Report of the Workshop on the Comprehensive Assessment of Southern Hemisphere humpback whales

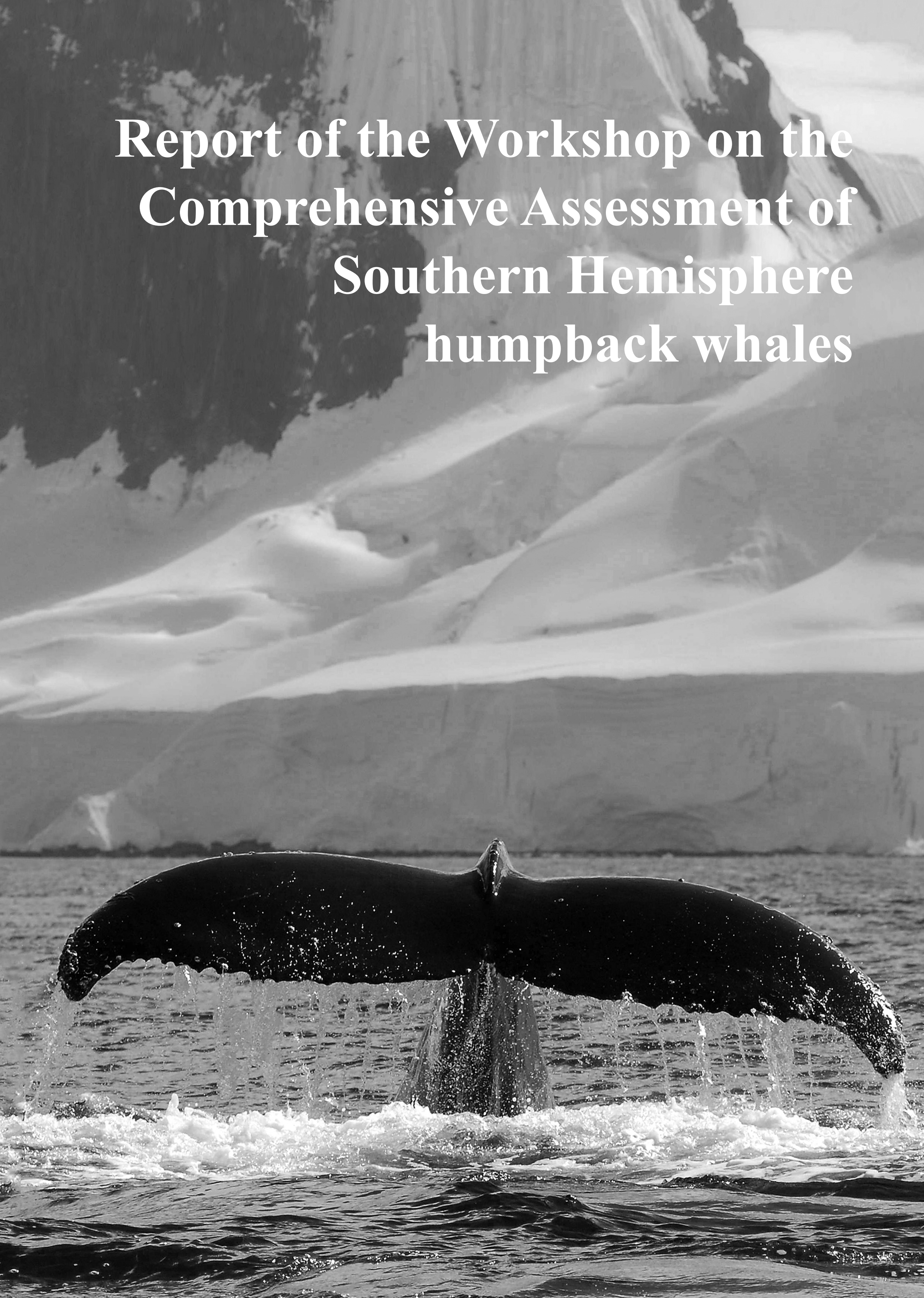

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Photo: © Humpback whale – Antarctic Peninsula. Photo by Emma Newcombe, courtesy of Carlos Olavarría (CEQUA-INACH).

Report of the Workshop on the Comprehensive Assessment of Southern Hemisphere humpback whales

The Workshop was held at the Australian Antarctic Division, Hobart, Tasmania from 4–7 April 2006. The list of participants is given as Annex A.

1. INTRODUCTORY ITEMS

1.1 Welcome and introduction
Gales welcomed the participants to the Workshop. He thanked the steering committee for their assistance in preparations for the meeting, in particular Findlay and Zerbini. He also thanked Bannister and Findlay for producing the summary information and metadata tables that can be found on the IWC website*. For logistical support he thanked Jemma Miller [now Jones] from the IWC Secretariat, and Sarah Robinson and Mandy Denny for local support. Funding for the Workshop came primarily from the Australian Government with additional support being provided by the IWC and the National Marine Fisheries Service (USA).

Donovan welcomed the participants on behalf of the IWC. In particular, he thanked Gales and Robinson for their hard work in providing the excellent facilities and arranging accommodation for the participants.

Donovan had the sad duty to inform the meeting of the recent death of Dr Geoff Kirkwood of Imperial College, London. Geoff had, along with Dr Kay Radway Allen, been one of the primary leaders in the field of population modelling within the Scientific Committee from the mid 1970s when he had been based at CSIRO in Cronulla, Australia and then Hobart. He had been Chair of the Scientific Committee and also chaired the RMP working group until the adoption of the RMP in 1994. He chaired with skill, wisdom and great humour. The meeting held a minute's silence in his honour.

1.2 Terms of reference
In 2005, the Scientific Committee agreed that an Intersessional Workshop be held to advance the Comprehensive Assessment of Southern Hemisphere humpback whales to the point where the process can be completed at the 2006 Annual Meeting.

The agreed Terms of Reference of the Workshop were:

(1) to advance the Comprehensive Assessment of Southern Hemisphere humpback whales to near completion using the best available data; and
(2) to review the abundance, population structure and status of Southern Hemisphere humpback whale breeding populations and their relationship to feeding grounds in the Southern Ocean.

1.3 Election of Chair and appointment of rapporteurs
Bannister was elected Chair. Donovan agreed to co-ordinate the production of the report with the assistance of Butterworth, Childerhouse, Clapham, Findlay, Polacheck and Wade. Final editing of the report was undertaken by Donovan.

* *http://www.iwcoffice.org/documents/sci_com/workshops/Table2.pdf* accessed October 2011.

1.4 Meeting procedures and time schedule
Gales detailed the practical arrangements for the meeting.

1.5 Adoption of the Agenda
The adopted Agenda is given as Annex B.

1.6 Documents available
The list of documents is given as Annex C. The Workshop also had available the most recent tabulated summaries of information available and metadata available as published on the IWC website*.

1.7 Publication of proceedings
It was agreed that, provided there were sufficient high quality papers, it would be appropriate to publish the report of this workshop and appropriate papers as a Special Issue of the *Journal of Cetacean Research and Management*, similar to that resulting from the earlier work on right whales (Best *et al.*, 2001). An editorial team will be assembled and the usual refereeing policy of the journal will be followed. Authors wishing to have their papers considered for publication were asked to inform Gales and Donovan.

2. ASSESSMENT PROCEDURES

2.1 Model or models to be used – general discussion
It was **agreed** that it would be valuable to have an initial general discussion on the modelling framework(s) that might be considered at this Workshop, in order to focus discussions on subsequent Agenda Items. Initial discussions were held in a Working Group convened by Clapham and its report has been subsumed here.

The primary issues identified were:

(1) allocation of feeding ground catches to breeding stocks, notably when mixing of two or more breeding stocks on a feeding ground is suspected;
(2) treatment of abundance estimates from the feeding grounds when allocation of animals to breeding areas is uncertain;
(3) treatment of possible sub-structure in the breeding grounds; and
(4) incorporation of demographic parameters not typically included in modelling (e.g. depensation).

2.2 Allocation of feeding ground catches to breeding stocks
Care must be taken when allocating feeding ground catches to breeding stocks, particularly when mixing of two or more breeding stocks on a feeding ground is suspected. The extent of this problem may vary with feeding area and breeding stock, as discussed under Item 3. In cases where structure is uncertain, multiple scenarios will need to be examined using different variants of the allocation models (e.g. the updated 'Naïve', 'Fringe' and 'Overlap' models proposed in IWC (2006) – and perhaps others such as the

'Fringe minimum[1]' and 'Fringe maximum[1]') to provide for suitable examination of the effect of uncertainty in catch allocation on assessments.

The need to examine the allocation of catches from land stations on migratory routes where there may be some uncertainty in the migratory destination of some or all animals at those locations (e.g. Tangalooma and Byron Bay in Australia, and all New Zealand coastal stations) must also be considered.

2.3 Use of abundance estimates in the models

The absolute estimates used in the models are those from breeding areas. If used, feeding ground estimates are usually incorporated as a test for consistency; if the model results appear inconsistent with the feeding ground estimates, attempts are made to identify the cause of such differences and to resolve them. The Butterworth-Johnston model typically incorporates estimates from feeding and breeding grounds, although to date this has made little difference to their results (SC/A06/HW22). The Workshop **agrees** that prior to their use in a model:

(1) the suitability or otherwise of all estimates of abundance should be determined and where possible, inconsistencies in estimates for the same putative stock should be resolved prior to their use[2]; and
(2) the suitability or otherwise of trends in abundance from feeding grounds should be determined (given *inter alia* the mixing on the feeding grounds problem).

These issues are considered on a case-by-case basis under Item 5.

2.4 Sub-structure in the breeding grounds

In addition to the question of mixing of breeding stocks on the feeding grounds, the question of possible sub-structure within a breeding ground (e.g. as has been suggested for Breeding Stock E) must be examined and this is dealt with on a case-by-case basis under Item 3.

2.5 Population dynamics variables for inclusion in the model

Current models (e.g. those using the logistic) are relatively simple in the way they incorporate demographic parameters. Incorporation of other factors (e.g. depensation, time lag responses) is desirable and probably practical. Genetic analyses may be used to 'ground-truth' estimates of minimum numbers to which the population was reduced (e.g. current mtDNA data set an absolute lower limit). This would set another prior that allows elimination of certain values for minimum population size (and thereby of certain rates of increase without depensation). Reviews of current biological parameters (e.g. maturity and pregnancy rates) should keep in mind that these may not be the same in declining versus increasing (recovering) populations (see Item 6).

2.6 Other issues

The Workshop **recommends** the following terminology:

(1) for the feeding grounds, the existing management Areas (i.e. Areas I–VI – see Donovan, 1991) be retained; and
(2) for the breeding grounds, Breeding Stocks A–G (Southern Hemisphere) and X (Indian Ocean) be used.

3. REVIEW OF STOCK STRUCTURE, DISTRIBUTION AND MOVEMENTS

In discussing these items, the Workshop attempted to focus initially on what information was available for each postulated breeding stock, to consider seasonal distributions and to finally address stock structure hypotheses. The most recent hypothesised stock structure for the Southern Hemisphere reprinted from IWC (2005, p.236) is shown here (Fig. 1).

3.1 Breeding Stock A (Brazil)

3.1.1 Individual movements

3.1.1.1 DISCOVERY AND OTHER ARTIFICIAL MARKS[3]

Table 1 summarises the artificial mark information for Breeding Stock A (SC/A06/HW33). No marks were recovered showing a link with any feeding grounds but it should be noted that only seven whales were marked in the breeding ground.

3.1.1.2 NATURAL MARKS

Photo-identification data (Freitas *et al.*, 2004) on the breeding grounds have shown that individuals photographed in the Abrolhos Bank area (*ca* 17–19°30'S, 38–40°W) were resighted in other areas, as far north as about 12°S.

The Workshop also considered information on known movements of animals from Breeding Stock A to the Antarctic.

SC/A06/HW44 presented the results of the comparison of 829 animals photo-identified in Brazilian waters with nine individuals marked in December 2004 in the waters of the Scotia Sea. An individual photographed on 4 August 2000 on the Abrolhos Bank was subsequently photographed on 4 December 2004 off Shag Rocks near South Georgia.

SC/A06/HW61 reported on an ongoing comparison of 2,500 animals photographed in Brazil with two animals that were photographed (and biopsied) near South Georgia and 18 animals photographed near the South Sandwich Islands in January 2006. Although the genetic studies and a full comparison are not yet complete, thus far three of the South Sandwich whales have also been photographed in Brazil in 1999, 2001 and 2002.

3.1.1.3 TELEMETRY

Information was presented on movements of individual whales from satellite telemetry. The animals were marked towards the end of the time spent on the breeding grounds and thus provide valuable information on migration routes and destinations but little information on within breeding ground movements.

SC/A06/HW46 summarised the results of satellite telemetry studies conducted off the coast of Brazil. Seven whales tagged on Abrolhos Bank in two different seasons, 2003 (Zerbini *et al.*, 2006) and 2005, migrated to an area east of South Georgia (54°20'S, 36°40'W) and north of the South Sandwich Islands (*ca* 58°S, 21°30W). One whale moved down to the South Sandwich Islands and then moved west.

[1] In the case of Fringe minimum, core areas in the feeding grounds are allocated with high probability to particular breeding stocks. However, it was noted that in some cases there may be mixing of animals from different breeding areas in even the core area (as is suspected to occur in Area V). The Fringe maximum model allocates to one breeding stock animals from both the core area as well as from a wider region out to the boundary of the core area in the adjacent feeding Area.

[2] This is important, as in some models, the average of widely different estimates is 'used' implying that equal plausibility is given to both estimates.

[3] Annex D provides a brief overview of the artificial mark information presented for humpback whales in the Southern Hemisphere. Artificial marks include Discovery marks, and marks placed under national schemes.

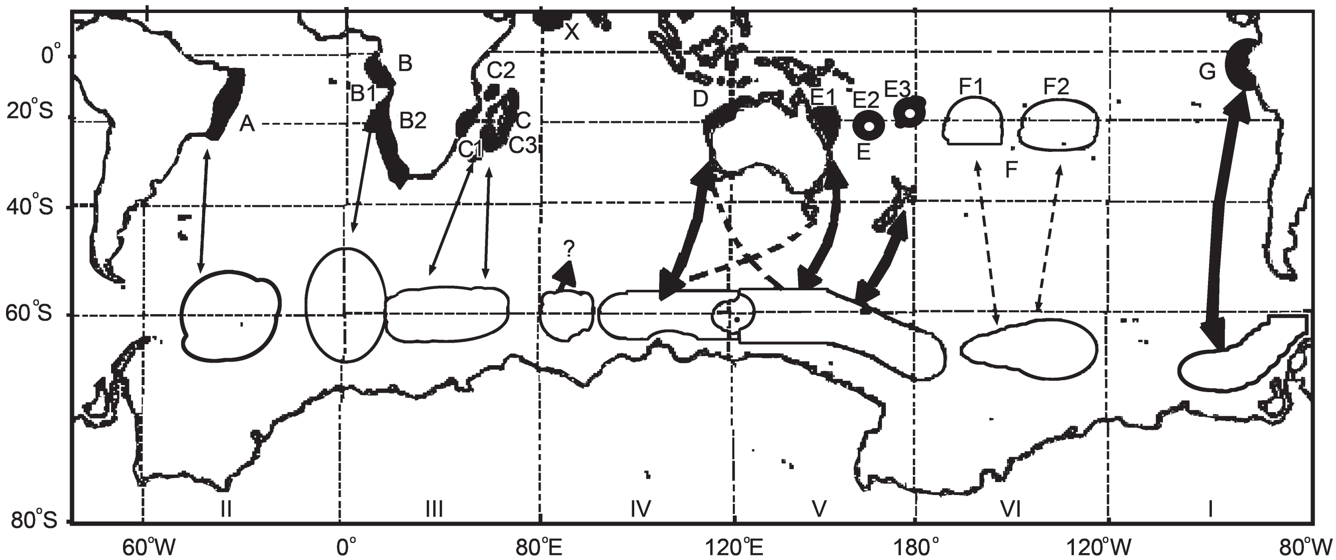

Fig. 1. New hypothetical stock structure for Southern Hemisphere humpback whales. This is for illustrative and discussion purposes only. The areas and sub-areas identified reflect approximate, rather than necessarily exact, boundaries. A dotted line represents hypothetical connection, thin lines represent a small number of documented connections between areas from resights using Discovery marks, photo-id or genetics, or satellite tracked whales, and thick lines represent a large number of documented connections between areas from resights using Discovery marks, photo-id or genetics, or satellite tracked whales.

Of note is that none of these whales migrated south of 60°S or east of 20°W, the current stock boundary of Breeding Stock A in the feeding grounds. These movements are consistent with the current hypothesised connection between Breeding Stock A (Brazil) and Area II. The satellite tagged whales had not migrated to nearer than 300km of South Georgia.

In general discussion, it was noted that in the early whaling years (1904 onwards), many humpback whales were taken within 100km of South Georgia and reference was made to the hypothesis (Perrin, 2001) that the present lack of whales close to South Georgia could be interpreted as suggesting that a population that fed close to South Georgia was extirpated and the cultural memory of feeding grounds close to South Georgia had been lost. However, it was noted that not only was the sample size of whales monitored small but also that the high density of krill in the area where the whales were feeding meant that there was no requirement for them to move into coastal South Georgia waters.

3.1.1.4 OTHER

No information was presented under this Item.

3.1.2 Stock structure

3.1.2.1 GENETIC STRUCTURE

Most of the information considered under this item concerned the links between animals found in Breeding Stock A and those found on the feeding grounds, notably Areas I and II.

SC/A06/HW11 reported on genetic analyses of whales from Abrolhos Bank, Brazil. Mitochondrial DNA control-region sequences were used to investigate genetic diversity and the putative association between Brazilian and Antarctic (Areas I and II) humpback whales to clarify the location of the feeding ground for the Brazilian population. For the Brazilian sample, 57 polymorphic sites were identified, defining 61 haplotypes. For the Antarctic samples, 24 and 21 segregation sites were detected defining 17 and 13 haplotypes for Areas I and II respectively. The high mtDNA diversity (nucleotide and haplotype) observed in the Brazilian sample is in agreement with other breeding areas studied in the Southern Hemisphere and in the North Atlantic. Both Antarctic Areas showed the highest number of shared haplotypes, while a high percentage of exclusive haplotypes (88.5%) occurred in the Brazilian population. Furthermore, in analyses such as AMOVA, pairwise F_{ST} and Φ_{ST}, the two Antarctic Areas could not be statistically differentiated while the Brazilian population was always significantly different from either Area I or Area II.

The authors noted the results showed a greater distinctiveness of the Brazilian population in comparison with the Antarctic Peninsula samples, indicating that Area I and the western portion of Area II (close to the Antarctic Peninsula), do not comprise the main feeding ground of Brazilian humpback whales.

In discussion, it was noted that these results were in agreement with results from satellite tagging and photo-

Table 1

Summary of information from artificial marks for Breeding Stock A.

	Breeding stock A	Putative feeding grounds (Area II)
Humpbacks marked (all marks)	7 (18°S, 38°W)	31
Marks recovered	0	1
Origin of marks recovered	0	2
Movements to other Areas	0	1*
Movements from other Areas	Marked: 62°S,116°W (Area I) Recovered: 28°S, 45°W**	–

*Recovered off Cape Horn in cooker. **Recovered in cooker.

identification (Items 3.1.1.2 and 3.1.1.3). It was also encouraging that genetic studies with relatively low sample sizes can still be useful for excluding some feeding grounds from a connection to a breeding ground. Rosenbaum noted that there were no shared haplotypes between this study and previous studies in the North Atlantic, suggesting that there has been no cross-hemisphere genetic exchange in the Atlantic, in contrast to what is thought to be the case in the Pacific.

3.1.3 Seasonal distribution

3.1.3.1 WINTER

SC/A06/HW02 reported on a series of four aerial surveys (2002–2005) on the Brazilian coastal breeding ground. The surveys covered coastal waters along Brazil within the 500m isobath. Humpback whales were found along most of the coastline covered (from nearly 5 to 23°S). The main area of concentration was the Abrolhos Bank where about 80% of the population was observed; no whales were found south of 23°S. Movements in the wintering grounds are still poorly known. Photo-identification data (Freitas *et al.*, 2004) have shown that individuals photographed in the Abrolhos Bank area were resighted in other areas, as far north as about 12°S. Animals tagged with satellite transmitters in the southern portion of the Abrolhos Bank showed marked individual variation in their movements (Zerbini *et al.*, 2006). Some whales moved south along the coast towards Cabo Frio (23°S) or west towards the outer continental shelf on the Abrolhos Bank. None of these whales moved further north than 16°30'S.

In discussion, it was noted that the information from the aerial surveys was consistent with that from satellite tracking (SC/A06/HW46) which showed that by around 23°S, the seven tagged whales had moved away from the coast on migration.

Clapham noted that both North Atlantic song, and a different song of unknown origin, had been heard from humpback whales near the equator, suggesting that the possibility of some genetic exchange across hemispheres exists in this part of the Atlantic (although see the lack of genetic evidence for this referred to under Item 3.1.2.1).

3.1.3.2 SUMMER

The telemetry information in SC/A06/HW46 revealed that the four whales for which the transmitters worked long enough, arrived on the feeding ground (an area about 250km northeast of South Georgia and 300km north of the South Sandwich Islands) between December and February with one remaining in the area until May. The authors commented that this fitted well with the concentrations of catches by Soviet whalers (Zerbini *et al.*, 2006).

3.1.3.3 MIGRATION

The telemetry information in SC/A06/HW46 suggests that the animals have a relatively narrow migratory corridor (*ca* 600km) from the Abrolhos Bank almost directly to the feeding areas (about 3,500km and taking about 45 days on average). Of the four animals that were tracked as far as the feeding grounds, three left Brazil in October and arrived in December, whilst one left as late as December, arriving in February.

3.1.4 Summary

At least based upon current knowledge (see Table 2 and Fig. 2), Breeding Stock A has a relatively simple structure which links it to the feeding grounds of the western South Atlantic (i.e. part of Area II), notably South Georgia and the South Sandwich Islands. Thus, the situation for this region is that of a single breeding stock (A) connecting with a single feeding ground (Area II). There is no indication that animals feeding off the Antarctic Peninsula migrate up the eastern coast of South America.

Table 2

Evidence for stock structure for breeding stock A. Key: ++ = strongly supports; + = is consistent with; ~ = evidence is ambivalent or uninformative; – = evidence is inconsistent with; – – = contradicts.

Hypothesis	1 (Single stock)	2 (Multiple breeding stocks)
Breeding grounds	1	>1
Rate of increase	~	~
Genetic differentiation	~	~
Acoustics	~	~
Photo-id interchange	+	– –
Discovery marks	~	~
Satellite telemetry	~	~
Catch data	++	—
Sighting data	++	– –
Total evidence	+++	– – –

3.1.5 Recommendations for future work

A consolidated set of recommendations for Breeding Stock A is given in Annex H.

3.2 Breeding Stock B (West Africa)

3.2.1 Individual movements

3.2.1.1 DISCOVERY AND OTHER ARTIFICIAL MARKS

Table 3 summarises the artificial mark information for Breeding Stock B (SC/A06/HW33). No marks had been

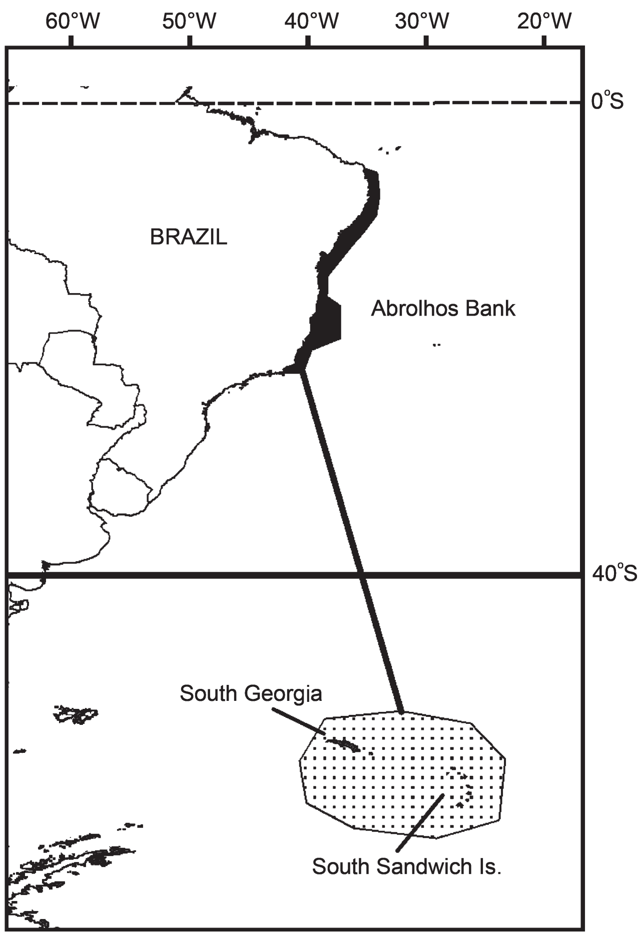

Fig. 2. Map of breeding and feeding grounds for Breeding Stock A, based on current knowledge.

Table 3

Summary of artificial marking information for Breeding Stock B.

Marking	Breeding grounds	Putative feeding grounds (Areas II and III)
Humpback whales marked (all marks)	0	48
Marks recovered	0	0
Origin of marks recovered	0	0
Movements to other Areas	0	2* moved into feeding grounds assigned to Breeding Stock A
Movement from other Areas	0	0

*One found in cooker west of Cape Horn 51°63'S, 33°02'W.

placed in the breeding grounds and no marks have been recovered there. One whale marked on the eastern edge of the putative feeding grounds (62°S, 10°E) was recovered at the southern tip of Madagascar (25°S, 44°E – Breeding Stock C) and the mark from one animal marked at 51°S, 10°W was recovered in a cooker at 51°63'S, 33°02'W.

3.2.1.2 NATURAL MARKS (PHOTO-ID, GENETIC)

It has been postulated that there may be two breeding stocks off west Africa: Breeding Stock B1 which is thought to winter (June–October) along central West African coasts and around the northern islands of the Gulf of Guinea; and breeding stock B2 which is thought to winter off the west coast of South Africa and Namibia, although the northerly extent of this remains undefined.

