ALLOCATIONS OF CATCHES OF HUMPBACK WHALES (1904 – 1973) FOR THE IWC COMPREHENSIVE ASSESSMENT OF SOUTHERN HEMISPHERE HUMPBACK WHALES

Report of an intersessional email group (Findlay (chair), Bannister, Best, Cerchio, Jackson, Loo, Paton, Rosenbaumn, Weinrich, Zerbini).

1. INTRODUCTION

The allocation of modern whaling catches of humpback whales to breeding stocks has been an ongoing and evolving process since the 1997 IWC Scientific Committee. Original catch allocation models, named "Naive", "Fringe" and "Overlap", were proposed (IWC, 1998), but a number of modifications of these models and the use of alternate nomenclature (e.g. "Core" areas) occurred. Participants of the Southern Hemisphere Humpback Whale Assessment Modeling Workshop held in Seattle in February 2009 noted that the current delineations between breeding stocks in the feeding grounds are confusing. Therefore, an email group was appointed to review and clarify the various catch allocation hypothesis. This report summarizes the work conducted by the group.

For clarification the original three models are referred to as NAÏVE, FRINGE and OVERLAP (in uppercase), the revised Hobart Workshop models are referred to as Core and Fringe (title case), while the core and fringe areas within the FRINGE model are referred to in lowercase. Core and Fringe models have been referred to by certain research groups as "Fringe Maximum" and "Fringe Minimum" models (e.g. SC/60/SH14).

2. THE INITIAL CATCH ALLOCATION MODELS

2.1. 1997 - SC/49 Meeting

A small working group was set up at this meeting to construct the sub-committee's best idea of putative breeding grounds, feeding grounds and migratory linkages for southern humpback whales and alternate biologically plausible scenarios (Appendix 4, Annex G, IWC, 1998, p. 181), and is reproduced here as Appendix 1). Based on the catch positions of previous Soviet Antarctic catches, mark-recovery information from the International Marking Scheme, and the distribution of sightings on IDCR cruises, seven concentration areas (= feeding grounds) were recognised in the Antarctic, and seven corresponding breeding grounds in lower latitudes. These were specified as follows:

(I) Group A: 70° W -20° W: linked to Brazil.

(2) Group B:20°W-10°E:linkedtoAngola/Gabon.

(3) Group C: 10°E-60°E:linkedto Mozambique/Comores/Madagascar.

(4) Group D: 60°E -120° E: linked to Western Australia.

(5) Group E: 120°E-170°W: linked to Eastern Australia, Tonga, New Zealand.

(6) Group F: 170° W -120°W: linked to Oceania.

(7) Group G: 120°W -70°W: linked to Colombia.

Three alternative models for allocating catches in high latitudes to these breeding stocks were proposed (the NAÏVE, FRINGE and OVERLAP models), and these were accepted by the sub-committee, recognising that they were tentative and subject to revision as new information became available.

While in the NAÏVE model whales from each of the seven breeding stocks are restricted to fixed feeding grounds (Appendix 1 – Table 1), the FRINGE model assumes a direct breeding stock – feeding ground correspondence for core feeding areas (Appendix 1 - Table 2) and 50/50 contribution of catches in the between core areas (the fringe areas) to the two nearest breeding stocks (Appendix 1 - Table 3). The OVERLAP model defines areas as for the NAÏVE model but divides catches in an 80/10/10 percent ratio with the 80% direct

allocation as per the NAÏVE model and 10% being allocated to the each breeding stock to the west or east. Appendix 1 assumed that, at the most, whales from one breeding ground would only disperse in summer as far as the adjacent feeding ground, either to the west or east. In terms of the model, historic catches south of 40°S are allocated to breeding stocks as per the stock distribution model above under consideration. Catches north of 40°S are allocated to the associated breeding stock in terms of the NAIVE model correspondence.

