matchability'. Photographs of Antarctic humpback whales from IDCR cruises have been evaluated and 100 were printed for the catalogue. Photographs of 40-50 individual humpback whales from the Peninsula region will be submitted to the catalogue this year by a Brazilian Antarctic survey team. It will continue to submit photographs each year. Photographs of Antarctic humpback whales from other sources (i.e. Chile; previous IDCR/SOWER cruise participants) should be solicited for the catalogue by the IWC Secretariat. The College of the Atlantic has agreed to curate the catalogue with agreement from the Committee. The proposal for curation, establishment of two additional catalogues for left and right dorsal fins and relational databases is presented above. The Working Group puts forward these items to the sub-committee for consideration.

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Appendix 5

COARSE EXTRAPOLATION OF IWC/IDCR-SOWER ESTIMATES OF ABUNDANCE FOR HUMPBACK AND SPERM WHALES TO COMPARABLE AREAS

D.S. Butterworth

SC/50/CAWS37 provides the following estimates (Table 1) of abundance (with CVs in parenthesis) for Southern Hemisphere humpback and sperm whales, following standard IWC methodology.

Table 1

Abundance estimates from SC/50/CAWS37.

	Humpback	Sperm
1st circumpolar	5,300 (0.39)	5,500 (0.44)
2nd circumpolar	9,700 (0.27)	11,400 (0.18)
3rd (incomplete) circumpolar	8,600 (0.26)	7,900 (0.19)

The difficulty with using these estimates to draw inferences about possible trends in abundance is that they do not correspond to identical survey areas. Approximately, the coverage of the area of open ocean south of 60°S is 63%, 79% and 55% respectively for the three sets of surveys.

This paper attempts some crude extrapolations to render the estimates all pertinent to the full area south of 60°S and therefore comparable. For the 1st and 2nd circumpolar surveys, this has been done by taking the effort-weighted average sighting rate (n/L) in the northernmost strata of each Management Area, and assuming that this applies also in the unsurveyed 'T' strata (see SC/50/CAWS37, table 2) between these northernmost strata and 60°S. Appropriate subtractive corrections are made in the few cases where existing strata extend slightly north of 60°S.

For the 3rd circumpolar surveys, lack of coverage is predominantly longitudinal. Very roughly speaking, this set of surveys (as far as analysed in SC/50/CAWS37) have covered Areas I, III, V and VI, with II and IV (constituting about 29% of the total open ocean area south of 60°S) still to be surveyed. The proportions of total abundances estimated in the earlier circumpolar surveys that correspond to Areas II and IV are given in Table 2.

These are not too dissimilar (on average) from the corresponding areal proportion of 29%. Thus it seems reasonable, as a crude first approximation, to effectively

Table 2

Proportion of total abundances estimated in earlier circumpolar surveys that correspond to Areas II and IV.

	Humpback	Sperm
1st circumpolar	0.18	0.29
2nd circumpolar	0.39	0.41

assume that densities of these two species are invariant over the whole area south of 60°S, and hence simply to scale the pertinent abundance estimates of SC/50/CAWS37 upwards to account for the 45% of the area south of 60°S yet to be covered.

The net effect of these adjustments is to provide the 'comparable' estimates given in Table 3.

CVs for the above would be straightforward, though messy to calculate, if the extrapolation uncertainties are ignored. Results for the first two circumpolar cruises would be similar to those of SC/50/CAWS37 quoted above as these abundance estimates are dominated by the contributions from the northernmost strata, whereas those given for the 3rd circumpolar formally remain unchanged in terms of the crude assumption made for extrapolation in that case.

Table 3

Comparable estimates following adjustments.

	Humpback	Sperm	Mid-period year
1st circumpolar	7,500	7,900	1981
2nd circumpolar	11,800	13,000	1988
3rd (incomplete) circumpolar	15,700	14,300	1993/94

Appendix 6

UPDATE ON THE STATUS OF INFORMATION ON THE NORTH ATLANTIC HUMPBACK WHALE

T.D. Smith, P.S. Hammond, N. Friday and P.J. Clapham

Information being developed on the North Atlantic humpback whale is described, updating Smith *et al.* (1998) to assist the Scientific Committee in determining if it should undertake a Comprehensive Assessment in 1999 or in 2000. We conclude that while an assessment could be done in 1999, there would probably be substantially more information still under development at that time. Therefore, we suggest that the assessment be conducted in 2000.

In 1997, the Scientific Committee reviewed the status of information on the North Atlantic humpback whale (*Megaptera novaeangliae*) and agreed to conduct a Comprehensive Assessment in 1999 or 2000. The Committee considered both existing information and planned analyses of data relevant to such an assessment (Smith *et al.*, 1998). Here, we update the status of information on this population, to determine if the information required for such an assessment is likely to be available in 1999, or if the assessment should instead be conducted in 2000.

Papers published and in press

Over the last year, one paper has been published and another has been accepted for publication. Stevick *et al.* (1998a) documented the migration of whales from Norwegian waters to the West Indies breeding grounds.

Smith *et al.* (In press) described major results from the Years of the North Atlantic Humpback (YoNAH) project, including sampling methodology and results especially relative to abundance. Sex ratios on the feeding grounds were near parity, while significantly fewer females than males were sampled on the breeding grounds. Different proportions of groups sighted on the breeding grounds were sampled by photography and by biopsy, and these proportions varied with behaviour. Three sets of photographic and biopsy based estimates of total abundance were compared; those based on samples only from the feeding areas, those only from the breeding areas, and those from both breeding and feeding areas. Feeding-only and breeding-only estimates were strongly biased downward. Estimates based on both breeding and feeding ground estimates appeared to be unbiased, and the inverse-variance weighted average of photographic and biopsy-based estimates were 10,600 (CV = 0.067) and 10,400 (CV = 0.138), respectively.

Sex-specific estimates of abundance using biopsy samples only from feeding grounds were biased downward for both sexes. Corresponding estimates using samples only from breeding grounds were biased downward for females, but not for males, as suggested by Palsbøll *et al.* (1997). Possible causes of such biases were discussed, and the authors concluded that in the North Atlantic it is not possible at this time to obtain reliable abundance estimates using photographs collected solely on the breeding grounds.