SC/A06/HW4 considered whales that have been grouped in wintering region B2. Geographically, western South Africa should function as a migration corridor. However, behavioural evidence (feeding and defecation), regular and extended presence of whales during summer (as late as February) and historical catches during this summer season, suggest that the area functions rather as a summer feeding ground. The paper reported on a within-area study of photographs (all years) and microsatellite markers (from 2001 and later). Most photographic effort took place from 2001 onwards. Both tail flukes and left and right dorsal fin photographs (including lateral marks and those on the caudal peduncle) were used for matching. The catalogue contains 266 identified individuals of which 44 were re-sighted at least once. The overall re-sighting rate was high (9.77% between years and 16.54% within and between). The overall sex ratio of animals of known sex (n = 104) is near parity but the proportion of females amongst re-sighted animals (64.7%) was higher (although not significantly so) than in whales seen only once (42.9%).

SC/A06/HW10 reported a within-season recapture rate for animals photo-identified off Gabon (Breeding Stock B2) of between 0.5% and 3.3%. Intervals between recaptures were quite variable for data collected between 2001 and 2004, ranging from 3 to 45 days, with means ranging from 9.4 and 15 days. No particular pattern was observed in the recaptures.

SC/A06/HW38 reported two genetic matches found between Gabon (B1) and western South Africa (B2) based on 11 microsatellite markers. These matches involved two females, one of which was accompanied by a calf, when first sighted in September in Gabon; a few months later (December and January) they were seen feeding off the west coast of South Africa. The authors stated that their findings suggest the possibility that pregnant or lactating females from Gabon migrate along the coast and stop to rest and feed in this area. This hypothesis is supported by well described feeding behaviours and female-skewed observed sex ratio for resighted animals off western South Africa.

3.2.1.3 TELEMETRY

SC/A06/HW42 reported the results from satellite tagging of 14 humpback whales (2 mothers with calves, 11 single adults and 1 juvenile) off Gabon (2°S, 9°E) between 29 August and 12 September 2002. Ten of the whales spent the entire time of their tags' operation in what is believed to be the reproductive winter range. Six whales used the areas north of Gabon into the Gulf of Guinea. Eight of the 14 tagged whales that initially moved north then travelled south of Gabon – six into Angolan waters. Two tagged whales migrated along the same general route (Walvis Ridge) until they reached the Antarctic Convergence, where they diverged. The last received locations showed one animal in Area II and one in Area III, both just either side of the boundary between Areas II and III at 0°.

3.2.1.4 OTHER (e.g. LOST HARPOONS)

No information was provided under this item.

3.2.2 Stock structure

3.2.2.1 GENETIC INFORMATION (POPULATION LEVEL)

SC/A06/HW41 provided a sub-region analysis of mtDNA lineages from humpback whales sampled off the coast of Gabon (B1, n = 466) and from Cabinda and the coast of western South Africa (B2, n = 166). There was a significant sampling or sex bias toward males in the B1 sample, but an equal sex ratio was found in the B2 sample. Haplotype and nucleotide diversity were high. For the ocean basin AMOVA, significant differences were found among and within the four wintering Regions (A, B, C and X) for both Φ_{ST} and F_{ST}. Significant differences were found in pairwise F_{ST} comparisons between B1 and B2. When samples were partitioned by sex, no significant differences between B1 and B2 were found (only males considered). Using the program MIGRATE (Beerli and Felsenstein, 1999; 2001), a preliminary analysis of gene flow revealed that the interchange between Gabon and western South Africa is very low (approximately 1–$2N_em$). Overall, there is clearly significant population differentiation between sub-regions B1 and B2 with some indication of dispersal (either historical or current) based on results from males only and estimates of gene flow. The degree to which whales show significant differentiation and still exhibit gene flow or movements between sub-regions within breeding stocks remains an important question for sub-stock differentiation in this region, and hence management.

SC/A06/HW38 presented a population structure analysis based on 11 microsatellite loci for 493 individuals sampled in Gabon (B1), 12 sampled in Cabinda, Angola (tentatively thought to be B2) and 110 off the west coast of South Africa

(B2). Significant differences were found in the AMOVA only when Cabinda was grouped with Gabon within B1; a significant difference was reported only for pairwise R_{ST} between Gabon and western South Africa. Although the sample from Cabinda was small, current data support a higher similarity between Gabon and Cabinda, than between Cabinda and western South Africa. Estimates of gene flow show that the expected exchange between Gabon and west South Africa is very low (*ca* $1N_em$). Two direct matches between Gabon and western South Africa (see Item 3.2.1.2), suggest that females breeding in B1 may use B2 as a migratory corridor and/or feeding ground.

Pomilla and Rosenbaum (2006) presented information regarding sex ratio and group composition in Gabon. Genetic sexing data collected for 405 individuals resulted in an observed sex ratio of 1.9:1 males to females. Most males were encountered in competitive groups and pairs. Females were more abundant than on other breeding grounds, however mother-calf pairs were under-represented. Of the pairs sampled, 8% were both females, 35% were both males and 57% were mixed sex; two female triads were found, as well as three instances of competitive groups that included two females. These data suggest that the coast of Gabon maintains some characteristics of wintering grounds, i.e. breeding may occur along the coast and extend into the Gulf of Guinea, rather than there being a concentrated breeding ground there.

In discussion, the different implications of the results from the Migrate program and F_{ST} statistics were raised. Pomilla summarised that mtDNA evidence supports a difference between samples off Gabon and South Africa, but the evidence from microsatellites was not as strong. It was also noted that the possible use of the B2 region by B1 females has implications for appropriate choice of grouping of samples.

3.2.2.2 OTHER INFORMATION (e.g. CPUE AND CATCH HISTORY)

Marked difference in crude CPUE indices from Gabon (French Congo) and other land stations off the African west coast were reported by Findlay (2001). While CPUE indices from the Cape, Namibia and Angola declined by 1917 and generally remained low until 1963, CPUE from Gabon showed initial declines by 1917 followed by three series of increases and associated declines between 1917 and 1963. Thus the available CPUE data provide some support for the the presence of more than one breeding stock.

3.2.3 Seasonal distribution

Information in SC/A06/HW53 suggests that some whales remain in low latitudes throughout the year. Findlay noted the differences in timing of catches off the west coast of southern Africa in that the catches from the Gulf of Guinea were during the austral winter, while catches off Namibia in the region of Walvis Bay were made in the austral summer. Animals caught off Namibia during summer were presumed to be feeding within the Benguela upwelling system.

3.2.3.1 WINTER

Available evidence and anecdotal records (e.g. SC/A06/HW10, SC/A06/HW38 and SC/A06/HW42; Rosenbaum and Collins (2006)) suggest a winter distribution for the B1 stock along the coasts of Angola (including Cabinda), Congo, Gabon, Equatorial Guinea (including Bioko), Cameroon, Nigeria, Togo, Benin and Ghana as well as around the offshore islands of São Tomé and Príncipe. Peak abundances are believed to occur in July, August and September although whales remain in the region into December. Throughout much of the Gulf of Guinea, the continental shelf is wide and survey effort has been limited to nearshore waters. Offshore distribution and distribution relative to depth remain unknown. Shore-based effort at Saldanha Bay during July and August of 2001 and 2002 yielded very low sighting rates for humpback whales when compared to summer months.

3.2.3.2 SUMMER

Behavioural evidence (feeding and defecation) along with regular and extended presence of whales during summer (as late as February), as well as the seasonality of historical catches, suggest that the west coast of South Africa (Saldanha Bay) functions as a possible winter migration corridor, but also as a summer feeding ground. This coincides with productivity associated with the Benguela upwelling system. There is no available information for summer abundances in the Gulf of Guinea but a degree of summer presence is suspected (Rosenbaum, pers. comm.). The limited telemetry data (SC/A06/HW42) on two animals showed that one marked near Gabon spent some time near Bouvet Island (*ca* 54°S, 3°E) while the other moved close to the ice edge. The last received locations showed the animals on either side of, but close to, the boundary between Areas II and III at 0°.

The analysis of mtDNA data in Annex E found significant differences between whales sampled from Breeding Stock B and those sampled in Area I (120°W–60°W) but no significant differences with samples from Areas II and III (60°W–70°E).

3.2.3.3 MIGRATION

SC/A06/HW42 revealed that migratory movements of tagged animals showed considerable heterogeneity and unexpected movements in terms of general direction (north vs south) and migration (inshore vs offshore) for both males and females. For the two tags that lasted the longest, both animals migrated along the same general route (but at different times) as far as the Antarctic Convergence, where their paths diverged.

3.2.4 Summary

There is some evidence for stock structure within Breeding Stock B on the African west coast. Some genetic difference between whales from Gabon and Cabinda and off western South Africa has been demonstrated. There is some recent evidence of breeding behaviour from Gabon, Angola, Cabinda, São Tomé, Equatorial Guinea and Congo to the north of the Walvis Ridge, and recent evidence of feeding behaviour, but no breeding behaviour to the south of the Walvis Ridge. Townsend (1935) shows evidence of historical concentrations of humpback whales in the Gulf of Guinea in winter and off Walvis Bay (Namibia) in summer. Satellite telemetry has identified movement from Gabon further northwards to Nigeria and into the Gulf of Guinea as far as Ghana; two animals migrated, primarily offshore, southward to the Antarctic. Summer presence of feeding whales within the Benguela Upwelling System suggests use of this region as a summer feeding ground. Catches of whales with full stomachs (clupeid prey) were made off western South Africa (Olsen, 1914). There is evidence of movement of two female whales (one nursing) from Gabon to western South Africa.

The Workshop **agrees** that, with a B1/B2 border in the vicinity of 18°S (where the Walvis Ridge meets the African

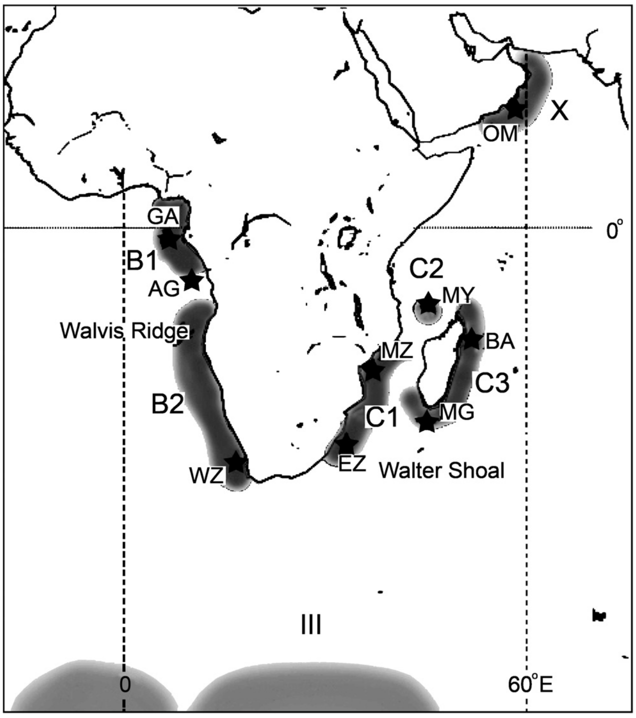

Fig. 3. Map with Breeding Stocks B, C and X and IWC Area III. Key: GA = Gabon; AG = Angola; WZ = western South Africa; EZ = eastern South Africa; MG = southern Madagascar; BA = Antongil Bay, Madagascar; MZ = Mozambique; MY = Mayotte and the Comoros; OM = Oman [taken from SC/A06/HW38].

coast and the Angola Current Benguela Current Front, see Fig. 3):

(1) B1 is a breeding ground; and
(2) B2 is a feeding ground and migration corridor within the productive waters of the Benguela upwelling system.

Some of the whales feeding within B2 breed within B1. The Workshop also noted that it is unclear whether subdivisions exists within B1. There is equivocal evidence for at least two breeding stocks on the western coast of Africa, and one of these clearly breeds in an area (perhaps only a portion) of B1; whether the other breeding stock(s) exist within the bounds of B1 or elsewhere remains unclear. The observed genetic differences among females between B1 and B2 may be explained by the existence of a second breeding stock which is sampled on migration in B2, but this is currently unknown. In order to try to resolve this question, two areas of work are required:

(1) further analysis of genetic samples to detect the signature of multiple breeding stocks (if these exist);
(2) surveys of other portions of B1 (notably off the Angolan coast).

The Workshop **recommends** that this be done (see Item 3.2.5).

3.2.5 Recommendations for future work
A consolidated set of recommendations for Breeding Stock B is given in Annex H.

3.3 Breeding Stock C (East Africa)
Three sub-regions have been postulated for Breeding Stock C: C1 (migrations along the east coast of South Africa up to breeding grounds off Mozambique and Tanzania); C2 (Mayotte Island, the Comoros Islands and other islands and reef systems of the Mozambique Channel); C3 (the coastal waters of Madagascar).

Table 4
Summary of information from artificial marks for Breeding Stock C.

	Breeding grounds	Putative feeding grounds (10°E–50°E)
Humpbacks marked (all marks)	8	249
Marks recovered	2	5
Origin of marks recovered	0	7
Movements to other Areas	0	0
Movement from other Areas	0	0

3.3.1 Individual movements

3.3.1.1 DISCOVERY AND OTHER ARTIFICIAL MARKS
Table 4 summarises the artificial mark information for Breeding Stock C (SC/A06/HW33). Two animals[4] marked in the putative feeding area (10°E–50°E) were recovered in breeding grounds (southern tip of Madagascar). Only eight whales were marked in the winter grounds of Breeding Stock C.

3.3.1.2 NATURAL MARKS (PHOTO-ID, GENETIC)
SC/A06/HW9 reported on mark-recapture studies (using fluke photographs) carried out between 2000 and 2005 in Antongil Bay, northeast Madagascar (C3). Within-year recaptures represented 6–18% of all individuals identified in a particular year. The mean intervals between first and last capture within a year ranged from about 3–8 days, suggesting short residency times within the Bay and high movement rates through the Bay and throughout the region. There were few recaptures between years (2.8% of all individuals within the study period). The timing of recapture of individuals showed marked periodicity such that most individuals were resighted in subsequent years within a few days of the sighting date in the first year.

In discussion, it was noted that the pattern of individual periodicity has important ramifications for both mark-recapture analysis and genetic sampling. Appreciable bias can be introduced if sampling is not temporally bounded so as to provide a representative sample.

SC/A06/HW12 reported on studies in the waters around and neighbouring Mayotte Island in the Comoros Archipelago within the northern Mozambique Channel (C2). Overall, the C2 sub-region is particularly data deficient regarding the occurrence and distribution of humpback whales, in that survey effort has largely been limited to Mayotte and the neighbouring Geyser-Zélée Reef Complex in the waters of the eastern Comoros Archipelago. To date, 113 tissue samples and 699 identification photographs of humpback whales have been collected and contributed to a photographic and genetic archive for C2. A total of 78 whales has been identified genetically and up to 250 photographically. Only four whales (all females) have been photographically or genetically recaptured in multiple years. The majority of humpback whale encounters in the waters surrounding Mayotte and the neighbouring Geyser-Zélée Reef Complex are mother-calf pairs (73%, n = 189), of which only 8% (n = 11) were accompanied by one or more (two) escorts. Competitive activity is rarely observed and

[4] One at the western edge of this feeding ground at the boundary with the putative feeding area for Breeding Stock B.

there is only one record of a group composed of more than five whales. The photographic and genetic evidence suggests that eight individuals (6 males and 2 females) have moved between C2 and C3 (or *vice versa*) between years. Addressing the issue of differentiation between the C2 and C3 sub-regions will require additional survey and sampling effort across other areas of C2.

SC/A06/HW38 (and see SC/A06/HW12) reported three genetic matches (two females and one male) between Mayotte (C2) and northeast Madagascar (C3) based on 11 microsatellite markers. One additional match (one male) was found between northeast Madagascar and the east coast of South Africa (C1).

3.3.1.3 TELEMETRY
No studies have been carried out in this region.

3.3.1.4 OTHER (e.g. LOST HARPOONS)
The recovery of one harpoon tip (Olsen, 1914) provides evidence of linkage between Durban on the South African east coast (C1 migration stream) and Linga Linga in southern Mozambique (southern C1).

3.3.2 Stock structure
3.3.2.1 GENETIC INFORMATION (POPULATION LEVEL)
SC/A06/HW41 reported *inter alia* on a sub-regional analysis of mtDNA lineages from humpback whales sampled off southern and central Mozambique and eastern South Africa (C1, n = 151), from the islands of Mayotte and associated reef systems (C2, n = 78), and from the east coast of Madagascar (C3, n = 511). There was a significant sampling or sex bias toward males in the C3 sample and towards females in the C2 sample; an equal sex ratio was found in the C1 sample. Haplotype and nucleotide diversity were high. For the ocean basin AMOVA, significant differences were found among and within the four Breeding Stocks (A, B, C and X) for both Φ_{ST} and F_{ST}. Significant differences were found in pairwise F_{ST} comparisons between C1 and C3, and C1 and C2, but not for C2 and C3. When samples were partitioned by sex, no significant differentiation was found between C2 and C3 for males or females based on pairwise F_{ST} comparisons. When only males were considered, no regional sub-structure was found within Breeding Stock C. While still preliminary, the highest degree of effective migrants per generation (as inferred from the program MIGRATE) occurs from C3 to C2 and from C3 and C1. Overall, there is clearly some significant population differentiation between sub-regions C1 and C2 and C1 and C3 with some indication of dispersal (either historical or current) based on results from males only and estimates of gene flow. The lack of significant F_{st} and Φ_{ST} pairwise comparisons for C2 and C3 is consistent with microsatellite analysis and photographic and genetic capture-recaptures between these sub-regions (SC/A06/HW38 and SC/A06/HW12). The number of samples and time of sampling from C2 have been limited. A more complete analysis of whales in the C2 sub-region is needed to better evaluate the degree of connectivity of C2 and C3 sub-regions. The authors noted that the degree to which whales show significant differentiation and still exhibit gene flow or movements between sub-regions within breeding stocks remains an important question for management.

SC/A06/HW38 presented a population structure analysis based on 11 microsatellite loci for more than 800 individuals sampled in C1, C2 and C3. When sub-region partitions were tested, the AMOVA did not identify significant variation and the pairwise comparisons reported significant differences only between Northeast Madagascar (C3) and both sites within C1 (eastern South Africa and Mozambique), and between Mayotte (C2) and eastern South Africa. In contrast with F_{ST} and R_{ST} results, the highest estimate of gene flow (over evolutionary time) was reported between sub-Regions C1 and C3, but exchange of migrants was estimated also across all other boundaries. However, this may reflect the small size of the C2 population. Comparisons of microsatellite data by sex (F_{ST} and assignment indices) show that gene flow within Region C is not strictly male-biased and females may play an important role in mediating gene flow related to Mayotte or the east coast of South Africa. This finding is consistent with functional differences among the sites within this wintering region. The authors suggest that an overview of all the evidence suggests separation of C1, but not between C2 and C3.

Two papers made reference to sex ratio data. Pomilla and Rosenbaum (2006) presented information regarding sex ratio for Antongil Bay (C3). Genetic sexing data collected for 564 individuals resulted in an estimated observed sex ratio of 1 female to 2.4 males. SC/A06/HW12 reported on studies in the waters around the Geyser-Zélée Complex and neighbouring Mayotte Island in the Comoros Archipelago in the northern Mozambique Channel (C2). Of the genetically identified calves (n = 8), the sex ratio was 1:1 (n = 8), whereas for non-calves (n = 69), the sex ratio was 1 males to 3.6 females (reduced to 1 male to 1.87 females if the 26 mothers are excluded).

Genetic (mtDNA) analyses reported in Annex E found significant differences between whales sampled from Breeding Stock C and animals sampled in Area I, but no significant differences with samples from Areas II and III.

3.3.2.2 OTHER INFORMATION (e.g. CPUE AND CATCH HISTORY)
Marked difference exists in crude CPUE indices from (i) Natal and Mozambique and (ii) Madagascar. While the Natal and Mozambique CPUEs declined by 1915, CPUE off Madagascar remained relatively high until the early 1950s (Findlay, 2001).

3.3.3 Seasonal distribution
3.3.3.1 WINTER
Findlay *et al.* (2011) showed concentrations of humpback whales off the coast of Mozambique as far north as Mozambique Island (15°S) in August and September. The distribution of whales to the north of this region remains largely unknown, although incidental sightings of humpback whales are reported as far north as Zanzibar.

Along the east coast of Madagascar (C3), there are reports of whales from Fort Dauphin/Talagnaro in the southeast to Antongil Bay in the northeast (Rosenbaum *et al.*, 2001, SC/A06/HW9). There are concentrations off Isle St Marie (where there is a whalewatching industry) and Antongil Bay (where there has been a 10-year research programme). Concentrations have also been reported in August (the peak breeding season) between Toliara and Fort Dauphin, south of 22°S (Best *et al.*, 1998). There is a question as to whether whales along the east coast represent whales migrating to a final breeding destination or whether the coast represents an extended breeding area. Given the short residency/transience of whales in Antongil Bay (SC/A06/HW9) and concentrations of whales observed in August in the south, it is probable that there are whales distributed along (and continually moving along) the coast throughout the breeding season. On the west coast of Madagascar there are reports of whales from Toliara in the southwest to Nosy Bé in the northwest. Boat-based surveys have documented whales (including competitive groups) off Toliara into late October/early November, well after a decrease in the density of whales in Antongil Bay in the northeast. It is possible that there are concentrations of whales off Toliara, as well as further north up the west coast, for the entire season; however the relationship of these whales to those on the east coast is unknown and requires further research.

There are also winter reports of sightings and historical records from the coasts of the Comoros Archipelago, other island and reef systems in the C2 region, and the Mascarenes (Mauritius and Reunion).

The observed female biased sex ratio and rate at which mother-calf pairs are encountered (SC/A06/HW12) suggests that the eastern portion of the Comoros Archipelago (C2) may be preferentially sought out by pregnant or nursing females, although systematic survey effort in reef lagoon systems has only been possible late in the wintering seasons to reef lagoon systems.

In discussion on winter distribution and the relationship of C3 with C2, it was noted that the several between-year matches between Mayotte (C2) and Antongil Bay (C3), combined with the low rate of recapture between years in Antongil Bay, suggests that there is a strong connection between C2 and C3. The Workshop **recommends** that an analysis of capture probability is undertaken to assess whether there is random exchange between the C2 and C3 regions.

3.3.3.2 SUMMER

There is some indication of humpback whale concentrations on Star Bank and Walter's Shoal (south of Madagascar) in the months of November and December. Rosenbaum *et al*. (2001) reported that mother-calf pairs were prominent in the concentrations on Walter's Shoal. It is unknown whether these are late or non migrators. It could not be confirmed if these whales were engaged in feeding behaviour. There is at least one confirmed sighting of a mother with a calf off the coast of Mozambique in the month of February.

Although there is considerable sightings and catch information from the Antarctic feeding grounds, without better knowledge of the relationship between animals on the feeding and breeding grounds, it is not possible to detail the summer distribution in Antarctic waters (and see Item 3.9).

3.3.3.3 MIGRATION

Findlay reported that humpback whales reach the east African coast as far south as Knysna (33°S) as early as April and move northwards along the east coast of southern Africa to the coastal waters of Mozambique. Migratory behaviour is observed as far north as Cape Vidal (28°S), while incidence of song suggests that breeding behaviour largely begins to the north of this. Humpback whales migrate southward along the east coast of Africa as far south as Knysna in September, October and November.

The meeting noted that there had been little research effort expended on regions to the east of Madagascar. Rosenbaum indicated that the limited survey effort has shown humpback whales in Reunion and Mauritius at times similar to those when whales are seen in Antongil Bay (C3).

3.3.4 Summary

There is evidence of breeding in sub-region C1 from approximately 28°S to possibly as far north as Tanzania/Kenya, while a migratory corridor exists to the south of 28°S. Breeding also occurs off the Comoros Islands and Mayotte (C2), and in the coastal waters of Madagascar, although the relationship between whales on the east and west coasts of Madagascar is unknown. Recaptures of individuals provide potentially extensive connectivity between Mayotte (C2) and Antongil Bay (C3), and to a lesser extent (one individual) between the east coast of South Africa (1) and Antongil Bay. No evidence of connectivity exists for South Africa/Southern Mozambique (C1) and Mayotte (C2). One lost harpoon (Olsen, 1914) provides a link between eastern South Africa (Durban) and Southern Mozambique (Linga Linga). Genetic differentiation has been found between Antongil Bay (C3) and eastern South Africa/Southern Mozambique (C1), and between Mayotte (C2) and East South Africa/Southern Mozambique (C1), while no genetic differentiation is found between Mayotte (C2) and Antongil (C3).

On the basis of what is known of the stock structure of humpback whales off the east coast of Southern Africa, five potential sub-regions were identified.

(1) C1 South (C1-S) including eastern South Africa and Mozambique as far north as Mozambique Island (15°S).
(2) C1 North (C1-N) extending northwards from Mozambique Island to the northern limit of the range (southern Tanzania possibly into Kenya).
(3) C2 including Mayotte Island, the Comoros Islands and the Mozambique Channel.
(4) C3 around Madagascar.
(5) C4 extending across the Mascarene group of islands, including Mauritius and Reunion.

The Workshop **agrees** that delineation between C1-S and C1-N may be a cline rather than a definite line, although given the current deficiency of data to the north of Mozambique Island the border can currently be considered a latitudinal line in the region of Mozambique Island (15°S). The links described above suggest that C2 and C3 may not be separate.

Seven models of stock structure were considered (Fig. 4). The Workshop **agrees** that the most plausible is that linking C1-N and C1-S into one breeding sub-stock and the separate linking of C2 and C3 into another. The next most likely model links (1) C1-N and C1-S and (2) C2 and C3 while including some overlap between the C1-N and the combined C2/C3 sub-stocks.

3.3.5 Recommendations for future work

A consolidated set of recommendations for Breeding Stock C is given in Annex H.

3.4 Breeding Stock X (Indian Ocean)

3.4.1 Individual movements

3.4.1.1 DISCOVERY MARKS

There is no information from Discovery or other artificial marks for this stock.

3.4.1.2 NATURAL MARKS

Recent information on photo-identification is limited to data collected from Oman (SC/A06/HW48). A total of 64 whales was photo-identified in Oman during surveys conducted between 2000 and 2004. Of these, six individuals have been observed on at least two surveys, four on three surveys, one on four surveys and one on five. Individually identified whales were resighted in both the Gulf of Masirah and Dhofar at different times of the year and across survey years, indicating a high degree of residence off the coast of Oman.