However the wording of Appendix 1 can lead to confusion, as Table 2, in defining core feeding areas of the FRINGE model, is labelled "Fringe model feeding areas", while Table 3 in defining "fringe areas between these ranges" is labelled "Fringe model overlap areas". It is suggested that the FRINGE model feeding areas in Table 2 be referred to as "FRINGE model core feeding areas", while the FRINGE model overlap areas in Table 3 be referred to as "FRINGE model fringe areas".

Figure 2 shows the areas of allocation of catches from breeding and feeding areas under the NAÏVE model. It is immediately apparent that the areas of allocation of catches from the breeding areas (north of 40°S) are incorrect according to this model (and in fact for all three models as the FRINGE and OVERLAP models adopt the NAÏVE model breeding ground catch allocations). Almost the entire B breeding ground catch (north of 40°S) would (under the definitions of the Appendix 1 models) be placed within the C breeding ground. Furthermore catches from western Australia (particularly from Albany and possibly on the north-western coast) would be extremely close to the D/E border. Furthermore comparisons of Tables 2 and 3 shows a further FRINGE model fringe area is required between 70°W and 60°W.

Initially the allocation of catches was carried out by Ken Findlay in SC/52/IA5 (Findlay et al., 2000), with the following departures from Appendix 1 (under advice / discussion with members of the working group):

All land based and low latitude pelagic catches from the West African coast (to the west of 20°E) were allocated to the B breeding stock,

All land based and low latitude pelagic catches from the West Australian coast (to the west of 135°E) were allocated to the D breeding stock,

Catches from the coast of Chile were allocated to breeding stock G regardless of the latitude at which they were made, and

Land based catches from New Zealand were allocated to breeding stock E regardless of the latitude at which they were made.

A full description of the catch allocation carried out in SC/52/IA5 is provided in Appendix II. Figure 3 shows the areas of allocation (including these departures) according to the NAÏVE model, while figure 4 shows the areas of allocation for the FRINGE model (including the core areas (in grey) and fringe areas (in blue)). Areas of allocation for the OVERLAP model are as for the NAÏVE model.

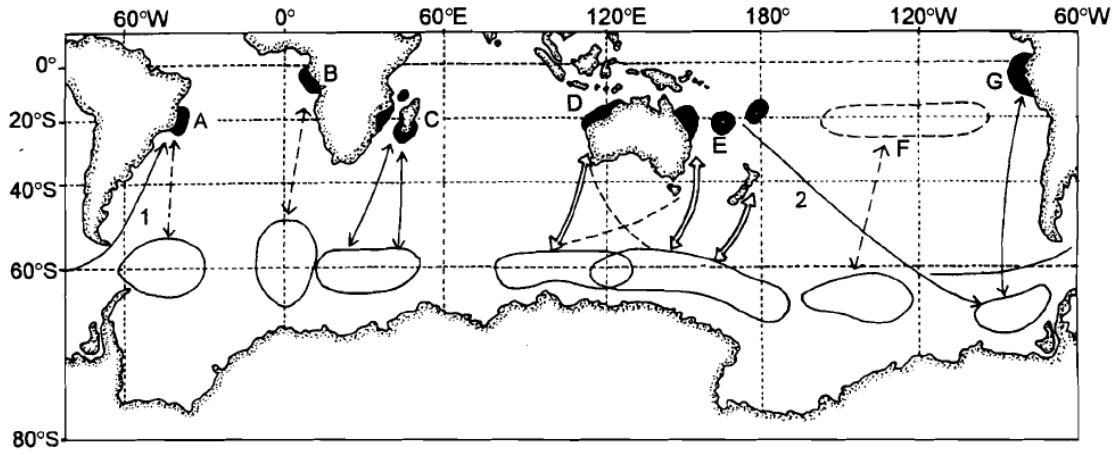

Figure 1. Putative breeding grounds, feeding grounds and migratory routes for Southern Hemisphere humpbacks (updated from Fig 1, IWC, 1997)