Conference presentations

Several additional results from the YoNAH project were presented during the World Marine Mammal Science Conference in Monaco. Mattila *et al.* (1998) described the sexual composition of humpbacks on their breeding grounds, noting that the date of first sighting of animals seen in successive years was highly correlated for females but uncorrelated for males. They suggested that this may be an explanation of the apparent bias in abundance estimates of females using only breeding ground samples.

Friday *et al.* (1998) described a method for evaluating the effects of photographic quality and distinctiveness (see SC/49/O19 for an earlier version of this work). The authors demonstrated the degree of upward bias that differences in photographic quality could introduce into abundance estimates based on the YoNAH data, and provided criteria for balancing bias and precision in such cases. They also demonstrated that individual animal distinctiveness does not bias photographic-based estimates using the YoNAH data.

Stevick *et al.* (1998b) compared photographic and genetic identifications to estimate the rate of errors in matching individuals in the YoNAH data. They found no false positives using either method. Further, they showed that for photographic identification using both techniques, false negatives occurred much more frequently with poorer quality photographs and less distinct individuals, and that biopsy identification errors tended to occur with animals that matched on all but one of the six microsatellite loci used. Despite these results, the overall rate of error in the project was found to be very low.

Palsbøll *et al.* (1998) evaluated the implications of glaciation for explaining the relatively low levels of divergence among populations of North Atlantic cetaceans, drawing in part on YoNAH data. They suggest that post-glacial range expansions must be considered when interpreting the genetic structure of many North Atlantic cetacean populations.

Papers in preparation

The results presented to the 1998 World Marine Mammal Science Conference are being finalised by Mattila, Palsbøll *et al.,* Stevick *et al.* and Friday *et al.*

Abundance: Hammond is conducting a joint analysis of the YoNAH photographic and biopsy mark-recapture data to develop a combined abundance estimate. He will draw on the error rates noted by Stevick *et al.* (1998b), as well as upon a study simulating the effects on abundance estimation of sampling by different behavioural classes on the breeding ground (Friday, 1997), and other aspects of humpback behaviour (see Annex V).

Trends: In light of findings from the YoNAH project (notably those relating to effects of photo quality), Stevick is conducting a reanalysis of previously published abundance estimates based upon data from the North Atlantic Humpback Whale Catalogue. When complete, these estimates will represent the basis for estimating trends in abundance from 1979 through 1993. Larsen and Hammond are conducting an analysis of photographic data from Greenland to estimate trends in abundance on that feeding ground.

Ocean-Basin-Wide Population Structure: Reviews of the population structure in the North Atlantic are in preparation based on genetic data (Mattila and Palsbøll *et al.*) and on photographic information (Stevick *et al.*). Additional analyses of mitochondrial DNA in the western North Atlantic and of microsatellite data from all regions will be used to expand upon previously published results.

Regional Population Structure: Palsbøll and Mattila are beginning a study of the family tree of humpback whales using the Gulf of Maine (pers. comm.). Clapham *et al.* are analysing photographic data from the Gulf of Maine to identify possible regional preferences within that feeding area. Sponer *et al.* are reviewing the genetic structure of animals that summer off West Greenland. Stevick (pers. comm.) is also examining the YoNAH data within Canada to better determine the definition of that feeding ground.

Migration and Breeding Grounds: In addition to the breeding grounds sampled by YoNAH, there are several other areas in the southwestern and southeastern North Atlantic where humpback whales are known to occur in the winter. The need for additional information about the whales using Windward Islands locations is described in Clapham *et al.* (1998). There is also a need for additional information concerning animals using the Cape Verde Islands (Reiner *et al.*, 1996). Reeves is reviewing log book data from the Windward Islands and from the Cape Verdes to better determine the temporal and spatial distribution of humpback catches. Also, further light may be shed by analysis of seasonal and area patterns of vocalising whales recorded using the United States SOSUS system (Chris Clark, pers. comm.).

Catch Data: Complete catch data will not be available as much of the whaling was poorly documented, especially in the north-eastern North Atlantic. Information has already been summarised for the western North Atlantic, including the West Indies (Mitchell and Reeves, 1983). Information for catches in the eastern North Atlantic in the 20th Century can be synthesised from several publications (e.g. Thompson, 1928; Brown, 1976). Additional information on years of harvesting may be forthcoming from logbook studies by Reeves for the Windward Islands and the Cape Verdes (see above), but information on total removals is likely to remain substantially incomplete.

Conclusions

Substantial information is available on the North Atlantic humpback whale. A large number of additional analyses drawing on the North Atlantic Humpback Whale Catalogue and on YoNAH data, as well as several other regional sets of data, are underway. The additional information that has been, and continues to be, obtained from genetic analyses of the biopsy samples, has revealed a complex population structure, the full extent of which is not yet apparent. Several of the ongoing studies are addressing aspects of the temporal-spatial behaviour on both ecological, historical, and evolutionary time scales. A thorough understanding of this aspect of North Atlantic humpback whale biology may be essential for a complete assessment of population status in this area.

The most important papers from the YoNAH project are expected to be available by the end of 1998. Although many of the other analyses mentioned above are substantially developed, the likely time frame for their availability is unclear. Critical areas include the analyses of trends in abundance, and clarification of population structure, notably as it relates to specific breeding grounds. Thus, while there could be sufficient information available to conduct the Comprehensive Assessment in 1999, there would probably be substantially more information still under development at that time. In the interest of allowing a complete assessment to be conducted, and given that there does not appear to be a pressing time frame associated with this, we suggest that the assessment be conducted in 2000.

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Appendix 7

REPORT OF THE *AD HOC* INTERSESSIONAL SPERM WHALE GROUP MEETING

R.L. Brownell, Jr., T. Kasuya, H. Kato and S. Ohsumi

The *Ad hoc* Group met at the Institute of Cetacean Research, Tokyo, Japan on 2 February 1998. The meeting participants were Brownell (Convenor), Kasuya, Kato and Ohsumi.