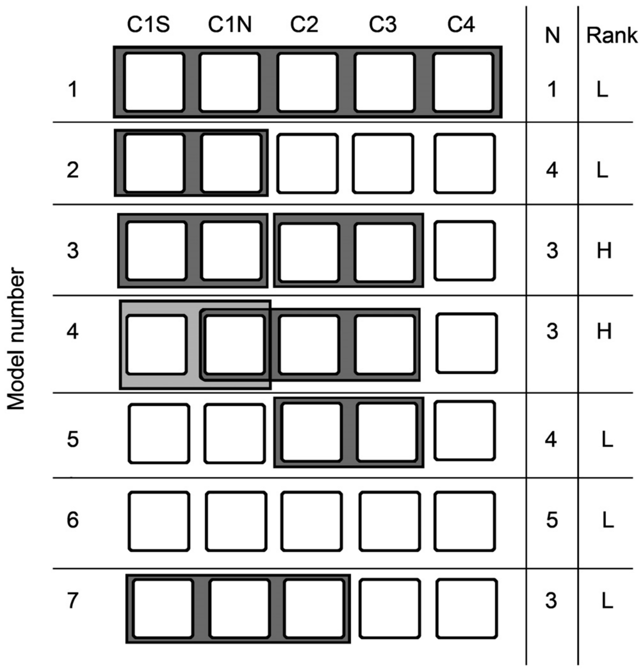

Fig. 4. Schematic diagram showing possible models for stock structure for east Africa. N = number of breeding stocks and Rank: L = low; H = high.

Resightings within surveys are few. Comparison of identified whales in the Oman catalogue with those from Zanzibar (n = 7), Madagascar (n = 1,104) and Mayotte (n = 185) yielded no matches (catalogues from April 2003).

SC/A06/HW38 reported the results of a genetic capture-recapture analysis of 34 individuals sampled off Oman and more than 800 individuals from Breeding Stock C. No matches were found.

3.4.1.3 TELEMETRY
No information was available.

3.4.2 Stock structure
3.4.2.1 GENETIC INFORMATION
SC/A06/HW38 and SC/A06/HW41 examined population structure for animals from Breeding Stocks X and C (its nearest geographical neighbour) using microsatellites and mtDNA, respectively. The results show significant differentiation between the two stocks for both markers, reflected both in the AMOVA and in the pairwise comparisons for F_{ST}, R_{ST} and ϕ_{ST}. Evolutionary gene flow estimated with the program MIGRATE is absent for mtDNA and limited for microsatellites. The program STRUCTURE sorted individuals from X into a separate cluster. All of the evidence suggests isolation of Breeding Stock X from the sampled sites in Breeding Stock C.

SC/A06/HW38 and SC/A06/HW41 also reported reduced genetic diversity within Breeding Stock X compared with reported diversity for other sampling sites for Breeding Stocks A, B and C. The reasons for such reduced diversity, as well as the origin of this stock, will be further investigated by the authors.

Both studies show a lack of gene flow between Breeding Stock X and Breeding Stock C, its nearest neighbour. Breeding Stock X has a strong genetic separation from all other areas to which it has been compared.

mtDNA data were examined to compare animals from Breeding Stock X with samples from feeding Areas I, II and III (Annex E). The significant differences found support the hypothesis that whales from Breeding Stock X do not migrate to southern high latitudes.

In discussion, Baker commented that the strength of the differences between Breeding Stock X and other Breeding Stocks was greater than that seen between other Breeding Stocks.

The Workshop **agrees** that the genetic information showed that animals from Breeding Stock X were reproductively isolated from the Southern Hemisphere Breeding Stocks.

Clapham commented that there were substantial Soviet catches in multiple areas of the Arabian Sea, and that they were probably from an Arabian Sea stock; although the population size in Oman is small and shows little sign of recovery, the lack of studies in other parts of the Arabian Sea prevent a definitive conclusion about whether any significant recovery at the population level has occurred or not.

3.4.3 Seasonal distribution
3.4.3.1 WINTER
Most of the available information (catch history and recent surveys) is limited to Northern Hemisphere winter months (September–March). Mikhalev (1997; 2000) reported on illegal catches of humpback whales across the northern Arabian Sea during October, November and December of 1966–1967. Of these 64 were taken in Oman, 164 in Pakistan and 12 in northwest India. Recent survey efforts have been limited to Oman and divided between two main areas, the Gulf of Masirah (central Oman) and Dhofar (southern Oman).

SC/A06/HW48 reviewed seasonal distribution and population characteristics of humpback whales off Oman. A higher proportion of whales is encountered in the Gulf of Masirah during early winter (September–December), with a shift in abundance to Dhofar during late winter (January–March). The Gulf of Masirah is a presumed feeding area. Sex was determined for 38 of 44 individually identified animals observed between October 2000 and November 2002 in the Gulf of Masirah and a 1:1 ratio of males (19) to females (19) was found.

A high incidence of singers and detected song was recorded in Kuria Muria Bay (Dhofar) in February and March and is consistent with the January–April breeding season predicted by Mikhalev (1997; 2000). Almost all (96%) of whales sampled during recent surveys in Dhofar in February and March were male (n = 28).

Observations of mother-calf pairs are sparse. None have been recorded since 2001 and competitive groups were absent. The high proportion of males observed in Dhofar in February–March, compared to the parity of sexes observed in the Gulf of Masirah in October–November, indicates that while the females are present in the Oman/Arabian Sea population, they are elusive or not present in the Dhofar region during February–March. Mikhalev (2000) also noted a paucity of mother-calf pairs in the Arabian Sea and only one mother-calf pair was observed during the hunt. The Soviet catch data do not provide more explicit details of catches by region, so it is impossible to determine whether pregnant females were found in the eastern Arabian Sea as opposed to off the coast of Oman. The ratio of males to females in the Soviet catch neared parity (126:112), so the paucity of mother-calf pairs in recent observations cannot be confirmed by bias in the Soviet catch toward females. It is possible that calving and nursing are taking place predominantly in other areas of the Arabian Sea. A suspected nursery area is the Gulf of Masirah. Weather conditions and logistic constraints have so far prevented planned surveys in the Gulf of Masirah in February and March.

3.4.3.2 SUMMER
Summer months coincide with the seasonal southwest monsoon. The monsoon generates large swells and dense coastal fog, making boat and shore-based observations difficult. It is highly probable that more active and regular feeding takes place between May and September, during the peak of upwelling. There have been few sightings in summer, presumably due to difficult weather conditions.

3.4.3.3 OTHER
The peak calving period is March, which indicates a Northern Hemisphere breeding cycle. However, it is also coincident with the monsoon-driven upwelling season, and calving may be tied more to food availability than to a Northern Hemisphere breeding cycle.

A mother-calf pair was recently reported from the Arabian Sea, in September. This is the first confirmed sighting of a mother and calf in the Arabian Sea since 2001 and is from a region for which no recent records exist. The size of the calf was consistent with a Southern Hemisphere breeding cycle.

3.4.4 Summary
The Workshop **agrees** that the evidence shows this to be an isolated population, resident in the Arabian Sea year round i.e. this is both a breeding and a feeding ground.

3.4.5 Recommendations
A consolidated set of recommendations for Breeding Stock X is given in Annex H.

3.5 Breeding Stock D (western Australia)
3.5.1 Individual movements
3.5.1.1 DISCOVERY MARKS
Table 5 summarises the artificial mark information for Breeding Stock D. A strong link was found between breeding (western Australia) and feeding grounds (Area IV). One animal marked in Area IV was recaptured on the east coast of Australia (Breeding Stock E).

Table 5

Summary of artificial marking information for Breeding Stock D.

Marking	Breeding grounds	Putative feeding grounds (Area IV – 70°E–130°E)
Humpbacks marked (all marks)	333	896
Marks recovered	41	29
Origin of marks recovered	16	42
Movements to other Areas	0	1*
Movement from other Areas	–	12** (approx 9% of whales marked in breeding stock E or Area V) were recovered in Area IV as far west as 113°E.

*Marked in Area IV and recaptured in eastern Australia. **In addition, 1 animal marked in Fiji was reported as recovered at 55°S, 87°E (western Area IV) by Soviet fleet – there is uncertainty surrounding this as it was reported as a fin whale.

3.5.1.2 NATURAL MARKS
Considerable photo-identification data have been collected off western Australia (see the metadata table available on the IWC website*). The Workshop **agrees** that it is extremely important to compare the major photo-identification catalogues from western Australia with catalogues from eastern Australia (see Item 3.5.5).

3.5.1.3 TELEMETRY
Telemetry studies are being undertaken for this area but as yet have not proved successful.

3.5.2 Stock structure
3.5.2.1 GENETIC INFORMATION
SC/A06/HW20 reported on a study involving a sample of 258 whale biopsy samples collected over 2002 and 2003 off North West Cape, Western Australia (along the migration route) which resulted in a male skewed sex ratio in both seasons. This area was selected because whales are in high density on the shelf there, and are therefore accessible for study. No sampling biases (towards sampling more males than females) could be detected from a multivariate test to identify relationships between the proportion of males and cue type, month, year, pod size, speed, sea state, swell, migration direction (including milling, north and south) and the various interactions. Given that measurements of sex ratio in Antarctica have shown evidence of fairly equal sex ratios, the authors suggest that further investigation is critical to ensure accurate estimates of population size are made.

There was considerable discussion within the Workshop as to whether the observed sex-bias (which has been seen on both breeding grounds and elsewhere) is real or just a bias in sampling for various reasons. It was noted that studies in Western Australia have previously found age and sex-structure in the migrating animals, so the timing of sampling could have an influence on the observed sex-ratio in the study presented in SC/A06/HW20. The issue is of particular relevance with respect to abundance estimation and how estimates relate to the total population. The issue is relevant to areas other than off western Australia.

The Workshop **agrees** that sex-bias has a potential to bias abundance estimates and thus inputs to the assessment models. It is less clear how a true skew in sex ratio in areas where catches occurred can be explicitly incorporated into the present assessment model which does not explicitly incorporate sex structure. With respect to the study reported in SC/A06/HW20, the Workshop **agrees** that there is still some uncertainty regarding possible heterogeneity of sexes across the area, given that biopsy sampling was limited to only a proportion of the area. This requires further examination.

The present state of studies using mtDNA data to examine population structure of humpback whales across the South Pacific and eastern Indian Oceans (New Caledonia, Tonga, Cook Islands, French Polynesia (Society Islands), Colombia and western Australia) was briefly summarised in the Workshop. A total of 1,113 sequences (470bp of the mtDNA control region) revealed 115 unique haplotypes based on 71 variable sites. Significant differences were found, at both the haplotype and nucleotide level, among the six breeding grounds (F_{ST} = 0.033; Φ_{ST}= 0.022) and between most pair-wise comparisons. With respect to stock structure for Breeding Stock D, although the level of genetic differentiation between the western Australian samples and other areas is not high (due at least in part to the high haplotypic diversity that prevents F_{ST} values from being higher), there are significant genetic differences between western Australia and the areas to the east of Australia with which it was compared. However, whilst noting this

* *http://www.iwcoffice.org/documents/sci_com/workshops/Table2.pdf* accessed October 2011.

conclusion, the Workshop **agrees** that a major limitation of this study is that no samples from eastern Australia were analysed (see Annex H).

3.5.2.2 OTHER INFORMATION

No additional information was presented.

3.5.3 Seasonal distribution

3.5.3.1 WINTER

It was noted that there were anecdotal records of humpback whales further north in Indonesia at approximately 8–10°S. The Workshop **recommends** that this anecdotal information be formally reported to the Scientific Committee and Bannister agreed to follow this up.

3.5.3.2 SUMMER

SC/A06/HW57 presented the results of JARPA (Japanese Research Programme in the Antarctic) sighting surveys in the waters south of 60°S in Areas IV and V. The research area was covered uniformly by systematic sighting surveys during the 1987/88–2004/05 austral summer seasons. Humpback whales were widely distributed in Area IV. The main concentration was between 80°E and 120°E in both northern and southern strata, i.e. on the eastern side of the Kerguelen Plateau. Apparent habitat expansion (from north to south) of humpback whales was observed in the longitudinal sector of the higher concentration between the first half of the JARPA survey period (1989/90–1996/97) and the second half (1997/98–2003/04). The average latitudinal position of the sightings was 60°30'S and 62°30'S in the two halves respectively. However, in discussion, the Workshop noted that the apparent expansion may reflect a combination of increase in density and some actual movement.

3.5.3.3 MIGRATION

SC/A06/HW21 reported on aerial and vessel based surveys conducted in each of the years 2000–2005 off North West Cape, Western Australia, along the migration route. In 28 aerial surveys and 38 boat surveys, a total of 3,466 humpback whales in 2,340 pods were sighted. Humpback whales were observed to migrate north past the study area during June and July, followed by a transition period in August. The southern migration past the study area occurred from September to November. Peak numbers were present in the study area during the transition period in August when approximately half of the whales observed were migrating either north or south. The majority of northbound whales migrated within the 300m isobath while southbound whales showed a preference for depths less than 200m. During the transition period, whales were most widely distributed over the area, with large numbers of whales observed offshore to the 1,100m isobath.

3.5.4 Summary

Recent information confirms earlier results, e.g. from Chittleborough (1965), with animals migrating northwards during winter from Antarctic Area IV along the west coast of Australia towards a current breeding ground destination as far north as 15°S (Jenner *et al.*, 2001) beyond North West Cape, Western Australia (*ca* 21°50'S, 114°10'E). The southerly migration takes place in late winter/spring. A few early northward migrating animals may reach the coast in April, but the main northbound stream arrives in June. Recent aerial surveys for southern right whales along the south coast between Cape Leeuwin, Western Australia and Ceduna, South Australia have recorded animals moving westwards until August, from as far east as Esperance (33°52'S, 121°54'E), with some stragglers reaching the coast even further east in the Great Australian Bight (Bannister, pers comm.). Catches off the south coast at Albany (35°01'E, 117°53'E) and off the west coast at Carnarvon (24°53'S, 113°40'E) and Point Cloates (22°43S, 113°40E), 1949–63 (Chittleborough, 1965; Dawbin, 1997), showed marked segregation during the northern migration, with sexually immature animals and mature females at the end of lactation in the vanguard, most adult males travelling in the middle of the period, pregnant females in the rear, and non-pregnant females being found throughout. On the southern migration, those first to arrive in warmer waters were the first to depart. Pregnant females, among the last to arrive from the south, having given birth were among the last to leave. Off North West Cape the highest numbers of animals, widely distributed, have recently been found in August at the time of transition between northern and southern migrations (SC/A06/HW21). Off Perth, Western Australia (31°57'S, 115°51'E) southbound animals are found mostly in September and October, with mother-calf pairs most commonly seen in November (Burton, 1991); humpbacks are generally not seen off the south coast after August, i.e. during the southern migration. The Workshop concluded that the question of a possible sex bias in migrating animals still remains to be resolved. In the Antarctic, the area of greatest concentration recently has been east of the Kerguelen Plateau, between 80°–120°E (SC/A06/HW57). There may have been some habitat expansion from north to south in that area in recent years.

3.5.5 Recommendations for future research

A consolidated set of recommendations for Breeding Stock D is given in Annex H.

3.6 Breeding Stocks E (eastern Australia) and F (Oceania)

3.6.1 Individual movements

3.6.1.1 DISCOVERY AND OTHER ARTIFICIAL MARKS

Table 6 summarises the artificial mark information for Breeding Stocks E and F.

There are strong links between Breeding Stock E and feeding grounds in this region. Animals marked in the breeding ground spread more widely in the feeding grounds that for any other breeding stock. Animals marked off eastern Australia were recovered as far west as 113°E in the Antarctic and one was recovered off Carnarvon, Western Australia (Breeding Stock D). There are links to the eastern

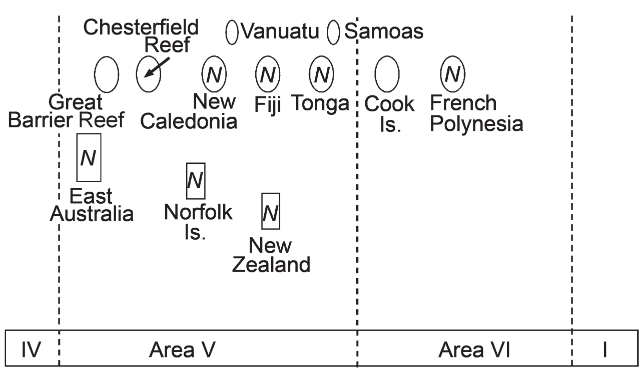

Fig. 5. Schematic map showing putative breeding grounds, migratory corridors and feeding areas of the South Pacific. Area V covers from 130°E to 170°W and Area VI from 170°W to 120°W. *N* = samples available.

Table 6
Summary of artificial marking information for Breeding Stocks E and F.

Marking	Breeding Stock E	Putative feeding grounds (Area V?)
Humpbacks marked (all marks)	2,712	664
Marks recovered	95	26
Origin of marks recovered	97	22
Movements to other Areas	9* (to Area IV), 3** (to Area I)	3 (movement to west to Area IV)
Movement from other Areas	1 movement from Area IV	1 movement from Area VI
Marking	**Breeding Stock F**	**Putative feeding grounds (Area VI?)**
Humpbacks marked (all marks)	7	66
Marks recovered	0	1
Origin of marks recovered	0	2
Movements to other Areas	0	1 movement to eastern Australia
Movement from other Areas	0	0

*1 animal marked in Fiji was reported as recovered at 55°S, 87°E (western Area IV) by Soviet fleet – there is uncertainty surrounding this as it was reported as a fin whale (see Item 3.5.1.1). **2 animals marked in Tonga were recovered at the western edge Area I – one of these marks was recovered from cooker.

Australia migratory corridor and New Zealand (interchange both ways). One whale marked in Fiji was recovered at eastern Australia (Tangalooma).

In contrast, no marks have been recovered linking Breeding Stock F with feeding grounds, but this reflects the very small sample size with only two animals marked on the breeding grounds and a total lack of whaling activity there.

3.6.1.2 NATURAL MARKS (PHOTO-ID, GENETIC)

There is a very considerable amount of photo-identification data for eastern Australia (Breeding Stock E) as indicated in the table of metadata available on the IWC website*. However, discussion at the meeting focused on papers examining photo-identification data from other areas relevant to Breeding Stocks E and F.

SC/A06/HW50 reported on photo-identification of humpback whales in New Zealand waters and their migratory connections to breeding grounds of Oceania. To help document the recovery of humpbacks in New Zealand and improve understanding of their migratory connections, photographs have been obtained opportunistically since 1994 and systematically since 2004. The catalogue of 34 whales has been compared with nearly 1,400 photographically identified individual whales throughout the wintering grounds of Oceania. To date there have been two whales resighted off New Caledonia, one resighted off Tonga and one New Zealand in different years. There have been no resightings from other regions in the same year. The connections with New Caledonia are consistent with recent genetic and song evidence suggesting a close relationship with this breeding ground. However the low rate of resighting in all available catalogues from Oceania (including New Caledonia) suggests that the primary wintering grounds for the New Zealand component of Breeding Stock E have yet to be identified. Systematic matching with a component of individuals identified from eastern Australia is planned for November 2006.

SC/A06/HW55 described the movement of individual humpback whales between winter breeding grounds of Oceania (South Pacific) documented by individual identification photographs collected from 1999 to 2004. The report extends previous comparisons for some of these regions (Garrigue *et al.*, 2002). Photographs were collected with comparable effort across the six years in four primary island breeding grounds: New Caledonia, Tonga (Vava'u) the Cook Islands and French Polynesia (Mo'orea and Rurutu) and with less effort in a few adjacent regions: Vanuatu, Fiji, Samoa, Niue and American Samoa. Catalogues from all regions were compared during annual meetings of the South Pacific Whale Research Consortium. For the six year period, regional catalogues of fluke photographs representing 1,148 annual sightings of 1,021 individual whales from Oceania were compared to investigate interchange between wintering grounds. Most resightings occurred within regions (e.g. see SC/A06/HW51) but 23 individuals were sighted in two regions (mostly adjacent) in different years, including interchange between Breeding Stocks E and F. One individual was resighted during the same year in two regions (Tonga and the Cook Islands), although a second was seen in two subregions of Tonga in the same year (Vava'u and Eau). No individual was sighted in more than two regions during the six years. The documented movement between regions was one-directional except for one individual sighted first in French Polynesia, then in American Samoa and then again in French Polynesia (in different years). No directional trend was apparent in the one-directional movement and movement between regions did not seem to be sex specific (although a sex bias could not be discounted).

SC/A06/HW19 noted that historically, humpback whales migrating through eastern Australia and New Zealand waters, and breeding off northeastern Australia, New Caledonia, Fiji and Tonga were assigned for management purposes to Antarctic Area V. So far within the current Comprehensive Assessment, humpback whales in these regions have been considered to be a part of Breeding Stock E. The paper reports on the relationship between the New Caledonia and Tonga breeding grounds, based on seasonal return and interchange of individual whales (photo-id and genotype-id), as well as population genetic differentiation (the latter is discussed under Item 3.6.2.1). The results showed significantly higher recapture probabilities within each breeding ground compared to the recapture probability between them, using both photo- and genetic-id.

SC/A06/HW49 described the results of an eight-year survey of humpback whales in the Cook Islands (South Pacific). At least 93 humpback whales were individually identified from tail fluke photographs. A separate catalogue uses the dorsal fin, scarring and underwater shots of lateral

* *http://www.iwcoffice.org/documents/sci_com/workshops/Table2.pdf* accessed October 2011.

pigmentation. Although tail fluke matches have been made with neighbouring countries (7 with Tonga, 1 with French Polynesia, 1 with Nuie, east of Tonga and 1 with American Samoa), the relationship of humpbacks in this region to those in adjacent tropical areas remains unclear. There have been no inter-annual re-sightings to date.

SC/A06/HW60 presented the results of research within French Polynesia. Using fluke photographs taken from 1990–2005, Poole identified 416 individual whales; there have been 37 inter-annual re-sights of 34 individuals. Identified whales were compared with those of New Zealand, New Caledonia, Tonga, Niue, the Cook Islands, Columbia, Ecuador and the Antarctic Peninsula. There has been one intra-annual resight between Moorea and the Cook Islands. Two inter-annual matches were found between French Polynesia and American Samoa; five matches with Tonga; and one with New Caledonia.

In discussion, the Workshop **agrees** that is was essential that a full comparison with catalogues for eastern Australia be undertaken as soon as possible. This is discussed further under Item 3.6.5.

3.6.1.3 TELEMETRY

No information is available for either Breeding Stock E or F.

3.6.1.4 OTHER (e.g. LOST HARPOONS)

No additional information was presented.

3.6.2 Stock structure

3.6.2.1 GENETIC INFORMATION (POPULATION LEVEL)

SC/A06/HW19 reported on the relationship between whales on the New Caledonia and Tonga breeding grounds, based on seasonal return and interchange of individuals (see Item 3.6.1.2 above), as well as on population genetic differentiation using mtDNA and microsatellite data. The analysis of mtDNA using samples from both regions after removal of replicates identified by microsatellite genotyping revealed significant differentiation. This was supported by a new analysis of microsatellite loci (up to nine), showing significant differentiation between the two regions. These analyses, and the previous report of demographic and reproductive isolation of New Caledonia (Garrigue *et al.*, 2004), demonstrate significant differentiation within Breeding Stock E. The authors conclude that the current Breeding Stock E must be subdivided into at least three stocks or substocks: one represented by the breeding grounds along eastern Australia (the Great Barrier Reef and perhaps Chesterfield Reef) referred to as E1; a second represented by New Caledonia (E2); and a third by Tonga (E3). They noted that the degree of isolation or interchange between these and other known wintering grounds, such as Vanuatu, Fiji and the Samoas, remains poorly described.

SC/A06/HW31 presented an analysis of the contemporary genetic diversity of New Zealand humpback whales, comparing mtDNA data (a 470bp of the mtDNA control region consensus sequence) with that from breeding grounds across the South Pacific (New Caledonia, Tonga, Cook Islands, French Polynesia and Colombia) and eastern Indian (western Australian) Oceans. A total of 30 samples collected around New Zealand, mostly during the northbound migration, was compared with 1,112 samples from breeding grounds. The analysis revealed 20 haplotypes in the New Zealand samples, all seen before in New Caledonia and some also in other breeding grounds. The New Zealand humpback whale haplotype diversity (h) was 0.97 ± 0.015, and the nucleotide diversity (π) was $2.18\% \pm 1.14\%$, similar to those from the compared breeding grounds, but they were significantly different only at haplotype level with the Cook Island, French Polynesia and Colombia breeding grounds. Significant differences were found only at haplotype level with the same three locations when a pair-wise AMOVA was performed. Three breeding grounds (western Australia, New Caledonia and Tonga) did not show significant differences at either nucleotide or haplotype levels. This genetic evidence and the available demographic data suggest a closer relationship of the New Zealand stock with New Caledonia and Tongan whales; however, the authors cautioned that because of the small sample size from New Zealand this should be considered a preliminary finding.

SC/A06/HW60 presented the results of research within French Polynesia. Analyses of sloughed skin (n = 101) resulted in a sex ratio of 1.5 males to 1 females; 22 haplotypes were found, few of which are shared with whales from other regions of the South Pacific. Based on genetic differences between and limited interchange with other regions of Oceania, the author considered that the whales of French Polynesia should be considered a distinct breeding stock, even from those of the Cook Islands, just 1,000km to the west.

Whilst welcoming these papers, the Workshop noted that despite the large number of samples available, there have as yet been no major genetic comparisons of the data from eastern Australia with samples from other parts of the South Pacific. The Workshop **strongly recommends** that such analyses be undertaken as soon as possible, since they are fundamental to understanding stock structure in these regions and in particular, may enable a reduction in the number of hypotheses in Item 3.6.2. This is discussed further under Item 3.6.3.

3.6.2.2 OTHER INFORMATION (e.g. CPUE AND CATCH HISTORY)

The meeting noted that CPUE series were available for certain areas, but considered that these did not provide information on stock structure *per se* for this region.