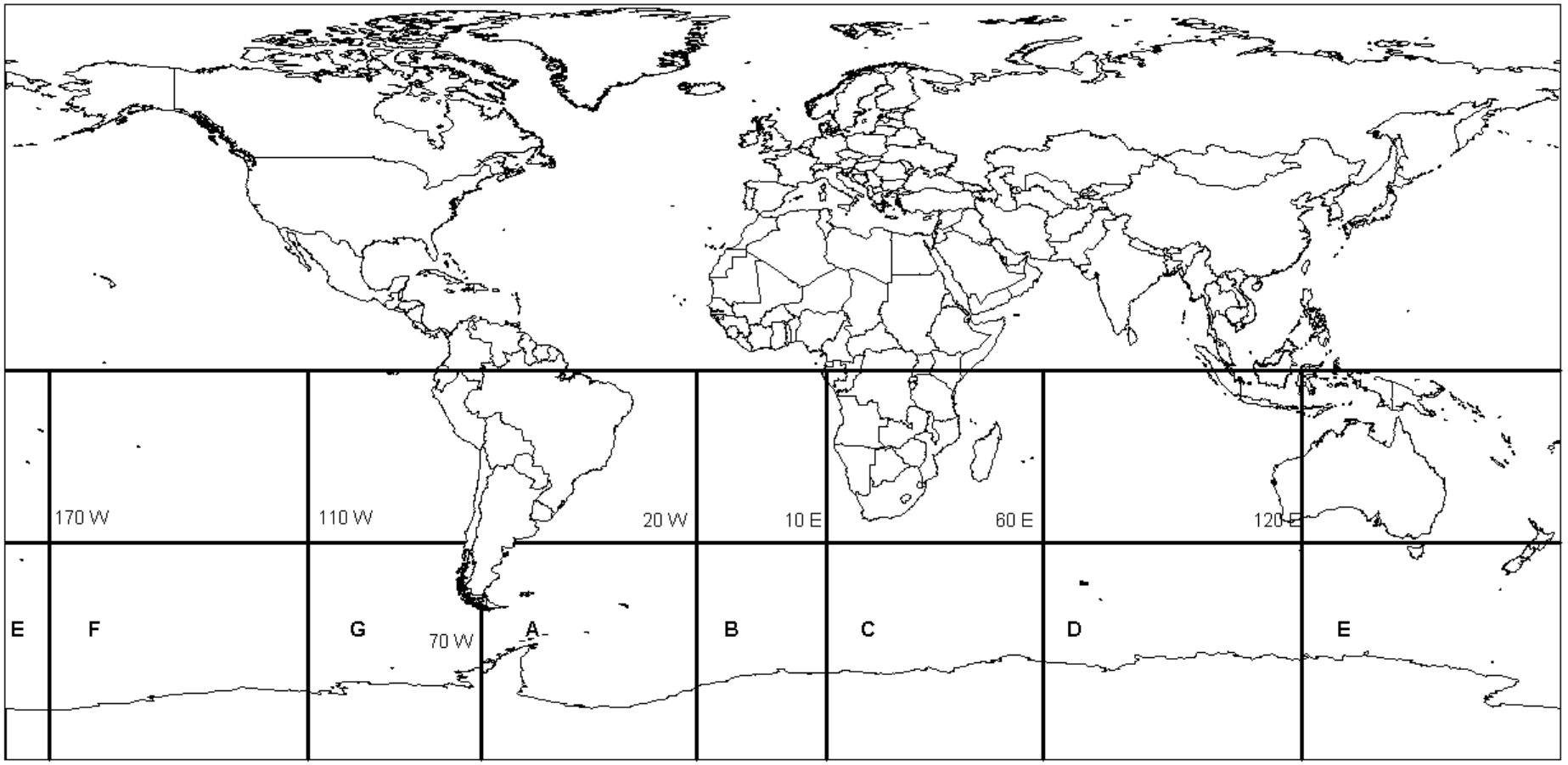

Figure 2. Original areas of allocation of catches from breeding and feeding areas under the NAÏVE model (IWC 1998) as presented in Appendix I.