Introduction
During the 49th meeting of the Scientific Committee, an intersessional e-mail sperm whale group was established to review plans for a Comprehensive Assessment. Our discussions in Tokyo were specifically related to sperm whales in the North Pacific.

Population studies
The following types of studies were identified for population studies: review of mark-recapture data and joint US – Japan genetic studies. A proposal by Brownell to pool US and Japanese genetic samples was discussed. Other possible sources of genetic material to be investigated are teeth from past Soviet whaling operations.

Abundance estimates
Kato and Miyashita will prepare preliminary abundance estimates for western North Pacific sperm whales. Some of the major problems associated with abundance estimates include $g(0)$, group size and acoustic corrections.

Review of past abundance estimates
It was agreed that past abundance estimates and models need to be reviewed.

Review of historical catch data
Problems in catch records relating to both numbers and sex were identified as an area of concern. Brownell noted that official Soviet pelagic whaling data were grossly under-reported. It was also noted that Japanese pelagic catch numbers are correct but that some problems exist with determination of sex and that Japanese coastal sperm whale catch data are unreliable. It was agreed that Ohsumi would review the history of sperm whale regulation in the North Pacific. Additional sources of sperm whale catch records include at least: past scientific reviews, IWC records, national records, industry records and records kept by old whalers.

Other items
Other important items that need to be discussed for a sperm whale Comprehensive Assessment include: life history, social behavior, ecosystem information, and current human-related mortality.

The *Ad hoc* Group agreed that it would recommend that the Comprehensive Assessment for sperm whales start with a focus on North Pacific sperm whales.

Appendix 8

PROGRESS REPORT ON THE WORK TO ADDRESS OUTSTANDING ISSUES OF JARPA

Government of Japan

1. Introduction
In May 1997 a meeting was held,to review the data and samples derived from the JARPA surveys (JARPA Review Meeting). The report of this meeting was adopted at the 49th Annual Meeting of the IWC Scientific Committtee held in September 1997. The Committee adopted the JARPA review report and listed several tasks to address unresolved problems, discussed the usefulness of past commercial samples and identified the plan to address the problem of sampling biases (IWC, 1998a, pp. 95-106). Progress made on each of these tasks is given in SC/50/O1.

The aim of this Appendix is to brief Committee members further as to progress on the tasks on JARPA identified last year. It should be noted that the period between the 49th and 50th meetings was shorter than normal. Thus, for some of the tasks identified there is, as yet, no substantial progress.

2. Future work of JARPA

The Committee listed the tasks below at last year's meeting (IWC, 1998a, p.103).

(1) Development of methods to correct bias of abundance estimate.
(2) Stock definition.
(3) Statistical analysis of mtDNA data considering the inclusion of school sizes as a covariate.
(4) Pilot study on nuclear DNA analysis on JARPA minke samples.
(5) Effort to obtain biological materials for genetic analysis from low latitude areas of the Southern Hemisphere.
(6) External morphology/morphometry analysis for stock structure.
(7) Examination of possible stock boundaries (geographical and temporal) in Areas IV and V.
(8) Segregation study.
(9) Recalculation of biological parameters by biological stocks.
(10) Mesoscale survey plan on marine ecosystem and environmental change.

The Committee also discussed two additional items: (1) on the availability and existence of commercial samples for stock-ID analyses; and (2) the problem of representativeness of samples. On the latter item, Japanese scientists presented their plans to address the problem of sampling biases as follows:

(i) the size of the biases will be evaluated using a resampling simulation model;
(ii) post (cruise) modelling methods will be applied to determine whether it is possible to resolve or reduce biases;
(iii) if this is not effective, modification of the sampling scheme will be considered, and the effectiveness and practicality of such a modification will be evaluated; while
(iv) simultaneously, the comparability between the current and any new scheme will be carefully evaluated.

3. Progress on the ten main items

3.1 Development of methods to correct bias of abundance estimate

With respect to item 1, a study was already in progress by Borchers and his colleagues. Some details of this work had already been submitted to last year's meeting (Clarke and Borchers, 1997), and further progress presented this year in SC/50/CAWS34.

3.2 Stock definition

On item 2, the Committee agreed last year that the lack of a working definition of stocks and sub-stocks is a general problem, not only for JARPA, and therefore needs to be addressed by the Committee (SC/49/Rep1). Japanese calculations of the sample sizes necessary to obtain adequate statistical power in identifying separate stocks in the JARPA program, have been based on the assumption that the extent of genetic variation found between the 'Western' and the 'Core' stocks is typical of that which distinguishes different breeding stocks. We hope the Committee will take the initiative for establishing stock definition and Japanese scientists are willing to cooperate in such work.

3.3 Statistical analysis of mtDNA data considering the inclusion of school sizes as a covariate

Japanese scientists will establish a group to include scientists in genetics and mathematics for this item. Work will start in the near future.

3.4 Pilot study on nuclear DNA analysis on JARPA minke samples

On item 4, Abe, Goto and Pastene have begun a preliminary microsatellite analysis in the Southern ordinary form minke whale. They used historical samples from Brazil, and JARPA samples from Area IV obtained in the 1989/90 survey. Samples from Area IV were grouped in a similar way as in the mtDNA analysis: Area IVW-early, Area IVW-late and Area IVE-early and late. Five microsatellites were used in the analysis: GT23, GATA98, EV1Pm, EV94Mn and EV104Mn. Given the preliminary character of this analysis, no document will be presented at this meeting. However, some preliminary results are shown in the progress report of the Institute of Cetacean Research (SC/50/O3).

3.5 Effort to obtain biological materials for genetic analysis from low latitude areas of the Southern Hemisphere

With respect to sampling in the breeding grounds, Japanese scientists also recognise that samples from the low-latitudinal areas (i.e. breeding grounds) are important. The results of a survey of biological material among researchers and institutions of the Southern Hemisphere was presented in draft at the 45th meeting. No comprehensive samples have been made available to date. Analyses of individual samples caught in the area off Brazil by commercial whaling are currently underway. Samples from minke whales, which were collected off Durban in the mid-1970s by Best, are available. We need to check whether these samples are useful for DNA analysis.