3.6.3 Seasonal distribution

3.6.3.1 WINTER

SC/A06/HW28 presented the results of a cetacean survey (visual and acoustic) in October in the waters of Independent Samoa in 2001. It revealed that humpback whales, including calves, are present at very low densities in the coastal waters of Samoa in October. The presence of calves and frequent singing indicates this is likely to be a small breeding area or migratory corridor to a breeding area.

SC/A06/HW49 described the results of an eight-year survey of humpback whales in the Cook Islands. Surveys were conducted at Palmerston Atoll, Aitutaki and Rarotonga during the austral winter months (June to October) from 1998 to 2005. Additional observations were made from the islands of Atiu and Mangaia. During 2,911 survey hours (over 563 days at sea), 522 humpback whale groups (846 animals) were recorded. All classes were observed, including singers, mothers and calves, mother/calf/escort trios and competitive groups. Although the Cook Islands region may represent a breeding ground for humpback whales, the low density of animals and the complete lack of inter-annual re-sightings to date suggest that it is not a central breeding location. These waters may well serve as a corridor for migrating humpback whales.

SC/A06/HW60 presented the results of research within

French Polynesia. Whales have been observed near at least 25 islands in all of French Polynesia's five archipelagoes, although sightings of whales in the Marquesas Islands are very rare and sightings within the Tuamotu Islands are not frequent. Calves represented 10% of all network sightings. During the austral winters of 1991–2005, boat surveys were conducted at Moorea in the Society Islands, and from 1999–2005 at Rurutu in the Austral Islands. Calves again represented approximately 10% of all whales. At Moorea, individual whales' residence times were usually limited to three days or less; at Rurutu, residence times for some individuals ranged from 2–6 weeks.

Humpback whales are thus known from at least seven areas in the South Pacific that are or may be breeding grounds: the Great Barrier Reef, Chesterfield Reef, New Caledonia, Tonga, Cook Islands, Samoa and French Polynesia.

3.6.3.2 SUMMER

SC/A06/HW57 presented the results of JARPA sighting surveys in the waters south of 60°S in Areas IV and V. The research area was covered uniformly by systematic sighting surveys from the 1987/88 to 2004/05 austral summer seasons. Humpback whales were widely distributed in Area V. It seems that there may be a boundary in the feeding grounds at around 130°–140°E. This sector is notable in that it includes the minimum distance between the Antarctic Continent and the southern boundary of the Antarctic Circumpolar Current. Whales in Area V were clearly distributed along the Pacific Antarctic Ridge where the southern boundary of the Antarctic Circumpolar Current is observed.

3.6.3.3 MIGRATION

There are three known migratory areas relevant to the currently designated Breeding Stock E: the eastern Australian coast, Norfolk Island and New Zealand. SC/A06/HW49 also suggested that Cook Islands waters may serve as a migratory corridor (and see Item 3.6.3.2).

Childerhouse reported on land-based sighting surveys undertaken during the northward migration in 2004 and 2005 at Tory Channel, Cook Strait in New Zealand over a two week period (18 June–3 July) each year. The purpose of the study was to investigate trends in abundance since whaling had ceased in 1964. Some 140 (2004) and 72 (2005) individuals were estimated to have migrated past during daylight hours; a crude analysis suggested that their numbers were at about 0.23 of the numbers in 1960.

3.6.4 Summary

Table 7 and Fig. 6 summarise the Workshop discussions concerning stock structure for Breeding Stocks E and F.

In discussion, it was noted that certain components of alternate models could not be excluded based on available genetic analyses and photo-identification comparisons.

The Workshop **strongly recommends** (see Item 3.6.5) that future analyses include:

(1) incorporation of samples from eastern Australia;
(2) consideration of possible yearly variation in the different localities;
(3) consideration of possible sex-bias in dispersal; and
(4) consideration of the possibility of replicate sampling of individuals.

With respect to point (4), it was noted that in breeding grounds in Oceania where this has been investigated (e.g. Tonga), it was not found to be a significant problem. Microsatellite genotyping is planned for other areas to ensure that this is not a problem for the rest of Oceania. Olavarria noted that analysis of yearly variation and sex-bias in mitochondrial DNA is underway.

3.6.5 Recommendations for future work

A consolidated set of recommendations for Breeding Stocks E and F is given in Annex H.

3.7 Breeding Stock G

3.7.1 Individual movements

3.7.1.1 DISCOVERY AND OTHER ARTIFICIAL MARKS

Table 8 summarises the artificial mark information for Breeding Stock G (SC/A06/HW33). There was no whaling effort and no whales were marked on the breeding grounds.

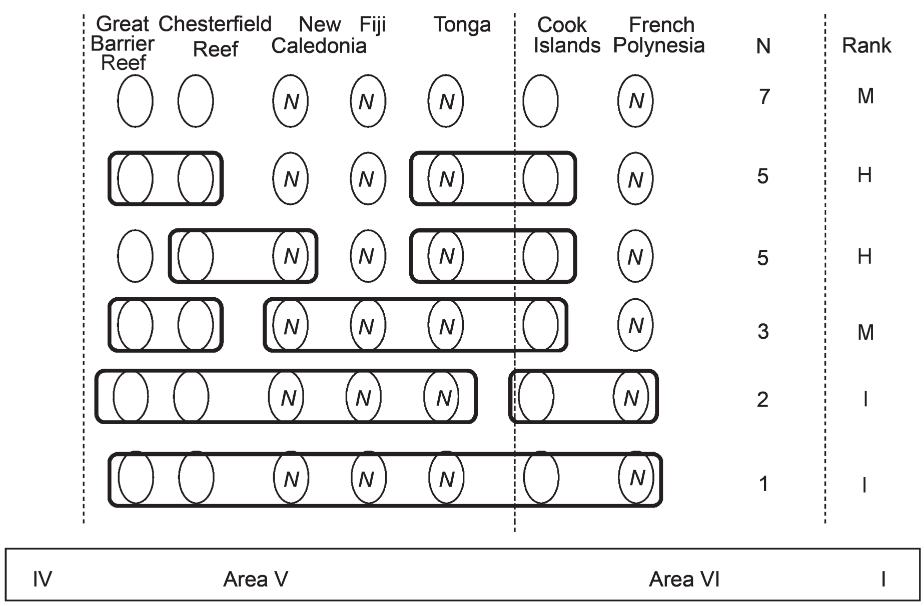

Fig. 6. Schematic diagram showing possible models for stock structure in the South Pacific. N = number of breeding stocks and Rank: L = low; M = medium; H = high.

Table 7a

Models of stock structure for breeding grounds (EA = east Australia [includes Great Barrier Reef except in Model 1]; CR = Chesterfield Reef; NC = New Caledonia; Tg = Tonga; CI = Cook Islands; FP = French Polynesia) of the South Pacific. Key: ++ = strongly supports; + = is consistent with; ~ = evidence is ambivalent or uninformative; – = evidence is inconsistent with; – – = contradicts.

Model	1	2	3	4	5	6
No. breeding grounds	7	5	5	3	2	1
	All separate	{EA-CR}; {NC}; {Tg-CI}; {FP}	{EA}; {CR-NC}; {Tg-CI}; {FP}	{EA-CR}; {NC-Tg-CI}; {FP}	E-F separation	All pooled
Rate of increase	+	+	+	+	– –	– –
Genetic differentiation	+	++	++	–	–	– –
Acoustics	+	+	+	–	–	–
Photo-id return	+	+	+	–	–	– –
Photo-id interchange	–	–	–	+	–	+
Discovery marks	~	~	~	~	–	–

Table 7b

Summary of the evidence used to construct Table 7a.

Rate of increase	There are at least 3 sites that are on migratory corridors for these populations. The east coast of Australia is almost certainly related to whales migrating to the Great Barrier Reef and possibly Chesterfield Reef. It has a 2004 abundance estimate of 7,090 whales and an annual rate of increase of 10.6% (SC/A06/HW27). Norfolk Is. has shown very little sign of recovery with current sighting rates of ~1/30 cf. those in the 1950s (SC/A06/HW36). Similarly, sighting rates from New Zealand are lower than in the 1950s (Childerhouse, pers. comm.). It is not known which breeding population or populations were related to the Norfolk Is. or New Zealand migratory routes although the lack of recovery is similar to that of Fiji.
Genetics	mtDNA differentiation rejects random intermingling of the four primary Oceanic regions, suggesting instead some degree of maternal fidelity (SC/A06/HW42; Olavarria *et al.*, 2006). Comparison with eastern Australia or Chesterfield Reef does not exist but should prove very informative. Nuclear DNA rejects panmixia of NC and Tonga. Information unavailable for other pair-wise comparisons. Paternity inference (gametic recapture analysis) suggests relative reproductive autonomy of New Caledonia – SC/A06/HW19, Garrigue *et al.* (2004); Baker *et al.* (2005) – but see Palsbøll *et al.* (2005).
Photo-id return	Photo-id returns suggest a reasonably high level of fidelity to primary breeding grounds (New Caledonia, Tonga, and French Polynesia) as reflected in relatively small estimates of abundance (SC/A06/HW51, SC/A06/HW52, SC/A06/HW60, Garrigue *et al.*, 2004). Few cases of documented interchange in the same winter season (SC/A06/HW55).
Photo-id interchange	Photo-ids suggest low, but detectable, levels of interchange or dispersal between neighbouring populations in Oceania with very low levels of movement among more distant populations across (SC/A06/HW55, SC/A06/HW60). There are several instances of movements between E and F (e.g. SC/A06/HW55). A very important gap is the lack of comparisons between eastern Australia and elsewhere.
Discovery marks	Discovery marks demonstrate a low level of dispersal among breeding grounds against a background of a higher level of fidelity demonstrated by photo-id. They also display some level of longitudinal movement on the feeding grounds compared with breeding grounds (SC/A06/HW33).
Acoustics	Song recordings demonstrate some similarity between Eastern Australia, New Caledonia and Tonga indicating there is some level of connection (probably inter-year dispersal) between these populations. They also demonstrate differences between these populations that suggest this connection is at a low level. Further investigation required to document rate of change across eastern Australia to Oceania (Helweg *et al*., 1998).

3.7.1.2 NATURAL MARKS

SC/A06/HW08 described a photo-identification study carried out between 1991 and 2004 off Ecuador (1°S, 80°W), during which 1,064 humpback whales were identified. 76 (7.14%) of these were resighted off Ecuador between these years. The longest span between capture and recapture was 11 years for one individual. 61 (5.71%) were individually identified within the same year. The maximum period within season between first and last recapture was 50 days, while the minimum was 1 day.

In discussion, it was noted that Columbia and Ecuador are the main wintering areas along the west coast of South America, and a previous study had provided photo-identification matches between Columbia, Ecuador and Panama (Flórez-González *et al.*, 1998), suggesting there is no differentiation between these areas.

3.7.2 Stock structure

3.7.2.1 GENETIC INFORMATION

SC/A06/HW29 presented the results of an investigation of the genetic (mtDNA control region sequences) relationship between humpback whales from the two summer feeding areas that have been linked to Breeding Stock G, the Antarctic Peninsula and the Magellan Strait. A total of 89 samples from the Antarctic Peninsula and 52 from the Magellan Strait areas were compared using an AMOVA analysis; significant differences were found between these two feeding areas to the haplotype (F_{ST}) and nucleotide (Φ_{ST}) levels. Comparison of these two feeding areas with breeding grounds of the South Pacific and the Indian Ocean revealed significant differences for each pair-wise comparison except for that between Colombia and the Antarctic Peninsula. The authors suggest that the genetic information, allied to that from the photo-identification link between the Antarctic Peninsula and Magellan Strait, reveals heterogeneity in the feeding areas of this Breeding Stock.

3.7.3 Seasonal distribution

3.7.3.1 WINTER

SC/A06/HW15 presented information on a survey (742km) undertaken in the central and southern parts of the Galapagos archipelago (1,000km from mainland Ecuador) between the 31 August and 10 September 2005 aimed at examining humpback whale presence, distribution and relationship to

Table 8

Summary of artificial marking data for Breeding Stock G.

Marking	Breeding grounds	Feeding grounds (Area I)
Humpback marked (all marks)	0	131
Marks recovered	0	4
Origin of marks recovered	0	4
Movements to other Areas	1* marked: 62°S, 116°W (Area I). Recovered: 28°S, 45°W (Stock A)	0
Movement from other Areas	0	2** marked in Tonga (breeding stock E(i)) recovered in Area I (west edge)

*Recovered in cooker and may (anecdotal) have been taken in the South Pacific. **One recovered in cooker.

other stocks in the South Pacific. Only one mother with a newborn calf was seen, giving an encounter rate of 0.27 whales/100km of survey. No sounds were recorded from 25 hydrophone stations. The adult female was biopsied and an mtDNA comparison with six animals from mainland Ecuador and other South Pacific areas undertaken. Four different haplotypes were defined, all previously described only in the Southeastern Pacific population. The Galapagos specimen had a haplotype found in one individual biopsied off Colombia, thus establishing some degree of relatedness with the mainland stock. The authors suggest that while there is evidence that the Galapagos Islands is occupied as a breeding area, the low density recorded suggests that the population is small.

Castro noted reports of cows and calves sighted from naturalists' cruises off Isobela Island in the Galapagos Islands from January to March. The timing of these sightings is unusual here and it was speculated that these may be Northern Hemisphere whales, perhaps connected to Costa Rica and Panama. Genetic studies (Baker *et al.*, 1998) suggest that there has been at least historic (perhaps during the last ice age) exchange between the eastern North and South Pacific humpback whale populations. There is also a match of an individual whale from Magellan Strait to Costa Rica (and back to Magellan Strait) with relatively few photographs from either area, there is thus the possibility that the northernmost whales on the feeding grounds (Magellan Strait) migrate furthest north to Costa Rica, passing through the breeding grounds in Ecuador and Columbia. There is considerable exchange between Ecuador and Columbia (Félix and Haase, 2005; Félix and Haase, 2001).

3.7.3.2 SUMMER

SC/A06/HW29 compared mtDNA control region sequences from 89 samples from the Antarctic Peninsula and 52 samples from the Magellan Strait areas. An AMOVA showed significant differences between the two feeding areas. Genetic and demographic data (based on photo-id) strongly suggest that both feeding areas are related to the same breeding grounds (Columbia and Ecuador) but that heterogeneity exists among the feeding areas, similar to that observed in North Pacific and North Atlantic humpback whale populations.

3.7.4 Summary

The Workshop noted the following.

BREEDING GROUND INFORMATION

(1) Genetic evidence of differentiation of Breeding Stock G (Colombia) from other breeding grounds in the Southern Hemisphere, including its nearest neighbours, A and F.
(2) Photo-id evidence of differentiation of South Pacific (E, F) Breeding Stocks and neighbouring Breeding Stock A (based on lack of movement between E/F and A).
(3) Evidence of historical and current distribution on wintering grounds off Ecuador and Colombia, but also extending north to Panama and Costa Rica.
(4) Some suggestion of differentiation within Breeding Stock G, in northern (Costa Rica/Panama) and southern (Colombia/Ecuador) areas, based on differentiation (photo-id and genetics) between feeding areas (see below).

FEEDING AREA INFORMATION

(1) Historical and current distribution of Breeding Stock G animals in Area I off the west coast of the Antarctic Peninsula, including South Shetland Islands.
(2) Current distribution during summer in the Magellan Strait and adjacent channels and fjords, in south-eastern South America (genetic and photo-id evidence shows strong differentiation between the two feeding areas).
(3) Satellite tagging shows residence off the Antarctic Peninsula during summer season.

MIGRATORY LINKAGE

(1) Some evidence from Discovery marks of movement between Breeding Stock E (Tonga) and the Antarctic Peninsula, but one mark was found in a cooker.
(2) Genetic evidence of a non-significant difference between the Antarctic Peninsula and the Colombian breeding area, but significant differences between it and the South Pacific (Breeding Stocks E, F) and Indian Ocean (D) and South Atlantic (A) breeding grounds.
(3) Genetic evidence shows a significant difference between the Magellan Strait area and the South Pacific (Breeding Stocks E, F and G) and the Indian Ocean (D).
(4) Photo-id analysis shows strong evidence for a linkage between the Antarctic Peninsula and Breeding Stock G and a lack of linkage with the South Pacific (Breeding Stocks E, F) and South Atlantic (A).
(5) Photo-id shows strong evidence for linkage between the Magellan Strait and Breeding Stock G.

CONCLUSION

Although the possibility of modelling the Magellan Strait feeding area as a separate stock was raised, given the lack of strong evidence for this and any information on a link to breeding grounds, the Workshop **agrees** that Breeding Stock G should be modelled as a single stock.

3.7.5 Recommendations for future work

A consolidated list of recommendations for Breeding Stock G is given in Annex H.

Table 9

Evidence for stock structure for breeding stock G.

Hypothesis	1 breeding stock	>1 breeding stocks
Rate of increase	~	~
Genetic differentiation	~	~
Acoustics	~	~
Individual interchange	+	~
Catch data	~	~
Total evidence	+	~

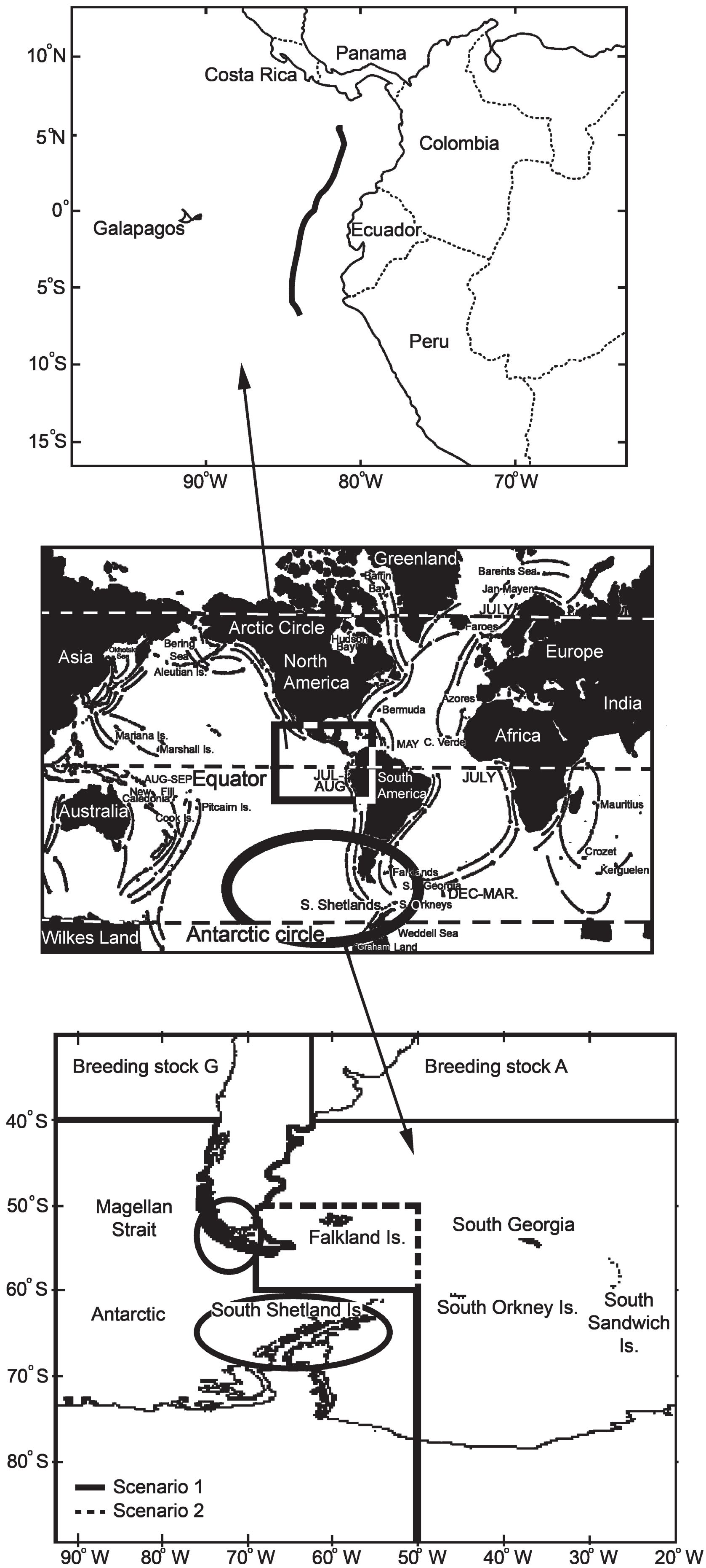

Fig. 7. Map showing possible links with feeding grounds for Breeding Stock A (see text).

3.8 Overall population structuring

3.8.1 Breeding grounds

SC/A06/HW41 presented an mtDNA analysis of humpback whale population structure from Breeding Stocks A, B, C and X. A total of 1,489 individuals was examined (130 of these were not genotyped and may have contained duplicates). Samples were stratified by sex and year for some regions. AMOVA analyses showed significant differences in all strata across all compared regions (A, B, C and X). Most pairwise comparisons using F_{ST} and M_{ST} were also significant. Preliminary analysis using MIGRATE gave the highest degree of migrants from B to A, but interpretation of this remains equivocal. Lack of, or low, gene flow was indicated between C3 and B2, and between C and X (and X and C in the other direction). Overall, the results suggest significant differentiation between breeding stocks in different ocean basins, although there appears to be some overlap between B and C.

SC/A06/HW38 used microsatellites to examine population structure among the same four breeding stocks. A much lower level of structure was found than in the mtDNA analysis, but significant differentiation among regions was found; the differences were bigger between A and B than between B and C. Some evidence was presented to suggest further substructure among B and C, and the suggested divisions did not correspond to the ones currently in use. Assignment indices and F_{ST} estimates for males and females were consistent with a scenario of male-biased dispersal (and therefore gene flow). Estimates of dispersal rates overall suggested high numbers of effective migrants per generation exchanged between adjacent wintering regions, as well as within regions. The detection of movement in genotypically identified individuals further suggests ongoing gene flow across existing stock boundaries.

SC/A06/HW59 presented a preliminary mtDNA analysis using a large sample set (total number of sequences = 2,683) from all recognised regions (i.e. A–G and X), and as such represented the first comprehensive comparison of all Southern Hemisphere humpback whale breeding stocks. AMOVA and F_{ST} comparisons showed significant differences between all regions and sub-regions, except between regions C2 and C3. The latter finding is consistent with other analyses presented at the Workshop, and the overall finding of differentiation elsewhere is broadly in agreement with existing stock structure concepts for Southern Hemisphere humpback whales.

Africa (B and C)

The Workshop considered stock structure for the breeding grounds off Africa (B and C).

With regard to possible links between Breeding Stocks B and C, one individual has been identified and genotypically identified in both areas (Pomilla and Rosenbaum, 2005). It was also noted that there was broad similarity in song between A, B and C (Darling and Sousa-Lima, 2005, Cerchio, unpublished data). Song is regarded by some as an overly sensitive indicator of dispersal in that a relatively small amount of male dispersal across regions can result in similarity, and as a result the utility of song in assessing population differentiation is limited. Furthermore, it is possible that song exchange occurs not by male dispersal across different breeding grounds but through mixing on migration or on a common feeding ground.

Some of the nuclear genetic analyses presented in SC/A06/HW38 do indicate a degree of mixing between B and C. However, given the clear separation shown in (female-mediated) mtDNA, the sex (male) of the one whale known to have moved between regions, and the similarity of (male-mediated) song, the most parsimonious explanation is that exchange between B and C primarily involves males.

Conclusion

It was noted that a very considerable amount of work had gone into producing the genetic data presented at the Workshop, and that some of this information was the result of intensive last-minute analysis. It had not been possible to fully evaluate such a large amount of work in such a short time. It looked forward to receiving a consolidated summary of the analyses at the next meeting of the Scientific Committee, and requested that this also include a table summarising pairwise comparisons between other breeding grounds. It was also suggested that additional analytical methods might be explored to examine structure, such as those being considered by the TOSSM program (IWC, 2007a).

3.8.2 Feeding grounds

SC/A06/HW40 provided the results of a genetic study based on biopsy samples from 411 humpback whales obtained during surveys of the Japanese Whale Research Program under Special Permit (JARPA) and the International Decade for Cetacean Research/Southern Ocean Whale and Ecosystem Research (IDCR/SOWER). The study was conducted to describe the genetic population structure of humpback whales on their Antarctic feeding grounds. Samples were obtained from the feeding grounds in Areas III (n = 81), IV (n = 172), V (n = 97) and VI (n = 61), and were examined for (1) sex, (2) the sequence variation of the first 334bp nucleotides of the mtDNA control region and (3) genetic variation at the genotypes of six microsatellite loci. Duplicate samples were excluded from the analysis. The level of genetic diversity in the Antarctic was high for both genomes: the nucleotide diversity at the mtDNA was estimated at 0.0263 and the mean expected heterozygosity at the nuclear loci at 0.7820 for the total samples. In general, results based on both mtDNA and microsatellites were similar and suggest population structure of humpback whales in the Antarctic feeding grounds. These genetic results are consistent with the previous view based on non-genetic data that Areas III, IV, V and VI are occupied by different populations. Marked differences were found between whales in Areas IV and V for both mtDNA and microsatellites, and the same pattern was found for both sexes. Results of the other pair-wise comparisons among Areas showed more subdivisions for females than for males. One explanation for this result is that the difference is due to the lower sample sizes for males in these comparisons. The possibility of intermingling of populations in bordering sectors cannot be discarded yet, and a comprehensive analysis that involves genetic data from low and high latitudes is recommended to resolve this issue. The authors also noted that they could not comment from their data on relationships between feeding and breeding areas, and recommended that a comparison between samples from the two regions should be a high priority for further work.

The Workshop welcomed this analysis from the feeding grounds. In discussion, it was noted that few biopsy samples were collected from the longitudinal sector near the division between Areas IV and V, which also coincides with a gap in sighting distribution (SC/A06/HW57). It was also noted that krill is not abundant in that particular sector.

SC/A06/HW57 provided information from JARPA surveys on the distribution of humpback whales in Areas IV and V, in waters south of 60°S. Humpback whales were widely distributed in both Areas, with a major concentration between 90° and 120°E, and wide dispersal in other parts of Area IV. An apparent habitat expansion was observed between 1989/90–1996/97 and the latter half of the surveys in 1997/98–2003/04. However, in discussion it was noted that the apparent expansion may result from a combination of an increase in density and some actual movement.

Pastene reported a single case of a molecular marker match for a female humpback whale first sampled in the western part of Area V (January 1995) that was subsequently re-sampled in the eastern part of Area IV (January 2000) (Pastene *et al.*, 2000).

A question was raised regarding whether the boundary of Area V (assuming this represents a stock) should be moved to 120°E (from 130°E). It was noted that this was consistent with Discovery mark data, and it was suggested that east Australian whales were indeed moving further to the west than the current boundary of Area V. However, given that the region between 120° and 130°E was identified as a high-density area in the JARPA surveys, it is possible that mixing occurs in this region between whales from Areas IV and V. Omura (1953) examined the distribution of humpback whales in the feeding grounds of Areas IV and V based on catch data. He suggested that two populations occur in these Areas with a boundary around 130°–142°E. He did not discard the possibility of intermingling between these two populations in the feeding grounds. He also examined the pattern of catches by month, and suggested that for the months where more data were available (November–March), the boundary between these two populations changed from 120°–130°E in November to the east of 140°E in December and to 120°–140°E in January.

SC/A06/HW26 presented analyses of mtDNA and microsatellites to address the question of structure and diversity of humpback whales in Areas I, II and III. High diversity was found in all areas in both genomes. Differences were found between Area I and both II and III; the two latter Areas were not easily differentiated, suggesting mixing between them. This conclusion is limited by the current small sample size, and it was suggested that the consequent power of the analysis to discriminate differences in populations was low, and required further work, notably using recently collected samples from IDCR/SOWER cruises. The results suggested substructure even at a fine scale in Area I, and that different breeding populations may mix in Areas II and III.

The Workshop noted that a further 71 biopsy samples were collected from the 2005/2006 SOWER cruise. It **recommends** that IDCR/SOWER samples be made available as soon as practicable. It was subsequently noted that owing to issues with CITES permits, it would not be possible for further analyses to be conducted prior to the 2006 Annual Meeting.

SC/A06/HW29 found significant genetic differences between two feeding areas, one off the western coast of the Antarctic Peninsula and another in the fjords and channels of Chile (the Magellan Strait area).

3.8.3 Linkages between breeding and feeding grounds

An analysis conducted at the Workshop by Loo and colleagues (Annex E) examined genetic differentiation between samples from Breeding Stocks A, B, C and X, and feeding Areas I, II and III. The analysis suggested that animals found in Area I are genetically isolated from Breeding Stocks A, B, C and X. Differentiation of Area I is consistent with the current knowledge that individuals summering in this Area migrate to the western coast of South America, with a lack of evidence of mixing of this population with other southern groups.

Humpback whales wintering in Region X are believed to comprise the only population that does not undertake the characteristic seasonal migration observed in this species. The results of this analysis, depicting a clear lack of gene flow between Breeding Stock X and all feeding areas, supports this hypothesis.

The lack of significant differences for comparisons between animals from Breeding Stocks B and C and Areas II and III suggests that whales feeding in any of these two Areas may use either wintering regions, the degree to which remains uncertain. The data cannot, however, rule out ancestral polymorphism presence, or historical gene flow causing this lack of differentiation.

Animals from Breeding Stock A show conflicting results from different tests with respect to connection to Area II, probably due to the fact that the Area II sample included samples collected around the South Sandwich Islands and Bouvet Island, while previous data so far support connection of Breeding Stock A only to the South Sandwich Islands (Zerbini *et al.*, 2006, SC/A06/HW11). Further work will be conducted to compare Area IIW and IIE samples separately as in SC/A06/HW26. Sub-Region B1 does not show significant differences from Area II, whereas sub-Regions B2 and C1 do not show differentiation from Areas II and III, and sub-Regions C2 and C3 are not significantly differentiated from Area III.

The opportunistic basis of the sample collection on the feeding grounds, as well as the small sample sizes presented, suggest some caution in the interpretation of these results. The authors noted that the results are highly preliminary and more detailed analysis and exploration of scenarios will be explored in a forthcoming paper using mtDNA and 11 microsatellite loci. To increase the power of the analysis, all available IDCR/SOWER samples are needed (see the recommendation under Item 3.8.2).

In summary, the results of this preliminary study support:

(i) significant genetic differentiation between Area I and Breeding Stocks A, B, C and X;
(ii) significant genetic differentiation between Breeding Stock X and Areas I, II and III;
(iii) significant genetic differentiation between Breeding Stock A and Area III, but an uncertain degree of differentiation between Breeding Stock A and Area II, because of the low sample size for Area II (and combining IIE and IIW);
(iv) no significant differentiation between Areas II and III with respect to Breeding Stocks B and C; and
(v) the conclusion that the newly proposed Feeding Area B2 shows no significant differences in pairwise F_{ST} with Area II and III, but a significant difference with Area I.

The genetic analysis in SC/A06/HW29 indicated strong links between the Antarctic Peninsula and Colombia; in contrast, there was no apparent link between the feeding grounds in the Magellan Strait and sampled areas off the west coast of South America. It is possible that the Magellan Strait population is related to animals from the north of Colombia (potentially including Central America), but it is not possible to assess this on current evidence (see Item 3.7).

The Workshop noted the great value in undertaking genetic analyses of animals from both the breeding and feeding grounds. It **recommends** that every effort be made for scientists to share data and carry out such analyses. It noted the positive discussions being held by Baker, Pastene and Rosenbaum in this regard, under the IWC Data Availability Agreement, and looks forward to their successful conclusion and the submission of one or more analyses to the Committee.

Rock *et al.* (2006) examined photographic evidence documenting the movements of three individuals between their breeding grounds on the northeast coast of Australia (Breeding Stock E) and feeding grounds in Area V. Photo-id pictures from low latitude breeding grounds and high latitude feeding grounds (obtained during JARPA surveys) had been submitted to the Antarctic Catalogue. Although these individuals exhibited marked site fidelity to the same low latitude breeding ground, their sightings in high latitude feeding grounds vary by 35° longitude, confirming dispersal of Breeding Stock E whales in the Antarctic feeding grounds of Area V. These results are generally consistent with existing knowledge about the migratory destinations of humpback whales migrating and breeding off the eastern coast of Australia.

Rock *et al.* (2006) also reported the case of one individual photo-identified twice in Antarctic Area VI. The individual was first sighted during an IDCR/SOWER survey (3 January 1991 at 64°56'S; 171°43'W), and again six years later at a similar geographical position during a JARPA survey (1 January 1997 at 65°33'S; 167°29'W).

3.9 Conclusions on stock structure

It was clear from discussions and data presented during the Workshop that the level of confidence associated with stock structure concepts varies considerably across the Southern Hemisphere. In some areas (e.g. Breeding Stock A and Area II) the connections between breeding and feeding grounds and the structure within them are reasonably well understood; in such cases discussion focused largely on the extent to which boundaries should be expanded or contracted in variations of model runs. In others (e.g. Breeding Stocks B, C, E and F), there is considerable unresolved complexity and insufficient data to discriminate among a variety of stock structure hypotheses. There was much discussion of how the boundaries of each stock should be shifted, and accordingly of how the 'core' and 'fringe' areas for some of the stocks should be defined for the purpose of catch allocation.

Stock A

The Workshop **agrees** that the most plausible hypothesis is that of a single breeding stock (A) connecting with a single feeding ground (Area II). Given that the great majority of the catches in Area II were taken at South Georgia and the South Sandwich Islands, catch allocation for the purpose of modelling is thus relatively straightforward (see Fig. 8).

Stocks B and C

The Workshop **agrees** that, at present, the situation for both stocks B and C is too complex and unresolved to allow useful attempts to develop stock structure hypotheses of value for assessment modelling.

Stock D

The Workshop **agrees** that the available information is sufficient to generate a reasonable hypothesis regarding Breeding Stock D and its general connection to the feeding grounds of Area IV. However, there remains the question of how much encroachment/mixing exists with Area V to the east and Area III to the west.

In relation to the discussion on the location for the core feeding grounds for Breeding Stocks D and E the following Discovery mark data support the division between the two stocks is being moved 10° to the west. It was noted that the previously agreed boundaries for the core area of the feeding grounds for Breeding Stock D are from between 80°E to 110°E with the eastern fringe set between 110°E to 130°E.

Of the 132 marks recovered from humpback whales marked in the breeding and feeding grounds associated with Breeding Stock E, 12 whales (approximately 9% of the recoveries) were recorded moving from Area V into Area IV.

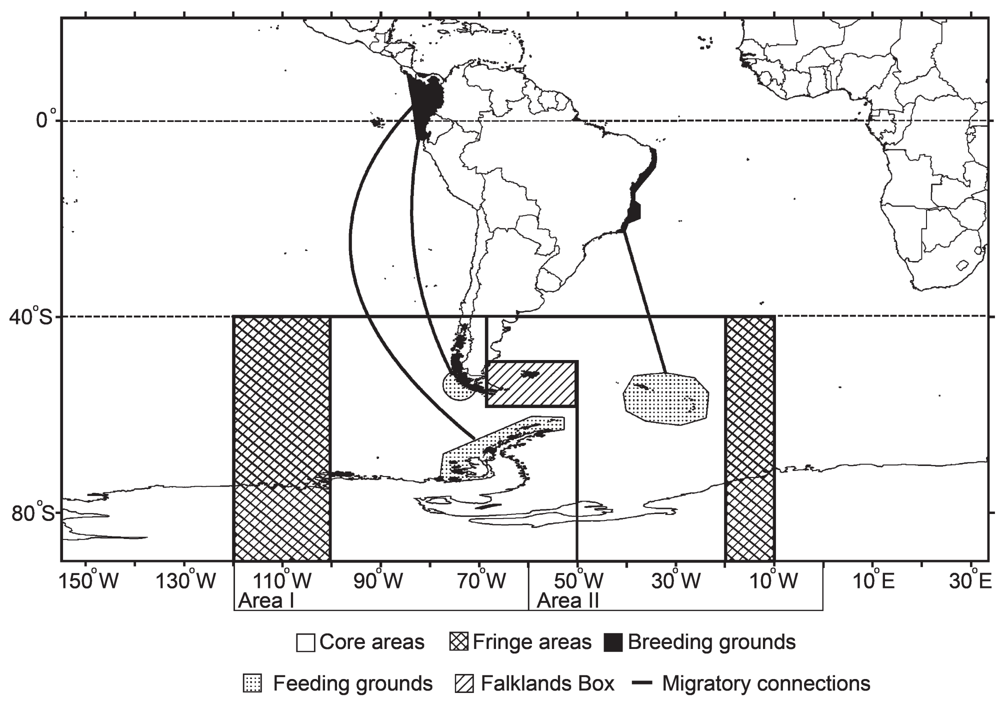

Fig. 8. Map showing the hypotheses to be modelled for Breeding Stocks A and G.

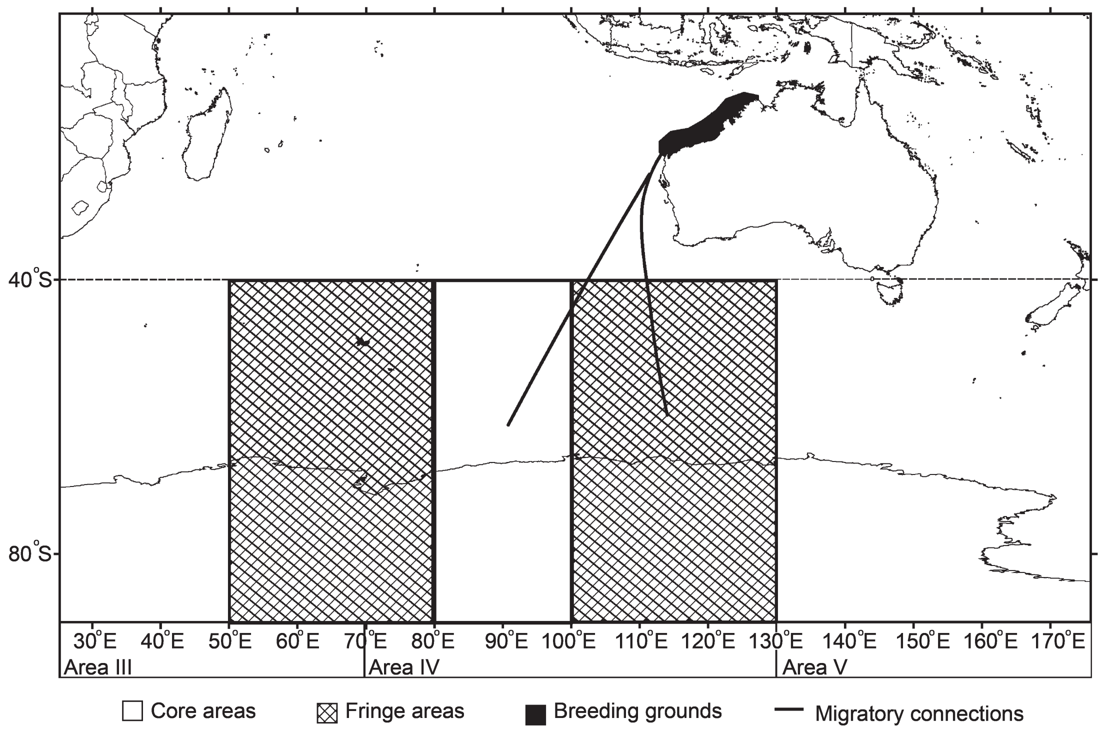

Fig. 9. Map showing the hypotheses to be modelled for Breeding Stock D.

All but two of these animals were recovered at a maximum longitude of 113°E in Antarctic waters. The exceptions are one animal marked in the breeding grounds/migratory corridor on eastern Australia (Breeding Stock E) that was recovered on the breeding grounds/migratory corridor on the west coast (Breeding Stock D) and one animal marked in Fiji which was recorded as recovered at 55°S, 87°E (on the western side of Area IV) by the Soviet whaling fleet (although there is some confusion in relation to this record as the animal was reported as a fin whale).

There is very limited marking data to suggest easterly movement of animals from Breeding Stock D. Only one animal (approximately 2% of all recoveries from Breeding Stock D) was recorded moving from the feeding grounds west of 110°W and to the east coast of Australia.

The Workshop therefore **agrees** that the core area of the feeding grounds for Breeding Stock D should be set at between 80°E and 100°E, with the eastern fringe set as between 100°E to 130°E and the western fringe at 50–80°E.

The agreed options for boundaries for Breeding Stock D are given in Fig. 9.

Stocks E and F

The Workshop **agrees** that the situation for Breeding Stocks E and F is complex and currently unresolved, and therefore that it is impossible to construct stock structure hypotheses for assessment modelling, particularly with respect to the assignment to Breeding Stocks of catches taken on the feeding grounds.

Stock G

As with Stock A, there appears to be a relatively straightforward connection between feeding grounds off the Antarctic Peninsula and the Colombia/equatorial western South America region that is considered as breeding stock G. The issue of where humpbacks feeding in the Magellan Strait breed remains open, but even if these animals bypass equatorial regions and winter in Central America, this remains in the area currently defined as stock G. Since the bulk of catches were taken in the Antarctic Peninsula region, catch allocation to stock G is straightforward. The boundary options for stock G are shown in Fig. 8.

Conclusion

The Workshop **agrees** that while it is possible to discuss modelling options to allow completion of the Comprehensive Assessment for Breeding Stocks A, D and G at the 2006 meeting, this is not possible for the other stocks, given current knowledge.

4. CATCH INFORMATION

4.1 Data sources

4.1.1 Whaling

SC/A06/HW47 summarised the work of Allison and the Secretariat computing department in developing the humpback whale catch database and providing information for assessment work at the Workshop.

There are two primary issues with respect to the catch series:

(1) the completeness of the total catch record; and
(2) allocation of catches in relation to what is known or suspected about stock structure (including alternative hypotheses).

With respect to the first issue, it is believed that the total record is largely without major gaps (although see Item 4.2.1). Before addressing the second issue it is important to consider the nature of the data themselves.

In the best case, individual catch records are available. These provide full information on a wide variety of factors, including operation, date, time, position to the nearest degree (or finer), species, sex and length. There can then be a gradation of data available down to the case where it is suspected that some catches occurred but their magnitude and details are unknown.

For Southern Hemisphere humpback whales, Allison reported that there are reasonable positional data for most catches (either exact position or at least land station in early years). A summary of the data available by year (since 1900) was given that included:

General position: Ocean, Area (e.g. Angola), Operation (Name).

Species: Humpbacks, Unknown, 'Final' humpback.

What is coded (resolution of data): e.g. exact, daily position, sex, length.

Qualifier: e.g. Any doubts over the quality of the data.

Notes: e.g. Discrepancies and how handled including unspecified.

With respect to known problems with data (excluding those related to the falsified Soviet data discussed below), these can be summarised as follows:

No data but some operation known: Angola catches in 1915; catches by the *Saragossa* in April/May 1930; subsistence catches at Tonga (see below) – no correction has been applied.

Unknown species: For some early years at South Georgia and the South Shetlands – this has been 'corrected' by comparison with proportions known for similar operations in the same year or the proportion known for the same or similar operations in surrounding years.

Unsure position: In the late 1920s for some South Shetlands 'pelagic' operations (if no information was available, all were allocated to the South Shetlands although it is known that some could range further) and catches ($n = 941$) by three Japanese pelagic operations in 1941/42 (allocated to same area as other Expeditions that year).

However, by far the greatest source of uncertainty in the database relates to the very large amount of falsified USSR catch data prior to 1972 where the issues are much more complex. Fortunately a small number of Soviet scientists managed to keep many of the original records and from this it has been possible to reconstruct the true catch (Yablokov, 1994; Yablokov *et al.*, 1998) but for some expeditions individual records are not available. In order to make the database as complete as possible, a small intersessional working group (Allison, Brownell, Clapham, Donovan, Mikhalev, Tormosov) met in Cambridge to determine if and how it was possible to assign catches to some level of geographical and temporal resolution. From examination of the data and the recollection of the Soviet scientists on board, it was found that the 'official' cruise tracks submitted by the USSR were generally reliable. For all but about 2.5% of the catch, catches by month were also known and from this it was possible to assign approximate positions of catches. In order to test the applicability of this method, the approach was also used for catches of 'known' positions and was found to be reasonably reliable (although inevitably the allocated catches were more widespread).

For the present meeting, Allison provided data broken down as requested at the 1998 and 2005 Annual Meetings of the Scientific Committee (see Item 4.2.2).

The Workshop thanked Allison and her staff for the considerable amount of work this represented.

The Workshop also considered SC/A06/HW53 that presented information on humpback whales killed by 19th century open-boat whaling. Catch and sighting data from Townsend (1935), Best (1987) and a small sample of logbooks of voyages not included in previous studies were used to describe the extent of humpback whaling in several oceanic regions, excluding the Antarctic. It was estimated that 16,188 humpback whales were taken between 1800 and 1900 in the Southern Hemisphere. The authors concluded that catch data extracted directly from the logbooks confirmed the general pattern of catches seen in the Townsend data, and sightings data from the logbooks revealed a more extensive distribution pattern than shown by catches alone. The catches assigned to humpback whale wintering grounds need to be compared to subsequent catches to determine their significance.

The Workshop **agrees** that in general, the level of the catches pre-1900 confirm its view that it was reasonable to assume that for modelling purposes, populations had recovered by 1900. It also **recommends** that persons having information on 'non-Yankee' humpback whaling should forward this information to the authors of SC/A06/HW53. However, it also **recommends** that for some of the Oceania grounds (notably Tonga), effort should be made to determine the level of undocumented pre-20th century catches to determine if this is a valid assumption.

4.1.2 Incidental catches in fishing gear

There are records of incidental catches in fishing gear and shark nets from several areas in the Southern Hemisphere, including Ecuador, South Africa and Australia. This information is summarised in the table of information included on the IWC website*. It was also noted that scarring patterns provide some information on the likelihood of entanglement events (e.g. SC/A06/HW48) although translating this into removal rates is not simple. The Workshop **agrees** that for modelling purposes, those with information on mortality in fishing gear should attempt to put 'bounds' on the likely extent.

Analysis of suitable caudal peduncle photographs for evidence of entanglement for humpbacks in Oman indicated that between 30–40% of sampled whales had been entangled (SC/A06/HW48). This rate is lower than the 65% estimated for the Gulf of Maine (Robbins and Mattila, 2000), and lower than the 57% estimated for North Atlantic right whales (Kraus, 1990). The Oman estimate is likely to be conservative, as some entanglements may have involved body parts other than the caudal peduncle and some entanglement scarring may have healed or been masked by other types of scars over time. Although documented humpback whale mortalities from entanglement in Oman are low, when viewed in relation to the low population estimates for humpback whales there, this entanglement rate may represent a significant threat, a concern shared with other small or isolated cetacean populations (e.g. Clapham *et al.*, 1999; D'Agrosa *et al.*, 2000; Kraus, 1990).

4.1.3 Ship strikes

The Workshop noted that Van Waerebeek would be presenting a global summary of ship strike information at the 2006 Scientific Committee meeting. It **agrees** to consider this issue further there.

4.2 Development of 'best' and 'alternative' catch/removal series

4.2.1 Total

The Workshop **agrees** that the total catches in the IWC database now reflect the best available data for Southern

* *http://www.iwcoffice.org/documents/sci_com/workshops/Table2.pdf* accessed October 2011.

Hemisphere humpback whale catches. However, as noted above (Item 4.1.1), the catch data for Tonga are incomplete for the post-1900 period and Baker agreed to try to determine the approximate extent of such catches and provide this information to Allison.

4.2.2 By stock structure hypothesis

The options for Breeding Stocks A, D and G are given under Item 3.9 above. Donovan reported that the IWC database will allocate catches by at least 10° square, using the correction approach discussed above (Item 4.1.1). The data are now available* for Scientific Committee members.

4.3 Catch-per-unit-effort (CPUE)

Catch-per-unit-effort data have two potential uses in the assessment process. The first is to provide a crude check on model outputs and the second is to provide a relative index of abundance for fitting. The Workshop recalled previous discussions within the Committee over the use of CPUE data as a measure of relative abundance (e.g. IWC, 1989). It **agrees** that if CPUE series are to be considered in the second context, authors proposing the use of such data must justify why they consider the data to be suitable.

5. ESTIMATES OF RECENT ABUNDANCE AND OBSERVED TRENDS

A summary of all information on reproductive parameters available by breeding stock is given in the table available on the IWC website*. Given the time constraints, the Workshop **agrees** to consider only issues related to Breeding Stocks A, D and G under this item. Abundance and trend information for the other stocks will be discussed at the 2006 Scientific Committee meeting.

5.1 Review of methods

This item was not discussed owing to lack of time although methodological issues were considered when reviewing presented estimates.

5.2 Available estimates by stock structure hypothesis

5.2.1 Breeding stocks

BREEDING STOCK A

SC/A06/HW2 reported on the monitoring of humpback whales on the Brazilian breeding ground from 2002 to 2005. The objective of the study was to monitor humpback whale abundance to provide information to support the development of future strategies for the conservation of humpbacks off Brazil, particularly given concerns over the potential impact of increasing vessel traffic and shoreline development. A four year series (2002–2005) of aerial surveys was undertaken on the Brazilian breeding ground and abundance was estimated according to standard line-transect methods. The authors presented an estimate of abundance for 2005 that incorporated a value of $g(0)$ calculated in a novel manner as described in SC/A06/HW24. In that paper, the authors stated that none of the traditional methods to estimate $g(0)$ could be used for the Brazilian aerial surveys. They instead developed an estimate based on the ratio between (i) a population size estimate from distance sampling assuming $g(0) = 1$ and (ii) an independent population size estimate based on mark-recapture methods. The estimate they chose to use was the average of a bootstrap sample and accounts for availability and perception bias combined.

There was considerable discussion of this approach. In response to a question as to whether the estimation of $g(0)$ from this method is consistent with an estimate derived from a simple model of surfacing rate, the authors noted that while no direct comparison had been made, they believed that their estimate was consistent with what is known about humpback surfacing behaviour.

The Workshop noted that there are a number of reasons to believe that the estimation of $g(0)$ from the direct comparison of abundance estimates from aerial surveys with mark-recapture estimates may not represent an appropriate procedure (e.g. as the two estimates are generated using different methods, they have different assumptions and strengths and may not be estimating the same population). It was suggested that the method does not really estimate $g(0)$ but rather is a calibration of the line transect technique using mark-recapture. It was observed that estimates of abundance for Hawaii obtained using mark-recapture methods are consistently higher than estimates from line transect surveys for the same time and area (Baker and Herman, 1987). This arises because mark-recapture estimates the population size for all the individuals that occur in the area during the season whereas aerial surveys estimate only the number of whales in the area at the time of the survey. By contrast, even the uncorrected aerial abundance estimate presented in SC/A06/HW2 was higher than the mark-recapture estimate (and correction for $g(0)$ further increases the size of the aerial survey estimate). In response to a suggestion that the mark-recapture estimate be used as the abundance estimate and the aerial survey dataset be used as a relative survey series for modelling, it was noted that the mark-recapture estimate does not apply to the whole breeding area.

The Workshop **agrees** that the above issues and other potential biases associated with this comparison should be addressed in a revised analysis, although the authors present stated that they continued to believe that the method described in SC/A06/HW24 was a valid approach.

In conclusion, the Workshop **agrees** that the uncorrected aerial survey estimate, corrected using the Barlow method (Andriolo *et al.*, 2006) provides the best estimate of abundance for 2005. The resultant estimate is 6,550 (CV = 0.29; 95% CI 3,700–11,400).

STOCK D

SC/A06/HW3 analysed the results of an aerial survey off Carnarvon, Western Australia in 2005, following a series of surveys in the same area since at least 1982. From 1982–1994 aerial surveys in that area had provided evidence of an increase (of 10.15%±4.6%, see Bannister and Hedley, 2001) in Group IV (Breeding Stock D) animals. The next survey, in 1999, had been designed to obtain an estimate of absolute abundance of northward migrating animals, as had the 2005 survey. A new approach was planned in 2005 whereby a land-based component was to be used to 'ground-truth' the aerial results. In the event, poor weather meant that only 11 of the 30 planned flights took place in good conditions and logistical problems caused relocation of the land-based operation to a site where a high proportion of animals was recorded as not moving in any definite direction (i.e. they appeared to be using the area as a 'resting' area). However, the authors developed a method to use the aerial and land-based results to obtain an estimate of $g(0)$ to take account of pods missed by the aircraft and animals not present at the

* *http://www.iwcoffice.org/documents/sci_com/workshops/Table2.pdf* accessed October 2011.

surface from which they estimated abundance for 2005. The authors highlighted a number of potential problems with the estimate. They also applied the 2005 estimate of *g*(0) to the 1999 results (where despite poor weather more complete coverage over the two-month period had been achieved) to obtain a revised 1999 estimate.