3.6 External morphology/morphometry analysis for stock structure

There has been no progress on the analysis of the morphology of minke whales, the problem of individual variations in measurement among researchers is not yet resolved.

3.7 Examination of possible stock boundaries (geographical and temporal) in Area IV

3.8 Segregation study

3.9 Recalculation of biological parameters by biological stocks

These items are closely linked to the context of the results of the Committee discussion on stock definition. After resolving this matter and sampling biases, Japanese scientists will recalculate biological parameters.

3.10 Mesoscale survey plan on marine ecosystem and environmental change

This item is under consideration. Under the present scale of the JARPA survey there is no time to incorporate the mesoscale survey. Restructuring of the research scale or use of another research vessel would be necessary before this item could be considered further.

4. Progress on the additional two items

4.1 Availability of existing samples for genetic analysis

Taylor (1997) suggested a method to incorporate commercial samples into the genetic analyses. Although JARPA is not a research only for genetic analyses, the suggestion contains interesting elements. As a first step, researchers in Japan sought to re-establish a comprehensive inventory of usable commercial samples. This list was made available to this meeting in Yoshida *et al.* (SC/50/RMP6).

On the second task of this issue in IWC (1998, annex U1), i.e. a test for usefulness of commercial samples for genetic analysis, a preliminary examination has been conducted using the JARPA samples by Goto *et al.* (1998). From this analysis, the Western Stock was only detected through comparison of offshore and ice-edge samples collected in JARPA surveys from Area IV. This suggests that commercial samples, usually collected in waters close to ice-edge, are not sufficient for stock distribution identification.

4.2 On sampling biases

Examination on item (i), i.e. simulation model, has already started. The original plan of the JARPA program was to incorporate both the abundance estimate in each school size and biological data for individual whales because the sampling rate differed by school size (Kishino *et al.*, 1991). As a first step, Japanese scientists are going to calculate the revised abundance estimates by school size incorporating the method of Burt and Borchers (1997). After this calculation, the work will be done, in order, from items (ii) to (iv).

At the last meeting, one approach was proposed for a possible modification of the current sampling scheme (IWC, 1998, annex U2). To respond to this suggestion, the next JARPA survey will be planned to include a limited scale, feasibility study on whether the modified method suggested is workable or not. Tentatively, the preliminary results of this feasibility study will be reported during the 1999 Scientific Committee meeting.

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Appendix 9

SOME COMMENTS ON VPA ASSESSMENTS OF SOUTHERN HEMISPHERE MINKE WHALES IN RESPONSE TO SC/50/CAWS32 BY POLACHECK

D.S. Butterworth and A.E. Punt

A key misunderstanding

SC/50/CAWS32 examines some aspects of earlier VPA assessments by ourselves and co-authors reported in Butterworth *et al.* (1999), which was considered by the 1997 meeting of the Scientific Committee. In particular, SC/50/CAWS32 argues that,

> estimated increasing recruitment trends prior to exploitation in Butterworth *et al.* (1999) are critically dependent upon their selectivity assumptions for the commercial catches

and that the results of SC/50/CAWS32,

> indicate that the issue of the pre-exploitation trends in recruitment remains unresolved.

Unfortunately, it seems that the author of SC/50/CAWS32 has missed/misunderstood the implications of certain sensitivity tests reported in Butterworth *et al.* (1999), which address his otherwise legitimate concerns, and negate his conclusions stated above.

To understand this, it is necessary first to explain the meaning of the parameter S^c_{26} introduced in Butterworth *et al.* (1997). That analysis allows for the possibility for a slope, either up or down, in the selectivity of the commercial catch over ages 21-30. A value $S^c_{26} < 1$ reflects a positive slope (i.e. selectivity increasing with age), while $S^c_{26} > 1$ indicates the reverse.

The 'base case' estimator of Butterworth *et al.* (1999) indeed set $S^c_{26} = 1$, i.e. it fixed the commercial selectivity to be flat over ages 21-30. This was motivated on the grounds that S^c_{26} was likely < 1 for reasons related to biological and operational information, which are detailed in that paper (and in regard to which SC/50/CAWS32 raises some legitimate questions concerning which comments are made below). The choice of $S^c_{26} = 1$ was made to ensure, in the context of this motivation, that the resultant estimate of an historic recruitment trend would be negatively biased. Indeed, this point and the sensitivity of this trend estimate for Area IV to the value of S^c_{26} was illustrated in fig. 4 of Butterworth *et al.* (1999).

But, though this approach was followed as it was considered the best defensible, other results in Butterworth *et al.* (1997) show that it is actually not necessary to impose this constraint on S^c_{26} externally, and that the conclusions of the paper re. historic recruitment trends follow from the VPA input data and the assumption of flat selectivity at large ages for the (intended random) JARPA catches alone.

Table 7 and fig. 4 of Butterworth *et al.* (1999) show results when S^c_{26} is treated as an estimable parameter. The consequent estimate for S^c_{26} is slightly above 1, though not significantly different therefrom. The associated historic recruitment trend is positive when S^c_{26} is estimated without constraints. Furthermore, the bootstrap 90% confidence interval for this trend estimate is entirely positive (see table 9 of Butterworth *et al.*, 1999), i.e. in this context the possibility of a flat or negative historic recruitment trend is statistically incompatible with the data.

This then negates the key conclusion of SC/50/CAWS32, the analysis in which is unable to address this point because it omits a contribution from the commercial catches-at-age in the likelihood.