The Workshop welcomed the analysis presented in the paper. However, while it **agrees** that the authors are to be congratulated for developing an ingenious method to try to obtain an estimate for 2005 despite the severe practical problems in the field, the Workshop also **agrees** that it is unable to accept this estimate for a number of reasons, including those listed by the authors themselves. However, for the purposes of modelling, it **agrees** to use the revised figure for 1999 of 10,000 (95%CI 8,000–12,500). However, it notes that caution is needed when applying the estimate of *g*(0) from 2005 to the 1999 survey and **recommends** that the problem be considered further and that an updated paper be presented to the 2006 Annual Meeting.

STOCK G

SC/A06/HW13 used mark-recapture data to estimate abundance for the southeastern Pacific stock. A total of 1,061 individuals were identified between 1991 and 2004 off the coast of Ecuador (2°S, 81°W) The best estimate obtained using the closed Petersen estimator was 2,917 whales (95% CI 1,751–4,859; CV 0.19), pertaining to the period 2003–2004. Estimates with the open Jolly-Seber model were more heterogeneous, even when data were pooled in periods of two years. An estimate of 2,881 whales (95% CI 1,722–4,039) was obtained for 2004 using this approach (assuming constant survival rate and time-specific capture probabilities). Although the authors recognised that several sources of bias probably affected the estimate (especially those related to sex ratio), they believed the estimate to be representative of the Southeastern Pacific migratory population because Ecuador is located in the southern part of the wintering area through which whales are most likely to pass. They noted that a more extensive collaborative effort including other wintering areas further north and the integration of breeding and feeding data would help to increase precision in abundance estimates.

There was some discussion of this paper with respect to mark-recapture assumptions (e.g. see Hammond, 1986). For example, at least one of the sampling periods must comprise a random sample. It was noted that there is consistent effort through the season including a dedicated research component on whalewatching trips, indicating that the later years of the study period met the assumption of a random sample. The later years were also those with the largest sample sizes. Matching with other catalogues in Area A is already underway but not yet completed. It was also noted that there has already been a comparison of Ecuador sightings with the Antarctic catalogue.

The Workshop **agrees** that the Petersen estimate for 2003–2004 (2,920 whales; 95% CI 1,750–4,850; CV 0.19) should be considered the best estimate from the analyses presented in SC/A06/HW13, as the sample size was highest over this period, the sample appeared to be random and it had the lowest CV.

SC/A06/HW54 reported on mark-recapture abundance estimates obtained for the Antarctic Peninsula area using Chapman's two-sample estimator. Photographic **s**amples used in the analyses were collected between the 1994/1995 and the 2001/2002 Antarctic seasons by three different groups: the College of the Atlantic (COA), the Brazilian Antarctic Programme, Projeto Baleias (PROANTAR) and Instituto Antártico Chileno, Proyecto (INACH). The samples used for the estimator were not segregated by time, as is typically the case, since doing so would result in small annual sample sizes, and also because any site fidelity by individual whales to specific feeding sites would result in heterogeneity in inter-annual capture probabilities. Instead, samples were segregated by the three primary groups conducting the sampling. Three estimates were made using the full collections from the three organisations as samples, and two with the COA sample selected to temporally match those obtained by the other organisations. The new estimates ranged from 1,960 (95% CI 900–3,000) to 3,260 (95% CI 2,100–4,500). However, in their discussion, the authors cautioned that most consistent high-use areas for humpback whales near the Peninsula are well known, and are likely to be frequented by the commercial cruise operators and also to be selected as the targets of dedicated research operations, so the areas worked by the three groups are unlikely to be truly independent.

The same authors presented SC/A06/HW56, which gives mark-recapture estimates of abundance for Breeding Stock G humpback whales. They noted that mark-recapture abundance estimates using two samples from the same habitat may be substantially biased, while small sample sizes lead to several other sources of bias. They therefore attempted to minimise such bias by: (a) using samples from different habitats that have independent sources of heterogeneity; and (b) increasing sample sizes by pooling across years. One set of samples was collected from the west coast of South and Central America and the other from the Antarctic Peninsula. Samples were collected between 1991 and 2004 and were pooled over spans from 0–12 years. To account for and estimate the influence of the open-population bias resulting from the pooling of samples, a regression was fitted to the mean of the abundance estimates for each span of time used after filtering the estimates for low-sample bias. From this, the authors estimated the abundance of humpback whales in Group G in 1997 to be 3,850 (95% CI 3,700–4,000).

The Workshop welcomed these papers that incorporated data from the feeding grounds. During discussion, it was noted that there are two apparently separate feeding grounds (Antarctic Peninsula and Magellan Strait) and that including data from the Magellan Strait feeding ground could improve the estimate. The Workshop **agrees** that while the approach described in SC/A06/HW56 appears to be a useful extension of mark-recapture analytical approaches, there is insufficient detail about how the method (and particularly the pooling) has been implemented or the potential sources of bias. It **recommends** that the authors provide more detail and explanation of this work to the 2006 Annual Meeting.

Despite the above, the Workshop **agrees** that for Breeding Stock G modelling purposes, both the estimates provided in SC/A06/HW13 (2,920 in 2003–2004; 95% CI 1,750–4,850) and in SC/A06/HW56 (3,850 in 1997; 95% CI 3,700–4,000) should be used. The Workshop also **recommends** a comparison of photo-id catalogues from Ecuador, Panama and Costa Rica.

5.2.2 Feeding grounds

SC/A06/HW57 reported on current distribution and abundance estimates in Areas IV (70°E–130°E) and V (130°E–170°W) in the waters south of 60°S, based on results obtained by the JARPA programme. This incorporates large-scale line transect surveys and has been carried out in a consistent way (alternating each year between Areas IV and V) since 1987/88. Humpback whales were widely distributed in Areas IV and V. It seemed that there was a distribution boundary around 130°E–140°E related to hydrographic features in keeping with previously noted distribution patterns. Further, it was found that humpbacks were concentrated between 90°E and 120°E in northern and southern strata on the eastern side of the Kerguelen Plateau, but were widely dispersed in other parts of Area IV. In Area IV, abundance estimates ranged from as low as around 2,700 in 1991/92 to as many as 33,000 in 2001/02, while for Area V, the range was from about 1,400 in 1990/91 to as many as 10,000 in 2004/05; CVs ranged from 0.11 to 0.33.

The Workshop welcomed the presentation of this work and thanked the authors. There was considerable discussion of the results. It was noted that similar discussions over the comparison of results from JARPA data and from IWC/IDCR and SOWER data are occurring in the context of abundance estimates for Antarctic minke whales. The Workshop **agrees** that full consideration of this issue is required. To facilitate this at the 2006 Annual Meeting, it **strongly encourages** presentation of the following information:

(1) clearer/enlarged displays of effort and sightings data, in particular to show details of the southern strata and the ice edge;
(2) display/analyses of the temporal distribution of searching effort within-season, particularly with respect to latitude and the ice edge, in order to allow evaluation of any changes over time and to evaluate whether following the path of any migration may be of concern;
(3) a full description of the policy that determines when the vessels steam/transit without sampling/sighting effort, how and when this may change over the course of a survey and displays/analysis of any potential bias that may result from policy decisions;
(4) analyses of sightings cues by *inter alia* area, time, season, sighting distance;
(5) separate analyses of sighting effort for vessels that carry out sightings only (SV) and vessels that also catch whales (SSV);
(6) separate analysis of school size by SV and SSV, taking into account time within a season and area, especially with respect to latitude and ice edge; and
(7) evaluate/display how the fraction/density of whales in the northern and southern areas covered by the vessels may have changed over time (taking into account seasonal differences in timing of effort, etc.).

SC/A06/HW6 presented estimates of abundance for humpback whales in the Southern Ocean in the austral summer based upon the IWC's IDCR-SOWER circumpolar (CP) sighting survey programmes. These have encircled Antarctica three times: 1978/79–1983/84 (CPI), 1985/86–1990/91 (CPII) and 1992/93–2003/04 (CPIII), surveying strata totalling respectively 64.3%, 79.5% and 99.7% of the open-ocean area south of 60°S. Abundance estimates were presented for each survey, for Management Areas I–VI, for longitudinal ranges corresponding to breeding stocks A–G as defined by the 'Naïve' model, and for circumpolar sets CPI–CPIII. Circumpolar estimates with approximate midpoints of 1980/81, 1987/88 and 1997/98 were 7,100 (CV = 0.36), 10,200 (CV = 0.30) and 41,800 (CV = 0.11). When adjusted for unsurveyed northern areas south of 60°S by assuming densities equal to those in the corresponding northern strata surveyed, these estimates become 9,700, 12,500 and 41,600 respectively. As estimates of total abundance, they are negatively biased because they assume that all whales on the trackline are sighted, and because some humpback whales remained north of 60°S during the period of the surveys.

In discussion, it was noted that while there appears to be reasonable agreement between SOWER and JARPA abundance estimates, there are still some large differences in some areas and years, in particular for Area IV in 2002/03. A potential explanation is that the SOWER estimate was generated over a three-year period while the JARPA estimate was derived from a single year survey. Effective strip width and school size have increased over the survey period. The proportion of humpback whales north of 60°S will vary around the circumpolar area and it was suggested that it would be useful to explore what proportion of whales are north of 60°S by each feeding area. That could be achieved through the use of JSV (Japanese Scouting Vessel) data but one potential difficulty is that the JSV data cover the years prior to most of the IWC and JARPA surveys when humpback whales were less abundant; it may not be reasonable to assume that the relative proportions north and south of 60°S have remained the same. It is interesting to note that in the most recent SOWER cruise, more humpback whales were seen north of 60°S than south of 60°S. While it is likely that the abundance estimates from JARPA and SOWER are negatively biased as whales north of 60°S are not being surveyed, it is also possible that extrapolation to the unsurveyed area south of 60°S in the CPI and CPII IDCR surveys may result in a positive bias in some areas if densities fall off monotonically away from the ice edge, and that the latitudinal movement of whales across the 60°S boundary may have resulted in changing proportions of the total abundance south of 60°S being surveyed in different years.

SC/A06/HW37 presented a re-analysis of the sighting data from the 1995/1996 BROKE East survey, to provide an abundance estimate of humpback whales within the survey area encompassed by IWC Area IV. These data had previously been examined by Thiele *et al*. (1998). However, those authors had found a large discrepancy between their estimate (900 animals) and estimates obtained from other surveys in a similar region. The new analysis provided a corrected estimate (10,813) that is more consistent with other survey results. The authors also discussed a strategy to compare the BROKE estimates with other estimates from similar surveys within Antarctic Area IV. Finally, abundance estimates obtained from a preliminary analysis of the latest 2005/2006 BROKE West survey were also presented.

During discussion, it was suggested that density estimates for the common areas surveyed by SOWER, JARPA and BROKE surveys be investigated. The Workshop noted that reanalysis of the SOWER and JARPA data would be very labour intensive. However, the comparison of the three methods could be extremely useful in investigating true variances from each of the surveys. Before this is undertaken it would be worth investigating if the respective datasets will allow for statistically robust comparisons. It was requested that SC/A06/HW37 be updated with a more detailed explanation of methods and results. It was noted that initial analysis of the BROKE survey had yielded an anomalous estimate of abundance, which had consequently raised questions about the reliability of the survey. The Workshop **agrees** that these new results allay such concerns and hence that the BROKE survey can now be considered a useful source of data for investigating humpback abundance. The

Workshop **recommends** that this work be further explored for discussion at the 2006 Annual Meeting.

SC/A06/HW43 reported on ship surveys undertaken by the Projeto Baleias/Brazilian Antarctic Program during the austral summers of 2006. The data were used to estimate abundance in the Gerlache and Bransfield Straits west of the Antarctic Peninsula (the eastern end of Area I). Distance sampling methods were applied. No statistical difference in encounter rate was evident between the Bransfield and Gerlache Straits, although the average was slightly higher for the former. Estimated abundance was 330 (95% CI: 150–700) and 1,700 (95% CI: 1,000–2,600) in the surveyed areas of Gerlache and Bransfield Straits, respectively, with a pooled abundance of 2,000 whales (95% CI: 1,300–3,000) and an extrapolated estimate for the whole Bransfield area of 2,800 (95% CI: 1,800–4,400). The authors note that the estimate is of limited use for stock assessment as it represents only a fraction of Stock G total abundance. The similarity of this estimate to the mark-recapture estimates for the breeding grounds (e.g. SC/A06/HW13) is evidence that the latter are underestimates.

5.3 Relating feeding ground estimates to stock structure hypothesis

SC/A06/HW25 derived estimates of rates of increase from time series of population estimates for humpback whales from the IDCR-SOWER sighting survey series (see Item 5.2.2). Estimates were reported for Management Areas I–VI, for longitudinal ranges corresponding to breeding stocks A–G as defined by the Naïve model, and for circumpolar sets CPI–CPIII. Point estimates were positive for all breeding stocks and were significantly greater than zero for stocks D and E. The circumpolar annual rate of increase was estimated at 9.6%, with a 95% CI of 5.8–13.4%.

In discussion, it was noted that the Naïve model is, by definition, somewhat simplistic and, at least for Breeding Stock E, incorrect. Given this, the results from this paper by breeding stock should be viewed with caution until the appropriateness of the Naïve model is better understood. The Workshop **agrees** that it would be useful to consider using a model (or models) with changing boundaries over time, as krill (and hence probably whale) distribution varies over time. This changing distribution may have implications for interpreting increase rates obtained from the feeding ground surveys; it is quite likely that there will be differences between rates of increase observed on feeding and breeding grounds. Although the available data are limited and exhibit large confidence intervals, the Workshop **agrees** that they may be useful as one of several datasets to be used in the modelling exercise.

5.4 Trend estimates by stock structure hypothesis

The Workshop **agrees** that for all Breeding Stocks, especially A, G and D (which are of immediate priority), there is a need to investigate how much the overall estimate of trend from abundance estimates is being affected by the abundance estimate from the fringe areas. It would be useful to generate abundance estimates for the core and fringe areas independently, or even by 10° longitudinal sector, to see what influence the fringe abundance estimates have on the trend to be used in the naïve model. The Workshop **recommends** that this work be undertaken and presented to the 2006 Annual Meeting.

BREEDING STOCK A

SC/A06/HW45 presented the results of a Bayesian assessment for Breeding Stock A. It provided information about rates of increase, however this did not represent the whole stock but rather the core area of the breeding grounds. The Workshop **agrees** that this information is suitable for use in the modelling exercise. The Workshop **recommends** that a revised modelling paper be submitted to the 2006 Annual Meeting that includes additional exploration (e.g. using a variety of models for r) and details clearly the caveats and limitations of the data. Zerbini agreed to undertake this work.

BREEDING STOCK G

Preliminary information for Breeding Stock G was provided in SC/A06/HW54. The Workshop **recommends** that the authors of that paper and all the catalogue holders co-operate and undertake reanalysis of all of the available data to provide further information about trend to the Committee as soon as possible. The Workshop **agrees** that in the interim, the models should be fitted assuming a variety of priors for r (and see Item 6.3).

BREEDING STOCK D

The Workshop was informed that there is an ongoing reanalysis of the entire western Australian catalogue that will include the provision of relative abundance estimates; however, this will not be completed in time for the 2006 Annual Meeting. Therefore the most recent trend information is that reported by Bannister and Hedley (2001) for the period 1982–1994 and the Workshop **agrees** that this be used in the modelling exercise.

6. BIOLOGICAL PARAMETERS

A summary of all information on reproductive parameters available by breeding stock is given in the table available on the IWC website*. New information is discussed below.

6.1 Natural mortality rates

It was noted that the models are not particularly sensitive to values of natural mortality rates. Given the time constraints, it was **agreed** not to discuss this item further.

6.2 Age and length at attainment of sexual maturity

SC/A06/HW5 reviewed estimates of the age at sexual maturity, given concerns over earlier calibration of earplug readings. In particular, Chittleborough (1959) and others, including Nishiwaki (1959) had concluded that humpback whales reach puberty at around five years of age. Although there was some support for this value from longitudinal studies of individual whales in the Gulf of Maine (Clapham, 1992), questions remained, given the accepted values for other rorquals of around 10 years. Chittleborough had assumed a biannual accumulation rate of earplug growth layer groups (GLGs), partly from comparison with readings from baleen plates. However, the reliability of baleen plate readings has subsequently been questioned (particularly owing to wear), even for young animals. The authors noted that the ovulation and natural mortality rates estimated on the basis of two GLGs per year now seem too high to be biologically feasible. They concluded that it was not that Chittleborough's readings were in error, but rather his interpretation of their accumulation rate.

The Workshop thanked the authors for this thorough review and encouraged its publication. The potential value of stable isotope studies to evaluate GLG formation in earplugs was noted.

* *http://www.iwcoffice.org/documents/sci_com/workshops/Table2.pdf* accessed October 2011.

In considering estimates of attainment of sexual maturity from photo-identification studies, the Workshop noted the large difference between the results from the Gulf of Maine (around five years, Clapham, 1992)[5] and those from southeast Alaska (first calving at 8–16 years, Gabriele *et al.*, 2007); the latter are more consistent with an annual GLG formation rate in earplugs (see above). It was noted that these differences may reflect different ecological conditions (including oceanographic productivity, prey bases and length of migration) and that extrapolating from one region to another may not be appropriate, particularly for a 'flexible' parameter such as age at attainment of sexual maturity, which has been shown to change over time within the same population for some species (e.g. Icelandic fin whales – see discussion in IWC, 2007b). The Workshop noted the large number of photo-identification catalogues available for the Southern Hemisphere and **urges** examination of these for obtaining further estimates of age at attainment of sexual maturity.

Further discussion of this issue occurs under Item 6.3 in relation to the maximum plausible rate of increase.

6.3 Reproductive rates

SC/A06/HW23 reported on the resighting histories of 292 female humpback whales identified as mothers along the east coast of Australia from 1984–2005. No animals were observed in every year of the study effort. There were 24 instances of observations in two consecutive years, 24 instances of consecutive three year sightings, and one each of four year and five year consecutive sightings. The mean proportion of sightings of calves was 0.417 (95% CI: 0.381–0.453), which may be taken as an estimate of overall calving rate for this group of females. The mean calving interval for the 72 females known to be mothers, observed over a 22–year period, was 2.39 years (95% CI: 2.20–2.62). Most known mothers (n = 58, 67%) had at least one calf in a 2 or 3 year interval of consecutive sightings. There were a number of examples of one-year cycles: 14 two-year sequences in which the mother gave birth in both years; two occasions in which the mother gave birth in each year of a three-year sequence; and one occasion in which the mother gave birth in each year of a five-year sequence.

In discussion, it was suggested that photographing females during the northward migration prior to parturition may result in an overestimation of the calving interval. The Workshop **agrees** that a reanalysis of these data excluding the early migration photographs would be valuable.

Much of the discussion under this item centred on the appropriateness of the value of 12.6% per annum given by Clapham *et al.* (2001) for the upper bound[6] for a maximum plausible increase rate, based on the simple model approach given in Brandão *et al*. (2000). The value had been obtained assuming survival rates for all age classes of 0.99, a pregnancy rate of 0.5 (i.e. a 2-year calving interval on average) and an age at parturition of 5 years (based on the Gulf of Maine). Reported rates of increase of around 10% have been reported for western and eastern Australia (e.g. Bannister and Hedley, 2001; Paterson *et al.*, 2001) and considerably higher estimates from the feeding grounds (SC/A06/HW57) and some doubts have been expressed that the feeding ground estimates represent true rates of increase for total populations.

With respect to calving intervals, it was suggested that an average calving interval of two years was unlikely. In this context there was some discussion on the occurrence of one year calving intervals. There is photo-identification evidence that this can occur from eastern Australia (see SC/A06/HW23), the Gulf of Maine (5% of females with calves) and Hawaii (13%) as well as information from whaling data (e.g. Cerchio, 2003; Chittleborough, 1955; 1959; 1965). However, it should be noted that there is no information on the neonatal survival of these calves (e.g. it may be lower due to nutritional stress in the mother, for example, or she may have been able to calve in consecutive years due to the early mortality of a previous calf). It was noted that the levels of one year calving intervals alone were insufficient to account for the high observed increase rates in some areas.

Following the discussion under Item 6.2, there was additional discussion on the age at first parturition and whether five years was a reasonable value. It was noted that increase rate estimation is highly sensitive to the age at sexual maturity.

In noting that changes in age at attainment of sexual maturity are thought to be one mechanism for density dependence to occur[7], it was suggested that Chittleborough's (revised for annual GLG formation) estimate for the age-at-maturity needed to be considered as applying to whales born before 1950 and hence before the onset of the main catches of humpback whales from Area IV. The estimate may thus apply to a population only slightly reduced from its initial level, and the value may have subsequently decreased in response to the later considerable reduction of the population as a result of catches. However, Clapham pointed out that blue and fin whale populations had already been appreciably reduced by the time Chittleborough's samples were taken, so that these could already at that time have reflected some change in age-at-maturity in response to consequential enhanced krill abundance.

Other information relating to reproductive rates briefly discussed included the possible effects of male biased sex ratios (see Item 3.5.2.1), mating outside the breeding grounds and the possibility of reproductive senescence, which is generally believed to be absent in mysticetes (see review by Marsh and Kasuya, 1986) although some anecdotal evidence was mentioned for the North Pacific.

In conclusion, the Workshop noted that the available information on biological parameters for humpback whales from around the world, such as age at sexual maturity, calving and survival rate, strongly suggested that the values currently used in modelling exercises (a maximum annual rate of increase of 12.6%) seemed biologically implausible. It **recommends** that a review of the available information be undertaken in 2006 that concentrates on examining the existing data in the context of determining a likely bound for r. This review should consider *inter alia*:

(1) the possible sources of bias in any existing estimates (including sample size and site);
(2) the likely direction of any such bias and if possible its maximum extent; and
(3) the time period for which the estimate applies and what is thought to be known about the status of the

[5] SC/A06/HW23 presented information on one animal observed as a calf that was identified as a mother six years later.

[6] The same authors presented a lower bound for the maximum plausible increase rate of 3.9% using the following values: adult survival 0.95; first year survival 0.92; pregnancy rate 0.4; age at parturition 9 years (based on southeast Alaska).

[7] Length at attainment of sexual maturity is thought to be more constant – thus an increase in growth rates as a result of more food being available will result in a decline in the age at attainment of sexual maturity.

population(s) to which the estimate applies. This review should be valuable in providing an appropriate upper bound for *r* in modelling exercises.

At this stage, the Workshop suggested that models be run with a uniform prior for the annual growth rate parameter *r* bounded above not only by 12.6% as in the past, but also by lower values to investigate sensitivity; it was recognised that at this stage, no analyses would be seen as definitive.

7. THREATS

There was insufficient time to discuss this item.

8. ENVIRONMENTAL PARAMETERS

There was insufficient time to discuss this item.

9. ASSESSMENTS AND PROJECTIONS

There was only limited time to review and discuss the papers presented under this item – SC/A06/HW22 and SC/A06/HW45 and issues related to assessment and projection models.

9.1 Inputs for models

The Workshop **agrees** that modelling to be undertaken before the 2006 Annual Meeting should use input parameters based on the decisions taken at this workshop with respect to catch estimates, population abundance estimates and population trends for stocks A, G and D (see above). Results based on these inputs will be the focus of the review of modelling results at the meeting, although exploration of model results based on alternative and/or additional inputs may be undertaken to provide insights into the sensitivity and robustness of the results. In particular, the Workshop noted that the abundance estimates from the feeding grounds for Breeding Stock D from the third circumpolar IDCR and the more recent JARPA surveys are substantially higher than those based only on the breeding ground estimates. This will need to be considered when reviewing the model results. However, the resolution of any such differences will not be straightforward due to confounding issues related to potential stock mixing and the interpretation of the feeding ground abundance estimates.

The Workshop noted that there are other model inputs that are required for one or more of the model implementations, and for which the workshop did not provide an agreed set of values. These include:

(1) Bayesian prior for the intrinsic rate of growth;
(2) estimates of minimum historic population sizes to use as a lower bound in the model; and
(3) Bayesian priors for the mixing matrix to use in multi-stock models (although the workshop did not have sufficient time to consider basic catches and abundance estimates for use in such models or the approach to take for these models).

With respect to the Bayesian prior for the intrinsic rate of growth, the Workshop suggested that models be run with a uniform prior for the annual growth rate parameter *r* bounded above not only by 12.6% as in the past, but also by lower values to investigate sensitivity (see Item 6.3).

It was noted that there are extensive data on length distribution for the commercial catches and more limited data on ages for some Areas. It was suggested that consideration should be given to development of length/age models, particularly with respect to the question of possible transient age structure in relationship to maximum intrinsic growth rates.

Finally, the Workshop **agrees** that where CPUE data have been used (e.g. SC/A06/HW22), results should also be presented where such data are excluded.

9.2 Outputs for models

SC/A06/HW25 reported on simulations conducted to test the robustness of assessment results to certain key assumptions. In particular, the most recent assessment of Breeding Stocks D and E uses a population model that allows for mixing between feeding areas (Johnston and Butterworth, 2005; 2002). The model makes a number of assumptions about whale movement in the feeding areas, the historic catch distribution across the feeding areas and the form of density regulation acting upon the populations. The sensitivity of this model to these assumptions was tested using a simulation approach. Specifically, data were generated from a population model where the assumptions were relaxed in a number of plausible ways and then the model was fitted to the data. Using this approach, the effects of whale movements over a finer spatial scale in the feeding areas, the catch distributions across this sub-area scale and the incorporation of density regulation on the feeding areas were explored. SC/A06/HW25 found that Johnston and Butterworth's model was robust to both whale movements on a fine scale and with catch distributed as per this scale. However, when density regulation was implemented in the form of density dependence on the feeding areas, the model produced estimates that were quite different from those from the simulated population. The authors recommended that the inclusion of density dependence on feeding areas in models that allow for mixing of whales on the feeding grounds be investigated further.

The Workshop welcomed this work. In discussion, it was noted that the results in SC/A06/HW25 may be overestimating the sensitivity of the results to assumptions about density dependence due to choice of parameter values used in the simulations. However, the Workshop emphasised the importance of independent checks of model performance and robustness and it **agrees** that it is important to consider alternative assumptions about density dependence; it **encourages** further model development that would allow the effects of such assumptions to be tested.

The Workshop noted the model outputs presented. It **agrees** that they comprise the basic outputs that should be presented in future assessment results. In addition, it **recommends** that covariance estimates should be presented for the primary output statistics from the assessment models (e.g. *K*, *r*, current depletion) and that the output statistic should include model estimates of minimum population size. The Workshop also **reaffirms** the importance of providing output results which test the sensitivity of the results to alternative values for the key inputs (alternative catch series or abundance estimates).

Finally, the Workshop **recommends** expansions of the assessment models be developed that include a floor on the minimum historical population and depensation, and that assessment results incorporating these be presented at the 2006 Annual Meeting.

10. CONCLUSIONS AND RECOMMENDATIONS TO THE SCIENTIFIC COMMITTEE

10.1 Recommendations for future research

The Workshop **agrees** a number of recommendations and these can be found throughout the report. Consolidated recommendations by Breeding Stock can be found in Annex H. Recommendations relevant to attempting to complete the assessments for Breeding Stocks A, G and D at the 2006 Annual Meeting are considered under Item 10.2.

From the perspective of completing the assessment for the other areas, the highest priority research is for studies of stock structure and movements for Breeding Stocks B, C, E and F, particularly those that will allow appropriate allocation of catches from the feeding grounds to breeding stocks. Information from a variety of sources is important in this regard, especially genetic, photographic, telemetric and acoustic studies. In this regard, the Workshop **strongly recommends** that high priority be given to the following work that can be undertaken using existing samples/catalogues from the breeding grounds:

(1) genetic and photo-identification catalogue (see Items 3.5.5 and 3.6.5) comparisons amongst samples/catalogues from Western Australia, eastern Australia and Oceania and comparisons with samples/catalogues from the feeding grounds.

In addition, the Workshop **agrees** that high priority should be given to comparison of existing samples/photographs from feeding grounds with those from the breeding grounds, and the collection of additional samples/photographs from the feeding grounds. This will be extremely valuable to help elucidate high and low latitude connections and to discriminate among alternative hypotheses concerning mixing on the feeding grounds and should be given high priority. The Workshop therefore **recommends** that:

(1) biopsy sampling and photo-identification of humpback whales remains a high priority for future SOWER cruises;
(2) samples from the 2006 SOWER cruise (Area III, $n = 71$) are transferred as soon as possible to the WCS/AMNH Cetacean Conservation and Research Program for analysis and subsequent transfer back to SWFSC for storage; and
(3) photographs from SOWER cruises continue to be sent to the Antarctic catalogue hosted by the College of the Atlantic;
(4) the existing protocols for access to SOWER biopsy samples and photographs be reviewed to see if modifications are required; and
(5) national programmes (e.g. JARPA II, BROKE) and international programmes (e.g. SO GLOBEC, CCAMLR) operating in the Antarctic, wherever possible, allocate time to the collection of photographs and biopsy samples and that all photographs should be submitted to the Antarctic catalogue.

The Workshop stresses that the value of individual identification data is dramatically increased by the sharing of data amongst research groups. Whilst recognising the rights of data collectors, it **strongly encourages** the development of inclusive regional catalogues (e.g. by Breeding Stock) and the comparison of such catalogues with (a) neighbouring Breeding Stock catalogues and (b) the Antarctic catalogue. Such catalogues also provide a means of obtaining estimates of biological parameters such as age at attainment of sexual maturity and natural mortality rates (see Item 6).

Similar considerations with respect to collaborative studies apply to the comparison of genetic samples. For example, the Workshop noted the great value in undertaking genetic analyses of animals from both the breeding and feeding grounds (Item 3.9). It **recommends** that every effort be made for scientists to share data and carry out such analyses. It noted the positive discussions being held by Baker, Pastene and Rosenbaum in this regard, under the IWC Data Availability Agreement, and looks forward to their successful conclusion and the submission of one or more analyses to the Committee.

The Workshop also **agrees** that for a number of areas, abundance data are lacking and that for most areas trend information is lacking. The most appropriate method for each stock/area needs to be determined: in some cases it may entail mark-recapture (photographic and/or genetic) methods and in other cases distance based methods (aerial, vessel or land-based). Detailed recommendations can be found in each of the individual sections under Item 5. With respect to mark-recapture data, the need to exclude short-period recaptures and to take account of the distribution of recapture effort in analysing such data to infer movement rates was emphasised.

10.2 Work plan before the 2006 Annual Meeting

The Workshop **agrees** that it should be possible to complete the assessments for Breeding Stocks, A, D and G based on the discussions held at the Workshop. With respect to Breeding Stock A, the Workshop **agrees** that **high priority** should be given to the following tasks, which must be conducted before the meeting.

(a) The estimate of rate of increase obtained from sighting per unit of effort data for the period 1995–1998 ($r = 0.055$, $SD[r] = 0.017$, SC/A06/HW46) should be reviewed. Alternative models (including non linear functions) and potential overdispersion in the data should be investigated. Zerbini agrees to undertake this task.
(b) The most recent estimate of abundance (SC/A06/HW2) should be used as an input parameter in the assessment models. However, the $g(0)$ methods applied to correct this estimation for perception and availability bias (SC/A06/HW24) should be reconsidered. It is **recommended** that for the assessment to be conducted at the 2006 Annual Meeting, the $g(0)$ estimated by Andriolo *et al.* (2006) should be used. Kinas and Engel agree to undertake this task.
(c) Considering the new catch allocation hypothesis (Item 3.10), new catch series should be produced from the IWC database and used in the assessment models. Zerbini agrees to consult with Allison and undertake this task.

The Workshop recognised the very considerable amount of work that had gone into producing the genetic data, some of which was the result of intensive last-minute analysis. It had not been possible to fully evaluate this work in the time available and the Workshop **requests** that a consolidated summary of the analyses be presented at the 2006 meeting. This summary should comprise a table summarising pairwise comparisons between breeding grounds.

In examining abundance estimates for Breeding Stock G (see Item 5.2.1), the Workshop notes that the method described in SC/A06/HW56 appears to be a useful extension of mark-recapture analytical approaches but agrees that there is insufficient detail about how the method (and particularly the pooling) has been implemented or the potential sources of bias. It **recommends** that the authors provide more detail and explanation of this work to the 2006 Annual Meeting. Similarly, the Workshop noted that caution was needed in the application of $g(0)$ from one survey to that in another survey in the estimate for Breeding Stock D (see Item 5.2.1) and it **recommends** that this be examined further and an updated version of SC/A06/HW3 be presented to the 2006 Annual Meeting.

With respect to estimates from the feeding grounds and in particular the JARPA surveys, the Workshop noted the ongoing discussions in the Committee of this issue with respect to Antarctic minke whales. It **encourages** provision of the information listed under Item 5.2.2 to assist in this work. The Workshop also **recommends** that the data from the BROKE surveys be explored further for discussion at the 2006 Annual Meeting (see Item 5.2.2).

The Workshop noted the need to review the available information for considering an appropriate value for the maximum rate of increase (*r*) for humpback whales (see Item 6.3). It **recommends** that a review of the available information be undertaken in 2006 that concentrates on examining the existing data in the context of determining a likely bound for *r* as detailed under Item 6.3. In the meantime, it **agrees** that those undertaking modelling exercises should consider examining the sensitivity to using lower values than the currently used annual rate of 12.6% (see Item 9.1).

11. ANY OTHER BUSINESS

No business was raised under this item.

12. ADOPTION OF REPORT

Given the time constraints, there was insufficient time available to review the report in detail at the Workshop. It was agreed that individual participants would send any comments on the available draft to Donovan. In addition, certain individuals agreed to formulate research recommendations for the various Breeding Grounds. Donovan agreed to co-ordinate all the responses and to undertake detailed editorial work on the report. Once completed the report would be circulated to all participants for final comments.

In conclusion, the Chair thanked Gales and his staff for their hospitality, and the rapporteurs and all the participants for their co-operative approach. The participants thanked Bannister for his customary wise Chairmanship.

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Annex B
Agenda

1. Introductory items
   - 1.1 Welcome and introduction
   - 1.2 Terms of reference
   - 1.3 Election of chair and appointment of rapporteurs
   - 1.4 Meeting procedures and time schedule
   - 1.5 Adoption of Agenda
   - 1.6 Documents available
   - 1.7 Publication of proceedings

2. Assessment Procedures
   - 2.1 Model or models to be used

3. Review of stock structure, distribution and movements
   - 3.1 Breeding Stock A
     - 3.1.1 Individual movements
       - 3.1.1.1 Discovery marks
       - 3.1.1.2 Natural marks (photo-id; genetic)
       - 3.1.1.3 Telemetry
       - 3.1.1.4 Other (e.g. lost harpoons)
     - 3.1.2 Stock structure
       - 3.1.2.1 Genetic information (population level)

3.1.2.2 Other information (e.g. CPUE and catch history)
3.1.3 Seasonal distribution
3.1.3.1 Winter
3.1.3.2 Summer
3.1.3.3 Other
3.1.4 Summary
3.1.5 Recommendations for future work
3.2 Breeding Stock B
3.2.1 Individual movements
3.2.1.1 Discovery marks
3.2.1.2 Natural marks (photo-id; genetic)
3.2.1.3 Telemetry
3.2.1.4 Other (e.g. lost harpoons)
3.2.2 Stock structure
3.2.2.1 Genetic information (population level)
3.2.2.2 Other information (e.g. CPUE and catch history)
3.2.3 Seasonal distribution
3.2.3.1 Winter
3.2.3.2 Summer
3.2.3.3 Other
3.2.4 Summary
3.2.5 Recommendations for future work
3.3 Breeding Stock C
3.3.1 Individual movements
3.3.1.1 Discovery marks
3.3.1.2 Natural marks (photo-id; genetic)
3.3.1.3 Telemetry
3.3.1.4 Other (e.g. lost harpoons)
3.3.2 Stock structure
3.3.2.1 Genetic information (population level)
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2. ANDRIOLO, A., KINAS, P.G, ENGEL, M.H. AND MARTINS, C.C.A. Monitoring humpback whale (*Megaptera novaeangliae*) population in the Brazilian breeding ground, 2002 to 2005. 12pp.

3. PAXTON, C.G.M., BANNISTER, J.L. AND HEDLEY, S.L. Group IV humpback whales: their status from aerial and land-based surveys off Western Australia 2005. 22pp. (Published in this volume).

4. BARENDSE, J., BEST, P.B. AND THORNTON, M. Preliminary results of photo-identification of humpback whales on the west coast of South Africa. 14pp.

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6. BRANCH, T.A. Humpback abundance south of 60°S from three completed sets of IDCR/SOWER circumpolar surveys. 14pp. (Published in this volume).

7. NO PAPER.

8. CASTRO, C., FÉLIX, F., FORESTELL, P., HAASE, B., KAUFMAN, G. AND SCHEIDAT, M. Site fidelity of humpback whales *Megaptera novaeangliae* in Ecuador between 1991–2004, based on photo-identification. 5pp.

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10. COLLINS, T., CERCHIO, S., POMILLA, C., NGOUESSONO, S., MBADINGA, N., DUSHANE, J., MURRAY, A., WEBER, D., ERSTS, P. AND ROSENBAUM, H.C. An estimate of abundance using mark recapture data for breeding stock B1: Gabon. 8pp.

11. ENGEL, M., FAGUNDES, N.J.R., ROSENBAUM, H.C., OTT, P.H., SCHMITT, R., SECCHI, E., DALLA ROSA, L. AND BONATTO., S.L. Mitochondrial DNA variability and evaluation of the likely feeding grounds of the humpback whale (M*egaptera novaeangliae)* population of the Abrolhos Bank, Bahia, Brazil. 15pp.

12. ERSTS, P.J., POMILLA, C., ROSENBAUM, H.C., KISZKA, J. AND VÉLY, M. Humpback whales identified in the territorial waters of Mayotte [C2] and matches to Madagascar [C3]. 7pp.

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17. FORESTELL, P. H., KAUFMAN, G. D. AND CHALOUPKA, M. Abundance estimate of humpback whales in Hervey Bay, Australia, based on CMR profiles, 1988–2002. 15pp.

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20. JENNER, K.C.S., JENNER, M-N., SALGADO KENT, C.P. AND BRASSEUR, M. A preliminary analysis of sampling biases of sex ratio from two seasons of biopsy samples for breeding stock D. 6pp.

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29. OLAVARRIA, C., AGUAYO, A., ACEVEDO, J., MEDRANO, L., THIELE, D. AND BAKER, C.S. Genetic differentiation between two feeding areas of the Eastern South Pacific humpback whale population: [Update on SC/57/SH3] 7pp.

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53. SMITH, T.D, JOSEPHSON, E. AND REEVES, R.R. 19th Century Southern Hemisphere Humpback whale catches. 10pp.

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58. ALLEN, J., STEVICK, T. AND CARLSON, C. The Antarctic Humpback Whale Catalogue: Description and Summary. 4pp. (Published in this volume).

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60. POOLE, M. An Update on the Occurrence of Humpback Whales in French Polynesia. 12pp.

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Annex D
Discovery mark summary

David Paton

SC/A06/HW33 reports on the Discovery marking data associated with the International Marking Scheme (IMS). Between 1932 and 1984, 5,165 humpback whales were reported as marked with Discovery marks in the Southern Hemisphere. Of these 3,111 humpbacks were reported as confirmed hits. Discovery marking was undertaken both on the breeding grounds and the feeding grounds. Concentrated effort in Discovery marking was undertaken within Areas IV and V with a total of 91% of humpback whales marked in the Southern Hemisphere marked within these two regions. Within these two Areas, the Discovery marking effort has been conducted in both the breeding grounds/migratory corridor (65% of confirmed hits) and the feeding grounds (35% of confirmed hits).

The whaling data also show a strong bias towards catch effort in Areas IV and V with 29% and 41% of the total catch for the Southern Hemisphere humpback whale catch between 1947 and 1973 recorded in these Areas respectively. A total of 204 Discovery marks were reported returned under this scheme for the Southern Hemisphere. Areas IV and V recorded the highest percentage of Discovery mark returns, with 34% and 58% respectively.

The Discovery mark data support the original finding of Mackintosh (1942) in relation to the stock structure for Southern Hemisphere humpback whales forming relatively discrete groups with strong linkages associated between breeding grounds within the longitudinal boundaries of the feeding grounds, and relatively low incidence of large-scale movement between areas.

Further analysis is required to assess bias associated with marking and whaling effort. Exclusion of short period recoveries from the analysis is also required.

Table 1
Discovery mark results, by area, for all recoveries under the International Marking Scheme.

Area marked	Area recaptured					
	I	II	III	IV	V	VI
I	4 (80%)	1 (20%)	0	0	0	0
II	0	2 (100%)	0	0	0	0
III	0	0	7 (100%)	0	0	0
IV	0	0	0	58 (98%)	1 (2%)	0
V	1(0.75%)	0	0	12 (9.1%)	119 (90.15%)	0
VI	0	0	0	0	1 (50%)	1 (50%)

REFERENCE

Mackintosh, N.A. 1942. The southern stocks of whalebone whales. *Discovery Rep.* 22: 197–300.

Annex E
Assessment of genetic differentiation between Breeding Stocks A, B, C and X, and Areas I, II and III based on mtDNA

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INTRODUCTION

In order to evaluate connections of Breeding Stocks in the Indian and South Atlantic Oceans with Antarctic Feeding grounds for humpback whales, we present an analysis of mtDNA control region sequences for Breeding Stocks A, B, C and X with Areas I, II and III.

METHODS

DNA isolation, purification and sequencing methodologies are detailed in SC/A06/HW41. In order to characterise patterns of genetic variation and gene flow between Breeding Regions B and C and Feeding Areas I, II and III, we followed the same statistical procedures detailed in SC/A06/HW41. This study includes all samples analysed in our previous report and incorporates 92 samples from Areas I, II and III.

RESULTS

Pairwise comparisons at the haplotype and nucleotide levels show significant differences between Breeding Region X and all feeding Areas, and between Feeding Area I and all wintering regions included in this study. In addition, Breeding Region A was significantly different from Area III at the haplotype level. No further differentiation was found between wintering sub-Regions and Areas II and III at both haplotype and nucleotide level.

The exact test of differentiation provided further resolution to that offered by our comparisons using ϕ_{ST} and F_{ST} indices. In addition to what was seen when computing pairwise comparisons using fixation indices, there are significant differences among the following population comparisons: Breeding Region A vs Feeding Areas II and III, Breeding Sub-Region B1 vs Feeding Area III, and Breeding Sub-Region C3 vs Feeding Area II.

DISCUSSION

Our study suggests that Area I is genetically isolated from Breeding Regions A, B, C and X. Differentiation of Area I is consistent with the current knowledge that individuals summering in this Area migrate to the western coast of South America, and with the lack of evidence of mixing of this population with other Southern groups.

Humpback whales wintering in Region X are believed to comprise the only population that does not undertake the characteristic seasonal migration observed in this species. Our results, depicting a clear lack of gene flow between Region X and all Feeding Areas, support this hypothesis.

The lack of significant differences for comparisons between Regions B and C and Feeding Areas II and III suggests that whales feeding in any of these two Areas may use both wintering regions, the degree to which remains uncertain. We cannot, however, rule out ancestral polymorphism presence, or historical gene flow causing this lack of differentiation.

Region A shows conflicting results with different tests as to connection to Area II, probably due to the fact that our Area II sample included samples collected around Sandwich Islands and Bouvet Island, while previous data so far support connection of Region A only to Sandwich Island (SC/A06/HW11). Further work will be conducted to compare Area IIW and IIE samples separately as in SC/A06/HW26. Sub-Region B1 does not show significant differences with Area II, whereas sub-Region B2 and C1 do not show differentiation from Areas II and III, and sub-Regions C2 and C3 are not significantly differentiated from Area III.

The opportunistic basis of the sample collection in the feeding grounds, as well as the small sample sizes presented, suggest some caution in the interpretation of these results. These results are highly preliminary, a more detailed analysis and exploration of scenarios needs to be explored using

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mtDNA and 11 microsatellite loci. To have the fullest power of the analysis, all available IDCR/SOWER samples are needed.

In summary, our results support:

(1) genetic isolation between Area I and Breeding Regions A, B, C and X;
(2) genetic isolation between Breeding Region X and Areas I, II and III;
(3) genetic isolation between Region A and Feeding Area III, but an uncertain degree of differentiation between Region A and Feeding Area II; and
(4) no significant differentiation between Feeding Areas II and III with respect to Breeding Regions B and C.

Table 1

Sample size (*n*) for each of the sites included in this study.

Site	*n*	Site	*n*
Breeding Stocks		**Feeding areas**	
Stock A (West South Atlantic Ocean)	164	Area I (170ΥW-50ΥW)	
Region B (Southeastern Atlantic Ocean)		Western Antarctic Peninsula	41
B1	466	Area II (50WΥ–0Υ)	
B2	119	South to Sandwich Is – South to Bouvet I.	24
Region C (Southwestern Indian Ocean)		Area III (0Υ–70ΥE)	
C1	151	Off Eastern Queen Maud Land-Off Mac Robertson Land (III)	27
C2	78		
C3	511		
Region X (Northern Indian Ocean)	38		

Table 2

Genetic differentiation between ten sampling sites, including three wintering regions, and three feeding areas. Pairwise ϕ_{ST}-values, F_{ST}-values and *P*-values for the exact test of differentiation are presented. Significant values are in bold ($P<0.05$), as estimated from 10,000 random permutations.

	ϕ- statistics			*F* - statistics			Exact test		
	I	II	III	I	II	III	I	II	III
A	**0.02546**	-0.00078	0.00088	**0.05442**	0.00382	**0.00919**	**0.00000**	**0.03980**	**0.00000**
B1	**0.03081**	-0.00665	0.00748	**0.0476**	-0.00205	0.00503	**0.00000**	0.24565	**0.00335**
B2	**0.02952**	-0.00792	-0.00535	**0.05286**	0.00159	0.00358	**0.00000**	0.18820	0.26250
C1	**0.02046**	-0.00919	0.00174	**0.04791**	-0.00525	–0.00002	**0.00000**	0.56520	0.33150
C2	**0.02756**	-0.00281	-0.00511	**0.05406**	0.00167	–0.0002	**0.00000**	0.05625	0.16580
C3	**0.02658**	-0.00301	0.00045	**0.04860**	0.00075	–0.00486	**0.00000**	**0.02970**	0.54570
X	**0.15396**	**0.08936**	**0.11033**	**0.20128**	**0.15224**	**0.11925**	**0.00000**	**0.00000**	**0.00000**

Annex F
Consideration of observed male-skewed sex ratios in humpback whales

M. Noad, D. Mattila, P. Wade, C. Salgado-Kent, S. Cerchio, C. Garrigue

The study in SC/A06/HW21 led into a discussion of the general issue of the male-skewed sex ratios that are commonly observed on breeding grounds and sometimes in other areas such as on migration routes. Irrespective as to whether this is a real phenomenon or is only due to sampling issues, it may lead to underestimation of abundance, especially with respect to mark-recapture studies. This can be explored in sensitivity analyses to examine whether it has a major effect on assessment models (i.e. increase potentially affected abundance estimates by an assumed amount and investigate the influence of this higher abundance on assessment results). A brief discussion was held on how this possible source of bias could be avoided in sampling schemes, such as having shore-based observers select groups to be sampled and relay this information to boat-based biopsy samplers, but there was insufficient time to discuss this in any detail.

Some evidence for true 50:50 sex ratio on breeding grounds

(1) Catches in Western Australia had a ratio of approximately 1.4:1 and Dawbin (1997) felt that male-biased sex ratios in the catch record were due to selection bias against females by whalers.
(2) Autumn-Winter aerial surveys in the Gulf of Maine showed that all whales departed the feeding grounds to presumably migrate to the breeding grounds.

Mechanisms that could cause biased sex ratio on all or part of a breeding ground

(1) Males reside longer on breeding grounds.
(2) Males may aggregate (the 'floating lek' hypothesis) and so higher density areas are probably male biased.
(3) Some females do not migrate – this seems unlikely as empirical evidence points to growth rates in some populations that are not feasible without all or most females migrating every year to alternately calve and mate.

Sampling problems that could cause bias in the observed sex ratio

(1) Greater detection and subsequent sampling of larger groups that are known to contain more males than females.
(2) Greater boat avoidance by females.
(3) Groups including females may be harder to approach and take more time and effort in order to successfully collect a sample.
(4) Large groups, which are easier to see are likely to contain a higher proportion of males.
(5) More difficulty in sampling pods of one or two animals which are likely to contain females.
(6) Sampling on higher density areas that may be male biased even if the whole breeding area is not.

REFERENCE

Dawbin, W.H. 1997. Temporal segregation of humpback whales during migration in Southern Hemisphere waters. *Mem. Queensl. Mus.* 42(1): 105–38.

Annex G
Considerations for matching large photo-identification catalogues

D. Mattila, S. Cerchio, P. Forestell, C. Garrigue, K. Matsuoka, D. Paton, M. Poole, C. Salgado-Kent

Comparing large photo identification catalogues can be very useful in illuminating a number of demographic parameters identified by this workshop. However, these efforts can be time consuming and/or costly, and may not answer the questions intended. Conversely, it may not be necessary to match all images to sufficiently answer some questions. Therefore, careful thought should be given to the following considerations:

What are the questions being addressed? These might range from:

(1) definition of population structure through exchange rates;
(2) distribution and residency of individuals within habitats;
(3) abundance estimates (e.g. mark/recapture, rates of discovery); and
(4) biological parameters (e.g. reproductive rates, survivorship, social organisation).

Catalogues which are candidates for comparison should be examined for the following:

(1) the area sampled and the likelihood of exchange to another area;
(2) year and season the images were collected;
(3) number of individuals identified in the catalogue;
(4) comparability of body parts used in identification (e.g. fluke, dorsal, lateral marks);
(5) biases associated with sampling for each catalogue (e.g. sampling platform, primary focus of study);
(6) other information associated with identifications (e.g. age, sex, reproductive history, genetics); and
(7) format of the images (e.g. black and white or colour, print or digital).

With regard to the actual process of matching, the following considerations were highlighted:

(1) reduction of the number of images to be matched through elimination of poor quality images is advantageous;
(2) understand resources available (e.g. personnel, funds);
(3) clearly define match criteria; and
(4) decide on appropriate matching process (e.g. pair-wise, stratified, double blind, computer assisted).

The Working Group is aware of several ongoing efforts to improve the efficiency of the image matching process itself as well as quantifying any problems or biases involved.

A sample of the quality screening criteria developed by Cascadia Research Collective was reviewed, and is given as Appendix 1.

Conclusion

The Working Group **agreed** to the following recommendations:

(1) large catalogues should be screened for quality prior to matching, eliminating poor quality images – this will save time and resources and produce a less biased outcome;
(2) the IWC Scientific Committee should clearly identify the highest priority questions to be addressed and the catalogues that would most likely be used to answer those questions;
(3) a standardised quality screening and match criteria should be identified; and
(4) the IWC Scientific Committee should review previous studies and ongoing efforts to improve photo-identification matching techniques and analyses of error and bias.