Other aspects

Older ages and associated selectivities

SC/50/CAWS32 states that results in Butterworth *et al.* (1999) imply that commercial selectivities decrease for whales above age 30. Given the estimability (and estimate) of S^c_{26} as explained above, this does not negate any of the conclusions of the latter paper. Nevertheless, the following points should also be kept in mind:

(1) the decision to restrict the ages considered in the base case analysis of Butterworth *et al.* (1997) to 30 and below, was made on the basis of the formal recommendation of the highly regarded ICES Working Group on Methods of Fish Stock Assessment, that data for VPA assessments be truncated in this manner – this is because of the poor precision associated with introducing low sample sizes into the analysis, greater possibilities of bias arising from the greater difficulties of reading larger ages accurately, the possibility of senescence – with its associated increase in M at large age, and so on;

(2) tests and alternative choices for the oldest age in the VPA computations do not indicate great sensitivity of results (see table 8 of Butterworth *et al.* (1999), tests '$m = 26$' and '$m = 32$');

(3) SC/50/CAWS32 reports only point estimates of commercial selectivities for ages above 30 – these estimates will not be very precise because of the low sample sizes involved, so that inferences about trends therefrom may not be statistically reliable.

Unequal sex ratio in the catches

SC/50/CAWS32 implies that failure to take the female preponderance in historic catches into account may have biased results. However, variants of the model of Butterworth *et al.* (1999) that did take account of this indicated no great sensitivity of final results (see table 8, tests 'Males only' and 'Females only').

Form of the term added to likelihood in SC/50/CAWS32

The form of the contribution of the recruitments for the years 1994-1971 (1950-1971 for Area V) to the negative of the log-likelihood function leads directly to the result that the estimates of recruitment for these years are equal to the mean recruitment. This is because the likelihood is minimised if the extent of process error (the deviations in recruitment from the average recruitment) is set **equal to zero irrespective of the fit to any other data**. This is because setting these deviations to zero leads to the negative log-likelihood being equal to $-\infty$. Punt *et al.* (1997) estimate the extent of 'additional variance' for Southern Hemisphere minke whales and show that account needs to be taken of the estimation of the nuisance parameters when constructing the likelihood function. It would seem that a similar approach would be needed in this case to obtain unbiased estimates of recruitment. However, owing to the complexity of the underlying model, it seems unlikely that construction of the reduced information matrix will be straightforward. Another way to deal with this problem would be to pre-specify rather than estimate the extent of variation in recruitment.

It is unclear whether it is appropriate to estimate the recruitments for 1944-1956 (1950-1956 for Area V) even if the likelihood function had accounted for the estimation of the nuisance parameters. This is because none of the data used in the analysis have any influence on the size of these recruitments. The model estimates of the IWC/IDCR abundance estimates for 1980 and 1989 (1980 and 1986 for Area V) do depend on the sizes of these recruitments, but this dependence is very weak, and certainly not sufficient to allow reliable estimation of these recruitments. Therefore, the estimates of these recruitments would be set equal to the average recruitment, seemlingy supporting the assumption of constant recruitment. In contrast to this, the age-data from the period of commercial whaling allow Butterworth *et al.* (1999) to estimate these recruitments.

Spatial/Temporal analyses of the age structure of JARPA samples

The author of SC/50/CAWS32 states that he is unaware of any such analyses. Cooke *et al.* (1997) as reported to the 1997 JARPA Review Meeting, found no significant evidence for heterogeneities in those respects for ages above 10 (though the power of such analyses is obviously somewhat limited given the sample sizes).

Are older minke whales less likely to be caught?

SC/50/CAWS32 raises a number of interesting considerations in this regard, such as older animals having a refuge from whalers in the pack ice. Indeed the analysis of Butterworth *et al.* (1999), which yields a 90% confidence interval for S^c_{26} of [0.94, 1.16], does not exclude this possibility.

Best (pers. comm.) also raises some interesting points on this matter. He observes that though minke length is difficult to estimate in absolute terms, it would nevertheless be relatively easy for the whalers to select the largest animal in a group, which points towards commercial selectivity increasing with age. He also draws attention to the fact that USSR vessels (being ice-strengthened) operated farther into the pack ice than did the Japanese vessels. Quick inspection of the length frequency distributions from the commercial catches in Area IV show the modal lengths of the USSR minke catches to be about 0.5m larger than for those by the Japanese, which could suggest a decreasing selectivity at large ages for the Japanese component of the overall catch. However, for larger lengths, there is little correlation between length and age for minke whales, so that this observation may merely reflect that bigger, and not necessarily older whales go farther into the pack ice. Also, if the Japanese commercial catches do show a declining selectivity at age for large ages for this reason, the JARPA catches would be expected to show the same feature, suggesting that the estimate of the extent of the change in the recruitment trend in Butterworth *et al.* (1999) would not be much affected.

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Appendix 10

COMMENTS ON APPENDIX 9

Tom Polacheck

This Appendix is divided into two main sections. The first is a short overview of the 'key misunderstanding' cited in Appendix 9 and the second, longer section, is a more detailed discussion of the technical issues raised in Appendix 9.

An overview of the misunderstanding

In Appendix 9, Butterworth and Punt suggest that I (the author of SC/50/CAW32) had 'a key misunderstanding' of the implications of certain sensitivity test reported in Butterworth *et al.* (1999). Unfortunately, the issues raised in SC/50/CAW32 do not stem from a simple (or complex) misunderstanding of the implications of the sensitivity tests discussed in Appendix 9. However, there definitely appears to be some misunderstanding and what is being misunderstood needs to be resolved.

Being fully aware of the sensitivity tests in Butterworth *et al.* (1999) and their implications, it was acknowledged in SC/50/CAW32 that the authors of Butterworth *et al.* (1999) had conducted extensive sensitivity tests of their results. However, the robustness of a set of sensitivity tests depends on the specification of those tests. As stated in SC/50/CAW32, its purpose was to provide some further evaluation of the robustness of the conclusions in Butterworth *et al.* (1999).

A key conclusion in Butterworth *et al.* (1999) is that there was an increasing trend in recruitments prior to exploitation. A common way to test the robustness of a conclusion is to assume it is false and then examine the implications. If one assumes that the conclusion is false while in fact it is 'true', then the expectation is that one should obtain a basic inconsistency. This is the approach taken in SC/50/CAW32. Given the assertion in Butterworth *et al.* (1999) that recruitment prior to exploitation was increasing, the expectation was that a basic inconsistency would be seen when it was assumed that pre-exploitation recruitments were constant. However, this did not occur. In fact, the only substantive differences in terms of what is being fit in the models were the resulting selectivities for the commercial catches (i.e. the fit to the survey abundance indices and the age structure of the JARPA catches were very similar). Thus, within this modelling framework, only if the selectivity curves obtained in SC/50/CAW32 are considered implausible can one consider the hypothesis that pre-exploitation recruitments were constant to be implausible.