Appendix 1

CASCADIA RESEARCH COLLECTIVE FLUKE SCREENING CRITERIA

The quality of the photograph is graded based on: the proportion of the fluke that was visible in the photograph, fluke angle (i.e., how perpendicular it is to the water), the lateral angle of the photographer, the sharpness and grain and the photographic quality (lighting, exposure and contrast), as follows:

Proportion of fluke visible
1 – 100%
2 – 75–99%
3 – 50–74% (base of notch still visible)
4 – <50%
5 – right/left side only

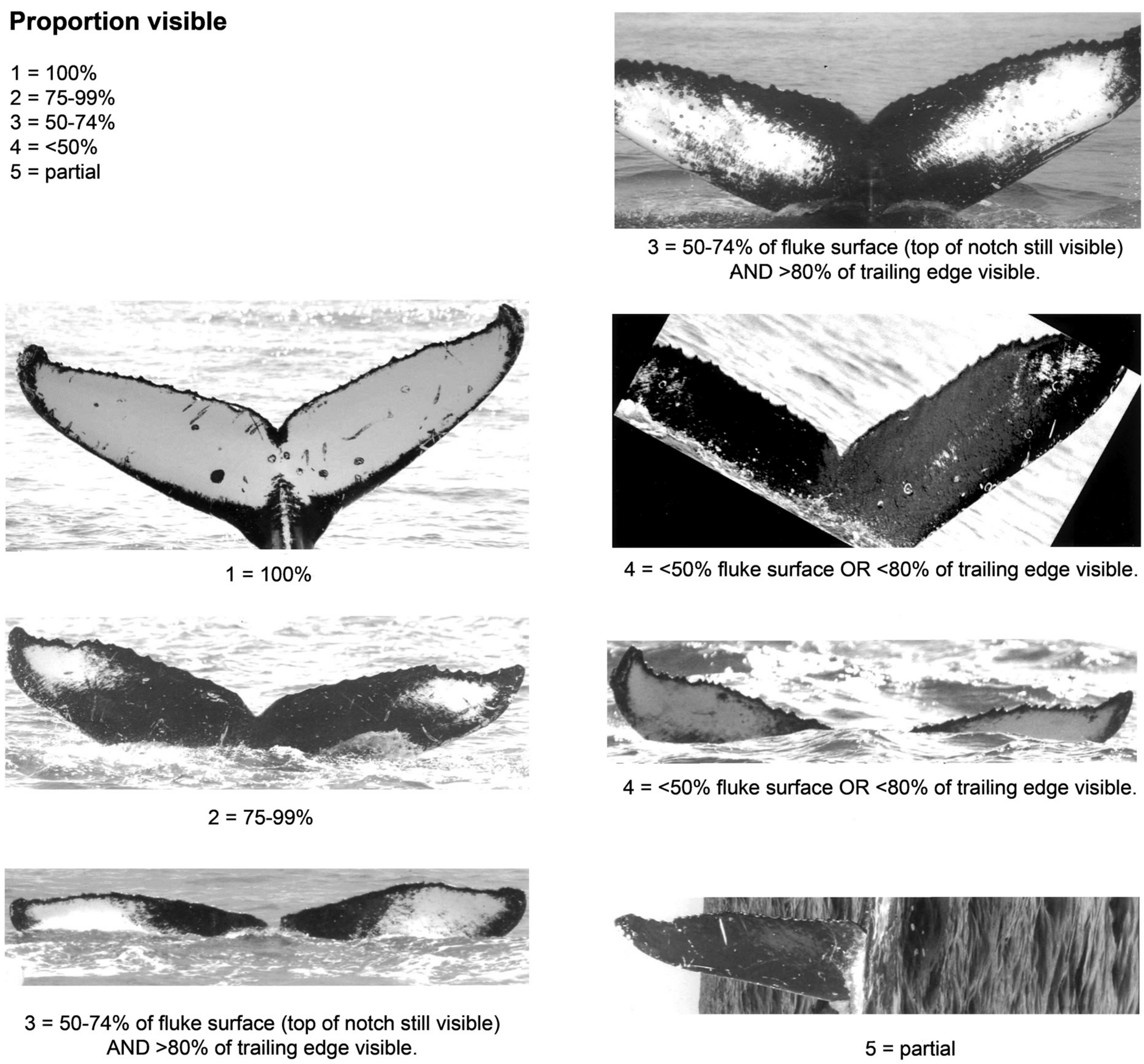
Fluke angle:
1 – perpendicular to the water
2 – short of perpendicular but no loss in visibility
3 – short of perpendicular with some loss in quality but ridging easily visible
4 – low angle, ridging only partially visible
5 – low angle, ridging and markings not visible or very distorted

Photographer lateral angle:
1 – straight behind
2 – not directly behind but minimal distortion
3 – angled about 45° to side
4 – angled >45° but markings still visible
5 – angle so extreme most markings obscured

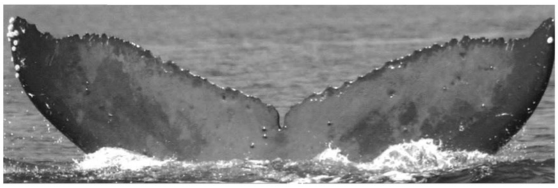
Focus/sharpness:
1 – excellent focus with clear grain
2 – good focus and grain with only minimal loss in quality
3 – okay focus and grain with some loss in ability to discern marks and edges
4 – fair to poor focus in grain with significant loss in clarity
5 – soft focus/grainy with extreme loss in detail

Lighting/contrast/exposure:
1 – excellent lighting and contrast, any marks present would be seen
2 – good but with some loss in contrast on ventral surface
3 – fair, some marks might not be seen at all but most would likely be visible
4 – fair to poor with significant backlighting or exposure problems
5 – poor (e.g. back lit or gray), likely many marks would not be visible

Examples of each grade are given below in Fig. 1.

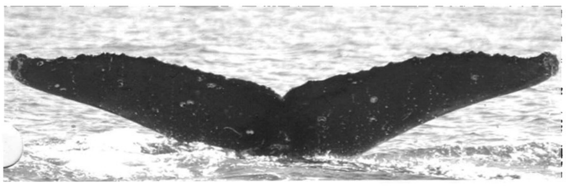


Fluke angle



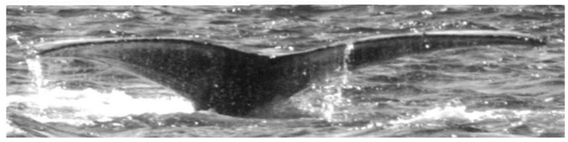
1 = perpendicular to the water

2 = short of perpendicular but no loss in visibility



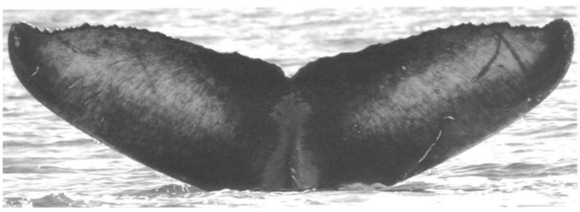
3 = short of perpendicular

4 = low angle, ridging only partially visible



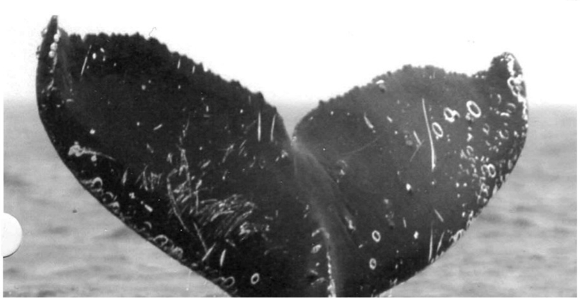
5 = low angle, ridging and markings not visible or very distorted

Photographer lateral angle

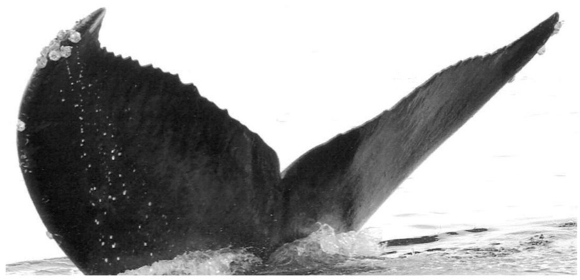


1 = straight behind

2 = not directly behind but minimal distortion



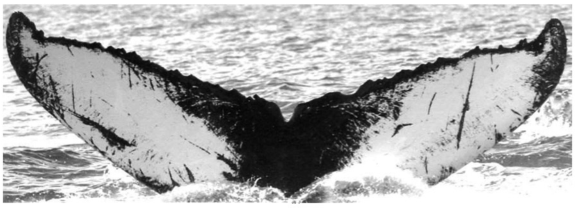
3 = angled about 45° to the side



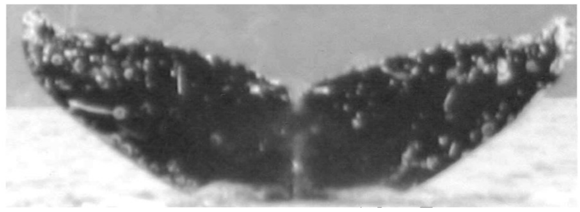
4 = angled >45° but markings still visible

5 = angle so extreme most markings obscured

Focus

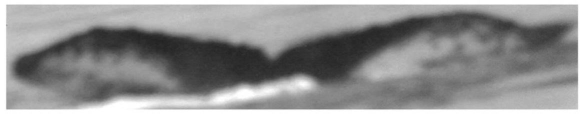


1 = in focus with clear grain



4 = fair to poor focus and grain with significant loss in clarity

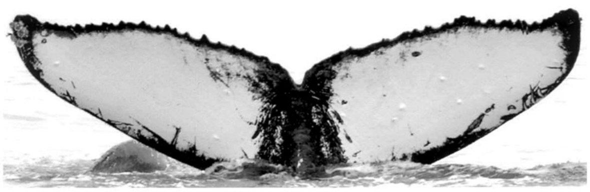
2 = good focus and grain with only minimal loss in quality



5 = soft focus/grainy

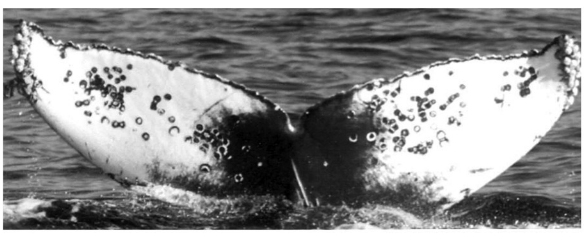
3 = OK focus and grain, some loss in ability to discern marks and edges

Exposure/contrast/lighting (light flukes)

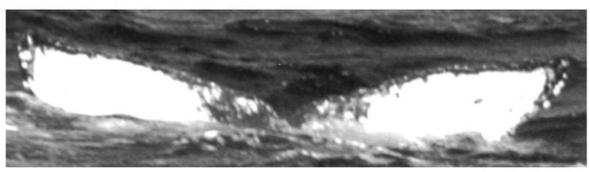


1 = excellent, all marks would be seen

4 = fair to poor with significant backlighting or exposure problems; may be difficult to assign colour category



2 = good but with some loss in contrast on the ventral surface



5 = poor (backlit or grey), likely some marks marks would not be visible; may be difficult to assign colour category

3 = OK, some marks might not be seen

Annex H
Recommendations for each Breeding Stock

Breeding Stock A

Recommendations for work to be completed for the 2006 Annual Meeting are detailed in the main report under Item 10.2. The Workshop **agrees** the following longer term priority recommendations for Breeding Stock A.

(1) Determine whether the northern coast of South America (north and west of 5°S) and oceanic islands off the coast of eastern South America (Fernando de Noronha, São Pedro and São Paulo Archipelago, and Trindade and Martin-Vaz) are areas of regular occurrence of humpback whales and determine their relationship (e.g. through photo-identification, genetic and/or satellite telemetry data) with the main population along the coast of Brazil;

(2) Increase research effort to collect biopsy samples and photo-identification data in the wintering and feeding grounds and migration paths to aid the following objectives:
(a) investigate whether sub-structuring of the population occurs in the wintering grounds;
(b) investigate the degree of interchange/isolation within and among wintering and feeding grounds; and
(c) estimate demographic parameters (e.g. survival, birth rate, age at first parturition).

(3) Satellite telemetry work should continue in the wintering grounds and be initiated in the feeding areas with the following purposes:
(a) investigate movement across current stock boundaries and possible interchange of individuals with other breeding populations;
(b) investigate alternative migratory routes and feeding-breeding ground connections;
(c) identify critical habitat; and
(d) investigate movements, behaviour and habitat use in relation to oceanographic and biological variables (e.g. distribution and concentration of food).

(4) Compare songs of whales from this breeding stock with others (especially B and G) to better understand the potential cultural connections between these stocks as suggested by preliminary studies (e.g. Darling and Sousa-Lima, 2005).

Breeding Stock B

The Workshop **agrees** to the following recommendations with respect to Breeding Stock B.

(1) Available evidence (satellite tagging, photographic and genetic studies, other reports and whaling data) suggests a region wide presence during the breeding season. The prevailing data presented at the Workshop were restricted largely to the coastal waters of Gabon (B1) and along the west coast of South Africa (B2). The Workshop **recommends** additional systematic boat-based surveys that will yield information on estimates of abundance and occurrence of calves, as well as photo-identification data for life history information and collection of genetic samples from under-surveyed areas in B1 and B2. Specifically survey and collections should occur at:
(a) west coast of South Africa and Namibia;
(b) Angola;
(c) Gabon out to São Tomé and Principe;
(d) northern Gulf of Guinea and Bioko Island; and
(e) southern coast of West Africa.

The Workshop **recommends** that survey effort across these regions be concurrent. The relevance of such surveys to the Comprehensive Assessment includes both estimation of abundance from areas for which no abundance estimates are currently available and the strengthening of the understanding of alternative models of stock structure and number of breeding stocks within the Breeding Stock B region.

(2) Genetic results are providing information on structure and interchanges within and between B sub-regions. These include evidence for clearer separation of B1 and B2, and a number of breeding stocks within the B1 region. The Workshop **recommends** that the large-scale genetic analyses be continued and expanded with new approaches to help resolve issues of relationships and population structure within this region, as well as connectivity to feeding grounds.

(3) Small boat surveys at existing field sites are largely focused on the period of July–October (B1), but an out-of-season presence is suspected. The Workshop **recommends** a greater degree of temporal coverage in survey effort.

(4) Telemetry studies in B1 have informed stock structure, migratory routes and destinations for some B1 whales. The Workshop **recommends** that new satellite tagging studies be initiated to identify breeding destinations for whales observed feeding in B2. Tagging should be conducted off:
(a) west South Africa in both early and late breeding seasons (on either end of migration);
(b) Angola, southern boundary of B1; and
(c) upper and/or offshore Gulf of Guinea, northern area of B1.

(5) Additional samples are needed from the Antarctic feeding grounds to help elucidate these high and low latitude connections as well as to discriminate among hypotheses concerning mixing on the feeding grounds.

The Workshop **recommends** that the genetic sampling of humpback whales remains a high priority of SOWER cruises. In order to facilitate this work, the Workshop **recommends** that samples from the 2006 SOWER cruise (Area III, $n = 71$) be transferred as soon as possible to the WCS/AMNH Cetacean Conservation and Research Program for analysis and subsequent transfer back to SWFSC for storage.

(6) Large-scale line transect surveys have the potential to estimate density, abundance and distribution of animals and establish coverage for areas that are difficult to sample comprehensively from shore (i.e. offshore distributions and diverse archipelago systems with humpback whale concentrations). Thus far, no ship-based surveys have taken place in the B region. The Workshop **recommends** that efforts be made to undertake more extensive ship-based surveys throughout the B sub-regions to estimate densities and collect information from areas that are difficult to survey.

The relevance of such surveys to the Comprehensive Assessment is estimation of abundance from areas for which no abundance estimates are currently available and the strengthening of the understanding of overlap of the B1 and B2 sub-populations and number of breeding stocks, through co-incident genetic and natural mark sampling.

(7) The Workshop **recommends** the involvement of scientists from relevant states in the region, and facilitation for future participation in IWC workshops or Scientific Committee meetings.

Breeding Stock C

(1) Based on: (i) un-surveyed areas of humpback whale concentration in northern C1, throughout C2 and in western and southern Madagascar; and (ii) identified C1, C2 and C3 connectivity (SC/A06/HW12), the Workshop **recommends** additional systematic boat-based surveys to gain information on estimates of abundance, as well as other life history information, and collection of genetic samples from under-surveyed areas in northern C1, C2 and in western and southern C3.

Specifically survey and collections should occur at:

(a) Grand Comoro Island, west side of C2;
(b) Mayotte, east side of C2;
(c) Toliara, southwest coast of Madagascar, C3;
(d) Nosy Bé, northwest coast of Madagascar, C3;
(e) Fort Dauphin, southeast coast of Madagascar, C3;
(f) Mascarene Islands;
(g) Pemba coast, northern Mozambique, C1 (initial surveys possibly to start in July 2006); and
(h) Mafia Island, Tanzania, C1.

The Workshop **recommends** that survey effort across these regions be concurrent. The relevance of such surveys to the Comprehensive Assessment includes both estimation of abundance from areas for which no abundance estimates are currently available and the strengthening of the understanding of overlap of the C1, C2 and C3 sub-populations.

(2) Genetic results have yielded valuable information concerning population structure and interchanges within and between C sub-regions. The Workshop **recommends** that the large scale genetic analyses be continued and expanded with new approaches to help resolve issues of relationships and population structure within this region, as well as connectivity to feeding grounds.

(3) Additional samples are needed from the Antarctic Feeding Grounds to help elucidate these high and low latitude connections as well as to discriminate among hypotheses concerning mixing on the feeding grounds. The Workshop **recommends** that the genetic sampling of humpback whales remains a high priority of SOWER cruises. In order to facilitate this work for the next two Annual Meetings, the workshop recommends that samples from the 2006 SOWER cruise (Area III, $n = 71$) be transferred directly to the WCS/AMNH Cetacean Conservation and Research Program for analysis and subsequent transfer to SWFSC.

(4) The satellite telemetry studies in the South Atlantic have greatly helped to identify stock structure and migratory routes and destinations, accordingly the Workshop **recommends** that satellite tagging studies be initiated in as many components of the C sub-region as possible. Tagging sites and times should be chosen to best discern northern and southern migratory movements in C1, distribution and movements throughout C2 and around Madagascar in C3, and interconnections between the 3 sub-regions. Such studies provide relatively rapid and cost effective results to further the understanding of migratory movements within the C region.

(5) Line transect surveys have the potential to estimate densities of animals and establish coverage for areas that are difficult to sample comprehensively (i.e. offshore distributions and diverse archipelago systems with humpback whale concentrations). Thus far only ship-based surveys have taken place in the southern and central C1 sub-regions, although a yacht-based line transect survey has been undertaken across the southern Madagascar region. The Workshop **recommends** that efforts be made to undertake more extensive ship-based surveys throughout the C sub-regions to estimate densities and collect information from areas that are difficult to survey.

These should include:

(a) northward up the coast of Mozambique to Tanzania;
(b) west along the coast of Madagascar and into the Mozambique Channel;
(c) throughout the Comoros Islands; and
(d) south of Madagascar to Walter's Shoal.

The relevance of such surveys to the Comprehensive Assessment is the estimation of abundance from areas for which no abundance estimates are currently available and the strengthening of the understanding of overlap of the C1, C2 and C3 sub-populations, through co-incident genetic and natural mark sampling.

(6) A comprehensive comparison of biological (photographic, genetic and acoustic) data collected in Regions A, B, C, D and X is needed to evaluate the existing preliminary findings of differences and similarities between these regions. The Workshop **recommends** that this work be undertaken and completed in order to finish the Comprehensive Assessment.

(7) Few estimates of population trends are available for Southern Hemisphere humpback whales apart from those arising from the coasts of Australia. The Workshop **recommends** the immediate continuation of the shore-

based surveys at Cape Vidal, South Africa to further the preliminary increase rate provided in SC/A06/HW16. Given the completed series of surveys, it is suggested that this be high priority.

(8) The workshop recommends the involvement of scientists from relevant states in the region, and facilitation for their future participation in IWC workshops or Scientific Committee meetings.

Breeding Stock D
Priority 1 – Genetic analyses
The Workshop noted that only limited genetic comparisons have been made between Breeding Stock D and other breeding areas, especially the Australian coastal areas of Breeding Stock E, despite the existence of relatively large numbers of samples. It **strongly recommends** that further genetic comparisons should be made between western Australia and adjacent breeding areas, particularly coastal eastern Australia (within Breeding Stock E) as soon as possible; this is essential to providing the necessary information on stock structure for the completion of the assessment.

Based on information in the metadata table available on the IWC website* those involved should include Brasseur (Edith Cowan University, Western Australia) and Pastene (ICR) – for samples from Breeding Stock D, both on the breeding and feeding grounds – and Anderson (Southern Cross University, New South Wales), Pastene (ICR), Olavarria (University of Auckland), and Paton (Southern Cross University) – for samples from Australian coastal Breeding Stock E, on breeding and feeding grounds. Given his previous involvement, Baker (University of Auckland) should also participate.

Priority 2 – Photo-identification comparisons
Again, the Workshop noted that despite large sample sizes, there has been no major comparison of photographs from western and eastern Australia. It therefore **strongly recommends** that such a comparison should be conducted as soon as practical, with a primary goal of examining connections between areas and estimating movement rates, both of which are extremely important to the completion of the assessment. From previous experience with comparison of large catalogues, it was **agreed** that rigorous fluke photo quality grading be conducted prior to matching, in order to efficiently allocate research resources and to facilitate efficient matching. Further details are given in Annex G.

Based on information in the metadata table available on the IWC website*, those involved should include, for Breeding Stock D, Jenner (Centre for Whale Research, Western Australia), Burton (Western Whale Research, Western Australia) and Kaufmann (Pacific Whale Foundation), and for Breeding Stock E, at least Franklin (Southern Cross University), Kaufmann (Pacific Whale Foundation), Paton (Southern Cross University) and Pastene (ICR).

Breeding Stocks E and F
Priority 1 – Genetic analyses
The Workshop noted that genetic comparisons have not been made between other breeding grounds and the migratory corridor of eastern Australia or the presumed breeding grounds of the Great Barrier Reef. It **strongly recommends** that genetic comparisons should be made between eastern Australia and the rest of Breeding Stocks E and F, as well as with western Australia (see main report Item 3.5.5); this is essential to providing the necessary information on stock structure for the completion of the assessment.

Priority 2 – Photo-identification comparisons
Again, the Workshop noted that despite large sample sizes, there has been no major comparison of photographs from eastern Australia with those from western Australia and Oceania. It therefore **strongly recommends** that such a comparison should be conducted as soon as practical, with a primary goal of examining connections between areas and estimating movement rates, both of which are extremely important to the completion of the assessment. From previous experience with comparison of large catalogues, it was **agreed** that rigorous fluke photo-quality grading be conducted prior to matching, in order to efficiently allocate research resources and to facilitate efficient matching. Further details are given in Annex G.

Other recommended research include the following.

(1) Filling in gaps in known or suspected regions of known or suspected, past or present high density by vessel-based, aerial or acoustic surveys:
  (a) Great Barrier Reef, including connectivity to eastern Australia migratory corridor and Hervey Bay; and
  (b) Chesterfield Reef, including connectivity to eastern Australia migratory corridor and Hervey Bay.

(2) Maintain or initiate surveys intended for historical comparison to CPUE and model trajectories, particularly in regards to resolving apparent variability in recovery:
  (a) Point Lookout, eastern Australia;
  (b) Cook Strait;
  (c) Norfolk Island; and
  (d) Fiji.

(3) Continue surveys in key location of eastern Australia and Oceania, particularly in regards to evaluating trends in abundance for Oceania:
  (a) eastern Australia: Point Lookout/Byron Bay/Hervey Bay/Whitsundays/Eden;
  (b) New Caledonia;
  (c) Tonga;
  (d) Cook Islands; and
  (e) French Polynesia.

(4) Resolve the degree of demographic and genetic interchange/isolation between eastern Australia migratory corridor and breeding grounds of Oceania by:
  (a) photo-id comparison of eastern Australian catalogues with Oceania (one component of which is planned by Garrigue and others for November 2006);
  (b) analysis of genetic differentiation between eastern Australia and Oceania (migratory corridor and migratory destinations, if possible) using both mtDNA and microsatellites; and
  (c) analysis of song exchange.

(5) Further resolve the degree of demographic and genetic interchange/isolation between eastern Australia's migratory corridor and breeding grounds of Oceania by:
  (a) improved Photo-id analysis for primary regions of Oceania using multi-state, closed or open capture-recapture models;
  (b) further analysis of genetic differentiation among Oceania using both mtDNA and microsatellites by sex and year; and
  (c) analysis of song exchange.

**http://www.iwcoffice.org/_documents/sci_com/workshops/Table2.pdf* accessed October 2011.

(6) Further investigation of Discovery marking and recovery:
   (a) investigate effort distribution as failing to take this into account can bias perceptions of proportions of whales moving between regions; and
   (b) exclude short period recoveries from analysis of returns.

(7) Initiate satellite tagging to address key questions of migratory destinations:
   (a) in New Zealand to track northward migration to breeding grounds destinations (Fiji?);
   (b) in French Polynesia to track southward migration to feeding area destination (Area VI?); and
   (c) in eastern Australia to track northward migration to breeding ground destinations (GBR).

(8) Further analysis of sex bias to:
   (a) correct (if necessary) shore-based counts from eastern Australia; and
   (b) correct (if necessary) for multi-year sighting/resighting analysis.

(9) Further analysis of migratory connections to feeding grounds (areas) by:
   (a) directed photo-id comparison of eastern Australia and Oceania to IDCR/SOWER, JARPA and other studies (one component of which is under proposal to the Data Availability Group by Garrigue); and
   (b) mtDNA and microsatellite assignment and analysis of differentiation for breeding ground and feeding area samples from IDCR/SOWER (underway by several groups but requires improved access to IDCR/SOWER samples).

Breeding Stock G

The Workshop **recommends** that it is a high priority that existing catalogues from Panama, Costa Rica, Columbia and Ecuador be fully reconciled and compared to catalogues from Antarctica and the Magellan Strait.

Breeding Stock X

Given that the humpback whales of Region X represent an isolated population that has a very low estimate of abundance, the Workshop **strongly recommends** that further research be undertaken that will aid in protection of this stock.

There are whales in unsampled areas between Oman and other study areas in Africa and Western Australia. The Workshop **recommends** that studies should be conducted in these areas.

It **recommends** that further genetic sampling and analysis be completed to more conclusively determine the degree of differentiation for humpback whales of Region X and the timing of its separation from other humpback whale populations.

Distribution of whales in Region X clearly occurs throughout areas of the Arabian Sea but surveys conducted to date have been limited to the coast of Oman. The Workshop encourages more survey effort in other areas to evaluate movements and relationships with whales off the coast of Oman.

Given the seasonal limitations in survey effort and an unresolved degree of movement and connectivity with other concentrations of humpback whales in the Indian Ocean, the Workshop suggests that satellite telemetry studies be initiated.