The differences in the selectivity pattern obtained compared to those in Butterworth *et al.* (1999) are displayed in figs 3-6 of SC/50/CAWS32. The selectivity patterns in both cases are dome shaped with the main difference being the age at which the peaks occur. Within the basic VPA model framework being used in both Butterworth *et al.* (1999) and SC/50/CAW32, the general selectivity pattern in SC/50/CAWS32, figs 3 and 5 will yield constant recruitment trends. On the other hand, the general selectivity patterns in SC/50/CAWS32, figs 4 and 6 (i.e. those for the base case in Butterworth *et al.*,1999), will result in increasing recruitment trends. For either selectivity pattern, the fit to the input data and the selectivity/separability assumptions for the JARPA catches are essentially equivalent. It is this equivalence in the fit that led to the conclusion that 'the estimated increasing recruitment trends prior to exploitation in Butterworth *et al.* (1999) are critically dependent upon their selectivity assumptions for the commercial catch'. Moreover, given all the factors that can affect the actual selectivity in commercial harvesting, the differences between the two sets of selectivity curve do not provide a sufficient basis for making definitive conclusions about pre-exploitation recruitment.

Elaboration and technical comments on Appendix 9

Sensitivity tests in Butterworth et al. (1999)

As Appendix 9 pointed out, Butterworth *et al.* (1999) provides some sensitivity tests to the commercial selectivity assumption of their approach. A careful look at this sensitivity analyses is quite informative. Butterworth *et al.* (1999) provides a set of sensitivity analyses for their selectivity assumptions by considering the hypothesis that selectivity between the three age groups, 23, 26 and 29 was a linear function and constant in time. For Area IV, results for values of the slope of this assumed relationship are provided (expressed in terms of the selectivity at age 26 compared to age 29). It is clear from the sensitivity tests, that if S^c_{26} were set to about 1.4 then the estimated slope of the pre-exploitation recruitment trend would go to zero. Thus, the sensitivity tests in Butterworth *et al.* (1999) demonstrate that an increasing pre-exploitation trend is dependent upon the specific selectivity/separable assumptions used[1].

[1] While a value of 1.4 is outside of the 90% confidence limit given for S^c_{26} in Appendix 9 and thus not statistically likely within the Butterworth *et al.* (1999) formulation, the range of selectivity models tested in Butterworth *et al.* (1999) was quite limited (see below) and these confidence intervals are dependent upon their selectivity and separable assumptions. With a value of 1.4, the model estimates a set of realised selectivity. Butterworth *et al.* (1999) results indicate that these realised selectivities are not highly likely in the context of the assumption of a constant linear selectivity relationship. However, for different assumptions about the selectivity patterns, they would be. Thus, the question is whether the formulation in Butterworth *et al.* (1999) encompasses the full range of plausible selectivity patterns for the commercial catches.

Appendix 9 provides two types of arguments why one would reject S^c_{26} being greater than one. One is based on their estimated likelihood and the other is based on biological and operational information. Since their estimated likelihood function in this case can only be derived from their selectivity and separable assumptions, it becomes circular to argue that the resulting estimated value for the likelihood provides support for those assumptions[2]. It is the second type of argument (i.e. those based on biological and operational information) that is relevant. The Discussion section of SC/50/CAW32 elaborates a number of observations, issues and concerns with respect to the interpretation of possible selectivity patterns in commercial catch from biological and operational information. SC/50/CAW32 notes the difficulty in attempting to infer selectivity patterns from such data. However, it suggests that a useful step forward would be to undertake more comprehensive analyses of the age and locational information from the commercial and JARPA catches.

Table 9 from Butterworth *et al.* (1999) notes that the 90% confidence intervals for the slope of the trend estimates in this table are entirely positive. It is worth noting that the lower limit for two of the eight confidence intervals in this table is zero (at least to three significant figures) and 0.002 for two others. Presumably, if one considered the more standard 95% intervals, the confidence intervals would encompass negative values. Also, the set of bootstrap results in Table 9 includes only one or two dimensional variants of the base-case estimator. The intervals would be wider if a fuller dimensional consideration of the uncertainties had been undertaken.

Older ages and associated selectivities

Appendix 9 states that decreasing selectivity for whales past age 30 does not negate any of the conclusions of the latter paper. In a formal sense, this is true since selectivity assumptions for whales past age 30 are not used in the likelihood formulation. Thus, whatever the selectivities are for these older animals, they have no effects on the recruitment estimates. However, the implicit selectivities for these older animals do have important significance for evaluating the relevance of the selectivity assumption for the commercial catch underlying the specific model formulation in Butterworth *et al.* (1999).

Butterworth *et al.* (1999) conclude, based on its consideration of biological and operational information, that selectivities should be non-decreasing up to age 29. Their rationale and arguments would seem equally applicable to animals past 30. Thus, the fact that the selectivities decrease past 30 in their model results would seem to be inconsistent with the basis for the selectivity assumption underlying their model formulation. Moreover, if selectivities decrease with age past 30, then the implication is that they are 'dome' shape. In this case, it is not clear why one should necessarily assume that the peak in the dome should be flat between ages 22-30, as is assumed in their base-case or that it is constrained to lie at either age 23 or 29, as is assumed in their sensitivity analyses. In fact, the maximum likelihood estimate for the slope parameter for the commercial selectivities between ages 22-30 in their sensitivity test results is negative. This indicates that the best estimate, even within their formulation, is that selectivities are 'dome' shaped below the terminal age of 28-30 and that the peak of the dome occurs at age 22. The results in Butterworth *et al.* (1999) do not allow for the possibility that the peak could occur below this age.

With respect to the three specific points that Appendix 9 list in this regard:

(1) It was never suggested (nor would I ever suggest) that one should not use a plus group in a VPA analysis of this type. However, one should not ignore the information contained in the age data for the plus group catches - particularly if direct ageing methods have been used. It should also be pointed out that if M was increasing within the plus group, that this would tend to require larger recruitments from the pre-exploitation cohorts. This is required in order for them to make the same contribution to the estimates of total population sizes when fitting to the IDCR and JARPA abundance estimates. This could reduce or eliminate the increasing recruitment trend in Butterworth *et al.* (1999).
(2) The sensitivity tests for choice of terminal ages does not free up the constraint that selectivities must be decreasing below age 22.
(3) The sample sizes for the plus group commercial catches in most years are quite substantial (i.e. >200) and if selectivity were flat the expected numbers would have been substantially greater.

Spatial/temporal analyses of the age structure data

In SC/50/CAW32 it was noted that I was not aware of any comprehensive analyses of the spatial/temporal patterns of the age structure of either the commercial catches or of the more recent JARPA samples. Appendix 9 points to Cooke *et al.* (1997) as such a study for the JARPA data. Having not been at the JARPA Review Meeting, I was not aware of the details of this paper. I thank the authors of Appendix 9 for directing me to it. I see no value and have no interest in getting into a debate as to what constitutes a comprehensive analysis. However, in making my original comment I had envisioned a more detailed examination of the spatial/temporal pattern of the age compositional data than is contained in Cooke *et al.* (1997) (e.g. latitude in this paper is only considered in terms of N/S of 65 and no longitudinal effects are considered). My comment was motivated by the analyses of portions of the JARPA data that are contained in a variety of papers which display latitudinal, longitudinal, and seasonal differences (some of them clearly significant) (e.g. Kato *et al.*, 1990; Fujise *et al.*, 1994).

Are older animals less likely to be caught?

Best's pers. comm. in Appendix 9, combined with the possible difference in lengths between the Japanese and Russian catches, does suggest that the declining selectivity for the Japanese commercial catch can not simply be dismissed as being outside of the range of plausible hypotheses. The suggestion that the selectivity in the JARPA catches may also have a decreasing selectivity with age because of whales within the pack ice needs to be further explored. However, it is not clear if this effect did exist in

[2] For example, in my formulation, I could turn the estimation problem around and assume that the underlying selectivity patterns during the commercial harvested were those pictured in figs 3 and 5 of SC/50/RMP32. In such a formulation, no assumptions about recruitment trends would need to be made. A likelihood component could then be derived for the catch-at-age data based on these assumed selectivity patterns. If I did this, I would get the same recruitment estimates and the likelihood component for the commercial catch component would equal 1. Of course, it would be totally inappropriate to then argue that the likelihood estimates can be used to justify the assumed selectivities.

both the JARPA and the commercial catches, what the combined effect would be on the recruitment trends in Butterworth *et al.* (1999).

Form of term added to the likelihood and the information for estimating pre-exploitation recruitments

Appendix 9 points out a problem with the formulation of the added term in the likelihood in SC/50/CAW32. The authors are correct that as formulated the negative of log-likelihood will go to negative infinity. While not intentional, it turns out that there was an error in the program that calculated the likelihood function that ensured that the nuisance parameter (i.e. the variance in the pre-exploitation recruitments) did not go to zero.

It should be noted that the results will not be very sensitive to whatever value is used for the nuisance parameter. The reason for this relates directly to the second paragraph of Appendix 9 on this topic. As pointed out in Appendix 9, there is only a weak link or dependence between each of the individual early recruitment estimates and the other data used in the analyses. The dependence comes from the contribution of these cohorts to the estimated total population size in years when there were abundance surveys. This dependence is sufficient to determine the general magnitude or 'average' recruitment levels during this period so that the total contribution from these cohorts to the estimated population numbers is of the appropriate magnitude in those years when there are survey abundance estimates for the total population. However, the dependence is not sufficient to provide much information for estimating the year specific recruitment estimates (and this is the reason that SC/50/CAW32 ends up with essentially no variation around the estimated constant mean levels in these early years). It is also for this reason that one could replace the constant recruitment assumption in SC/50/CAW32 with either an increasing or decreasing trend and still get essentially the same fit in terms of the other components of the likelihood function. The model is informative about the overall level of recruitment that must have occurred in these early years, but not about its pattern.

The question can be asked how does Butterworth *et al.* (1999) get around this problem so as to provide 'informative' estimates of the individual recruitment estimates for these early years? It uses no additional external data than that used in SC/50/CAW32. The answer is that Butterworth *et al.* (1999) gets around this problem through the use of selectivity and separability assumptions for the commercial catches. These assumptions allow one to construct a likelihood term for these catches based on the relative proportions by age in the catches within a year. However, the form of this likelihood term is dependent upon the assumptions made about the selectivities during the commercial catch; change the selectivity assumptions and one will get different recruitment estimates (also see above and footnote 1). Thus, Appendix 9 is correct in stating that 'age-data from the period of the commercial whaling allow Butterworth *et al.* (1999) to estimate these recruitments', but this is only true because of the selectivity assumptions made in that paper[3]. There is no external data (such as survey abundance estimates) used to estimate these trends. This is the basis for SC/50/CAW32 concluding that the 'estimated increasing recruitment trends prior to exploitation in Butterworth *et al.* (1999) are critically dependent upon their selectivity assumptions for the commercial catches'.

Is there a way forward?

SC/50/CAW32 suggests one way forward; to undertake more comprehensive analyses of the commercial and JARPA age compositional data. This might provide a firmer basis for developing a range of plausible hypotheses for the selectivities during the commercial harvest. In conjunction with this, it may be worthwhile considering within the context of Butterworth *et al.* (1999) a broader range of functional forms for the expected selectivities in the commercial catch (e.g. quadratic over the 10 plus age range with allowance for a temporal component). This would at least provide an assessment of whether there is some statistical basis in terms of likelihoods and number of parameters (e.g. AIC) for excluding particular selectivity patterns - although one needs to be cautious about the potential power to distinguish between different selectivity patterns solely on statistical grounds. In this regard, it would be valuable to know how the likelihood for a functional representation (based on a small number of parameters) of the selectivity patterns that yielded constant recruitment in SC/50/CAW32 compares with those in Butterworth *et al.* (1999).

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[3] It should be noted that the JARPA catch data have little or no influence on the individual estimate of recruitment for these early recruitments and that it is these early recruitment estimates which determine if an increasing trend existed. Appendix 9 does not appear to be consistent about this. On the one hand it states that the 'age-data from the period of the commercial whaling allow Butterworth *et al.* (1999) to estimate these recruitments', which makes sense based on the above discussion. On the other hand, earlier in the paper it is assertes 'that the conclusions of the paper re. historic trends follow from the VPA input data and the assumption of flat selectivity at large ages for the (intended random) JARPA alone'.

Appendix 11

ON QUERIES RAISED IN SC/50/CAWS32 CONCERNING INFERENCES ABOUT THE HISTORIC RECRUITMENT TREND FOR SOUTHERN HEMIPSHERE MINKE WHALES BASED UPON VPA ASSESSMENTS

D.S. Butterworth

The selectivity assumptions for the commercial catch in Butterworth *et al.* (1999) which are queried by Polacheck in SC/50/CAWS32, were motivated on two independent grounds, 'biological' and 'statistical'. The following responses are offered to his criticisms.

Biological grounds

(i) An increasing selectivity-at-age was suggested by the combination of the whalers' desire to take larger animals, coupled to the fact that whaling took place close to the ice edge, and a larger proportion of bigger animals are indicated to be there by IDCR percent takeable data, commercial whaling data and JARPA data (see table 4 of Butterworth *et al.* (1999), which indicates an increasing trend in the age of animals caught in Area IV by degree latitude strip from 61º 10°S to 66+° 10°S).

(ii) Suggestions in SC/50/CAWS32 that results are confounded by differential male/female availability spatially are refuted by sensitivity tests in Butterworth *et al.* (1999), table 8, which shows historic recruitment trend estimates to be essentially unchanged when the analyses were conducted on a sex-disaggregated basis.

(iii) The commercial selectivity curves reported in SC/50/CAWS32 to correspond to an assumption of a flat historic recruitment trend, reflect an unavailability of some 25% of otherwise takeable minke whales. Of the explanations offered by Polacheck for this:

(a) a reflection of local depletion caused by the concentration of whaling close to the boundaries of Management Areas – this is refuted by calculations of additional variance reported in Punt *et al.* (1997) which indicate substantial inter-annual movements of minke whales on a greater longitudinal scale than this;

(b) presence of these older animals in lower latitudinal waters – this is refuted by analyses using Japanese Scouting Vessel data to extrapolate minke whale abundances north of the IDCR survey area to 30°S (Borchers *et al.*, 1990) which show there to be a relatively small proportion of the population in this area in mid-summer, much of which must comprise younger animals given IDCR estimates of proportion takeable and relatively low abundances of the youngest age classes in JARPA survey samples; and

(c) animals in the pack-ice unavailable to whalers – an average value of some 25% over time seems large, but even if this is the case, it would indicate that the JARPA selectivity-at-age also decreases at large age; since the conclusion of an historic increasing recruitment trend is a reflection of *changes* over time in the catch-curve slope (Butterworth and Punt, 1990, see equation 5 and following), similar changes to the selectivity assumptions for both the commercial and JARPA catches would not likely change conclusions regarding recruitment trends (though it would also be desirable to check this computationally in this particular case).

Statistical grounds

(i) Butterworth *et al.* (1999) shows (table 9) that when the slope of the commercial selectivity-at-age from ages 22-30 is treated as an estimable parameter rather than fixed to be flat ('2-parameter approach'), the conclusion of a historic increase in recruitment significant at the 5% level remains.

(ii) Polacheck has correctly pointed out that the calculation in (i) is conditional on any maximum in the commercial selectivity-at-age occurring at ages above 21; however, the text of Butterworth *et al.* (1999) indicates that other runs of the model considered there, which allowed a fully flexible shape of this selectivity function ('4 parameter' approach) as sought by Polacheck, were rejected in favour of the simpler parameterisation for which results were reported ('1 parameter' approach) on the basis of likelihood ratio tests (though since such other results are not reported in detail in Butterworth *et al.* (1999), I would wish to recheck the outputs in question before being absolutely definitive on this point); furthermore, rough calculations based on the base-case ('1 parameter') commercial selectivity-at-age estimate for ages 16-21 (0.86 compared to 1 for ages 22-30), coupled with the best estimate of the age 22-30 selectivity slope when treated as an estimable parameter (a decrease of some 0.08 to 0.10 over this age range), suggest that the constraint of a selectivity maximum at an age above 21 is not impinging on the results corresponding to the latter ('2-parameter') approach which limited the selectivity on ages 16-21 to a maximum of 1.

(iii) The general formulation considered in Butterworth *et al.* (1999) does not impose any selectivity pattern on the commercial catches-at-age at ages less than 16 in the light of results in Sakuramoto and Tanaka (1985) which suggested high variability in commercial selectivity for such younger ages, and makes only the weak assumption of temporal invariance in expectation (i.e. not deterministic invariance) for the selectivity pattern above that age. In contrast, the likelihood in SC/50/CAWS32 gives infinite weight (in principle – though reportedly only very large in practice) to the contribution seeking constancy in the recruitment prior to the onset of commercial whaling, while omitting any contribution from the commercial catches-at-age entirely, thus allowing no possibility for at least some selectivity pattern in such data (as is conventionally allowed in VPA assessment of fish stocks) to influence results.

(iv) Inferences SC/50/CAWS32 about selectivity at age above 30 derived from the results in Butterworth *et al.* (1999) are of questionable reliability because of the small sample sizes available, the absence of variance estimates accompanying the results reported and plausible alternative interpretations of increasing natural mortality with age or ageing error at such relatively large ages.

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