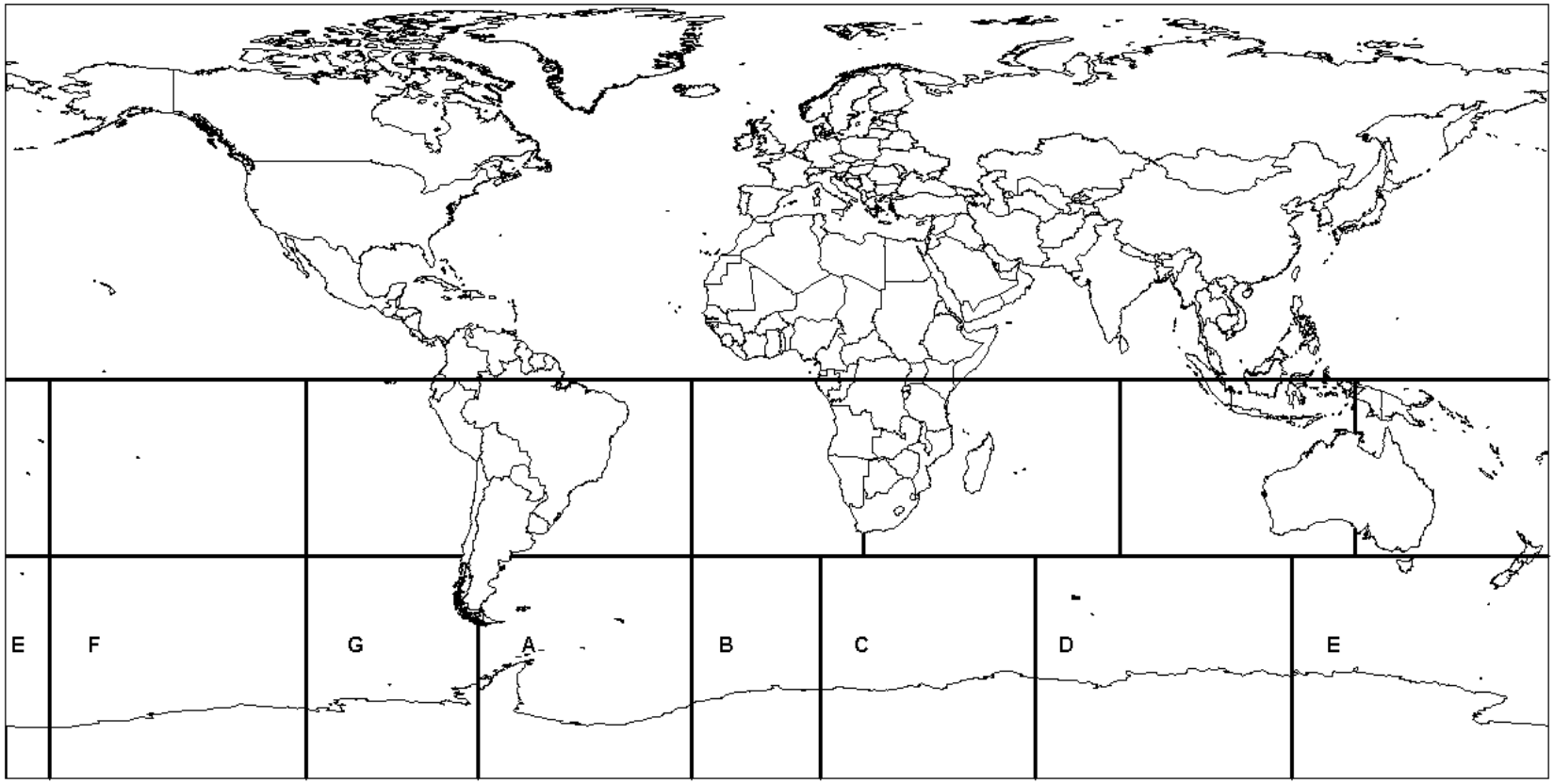

Figure 3. Modified (modifications to breeding areas to consider error or omissions within the Tables of Appendix 1 see text above) areas of allocation of catches from breeding and feeding areas under the NAÏVE model as presented in Appendix I, and as allocated in the KF catch series (Findlay et al. 2000).

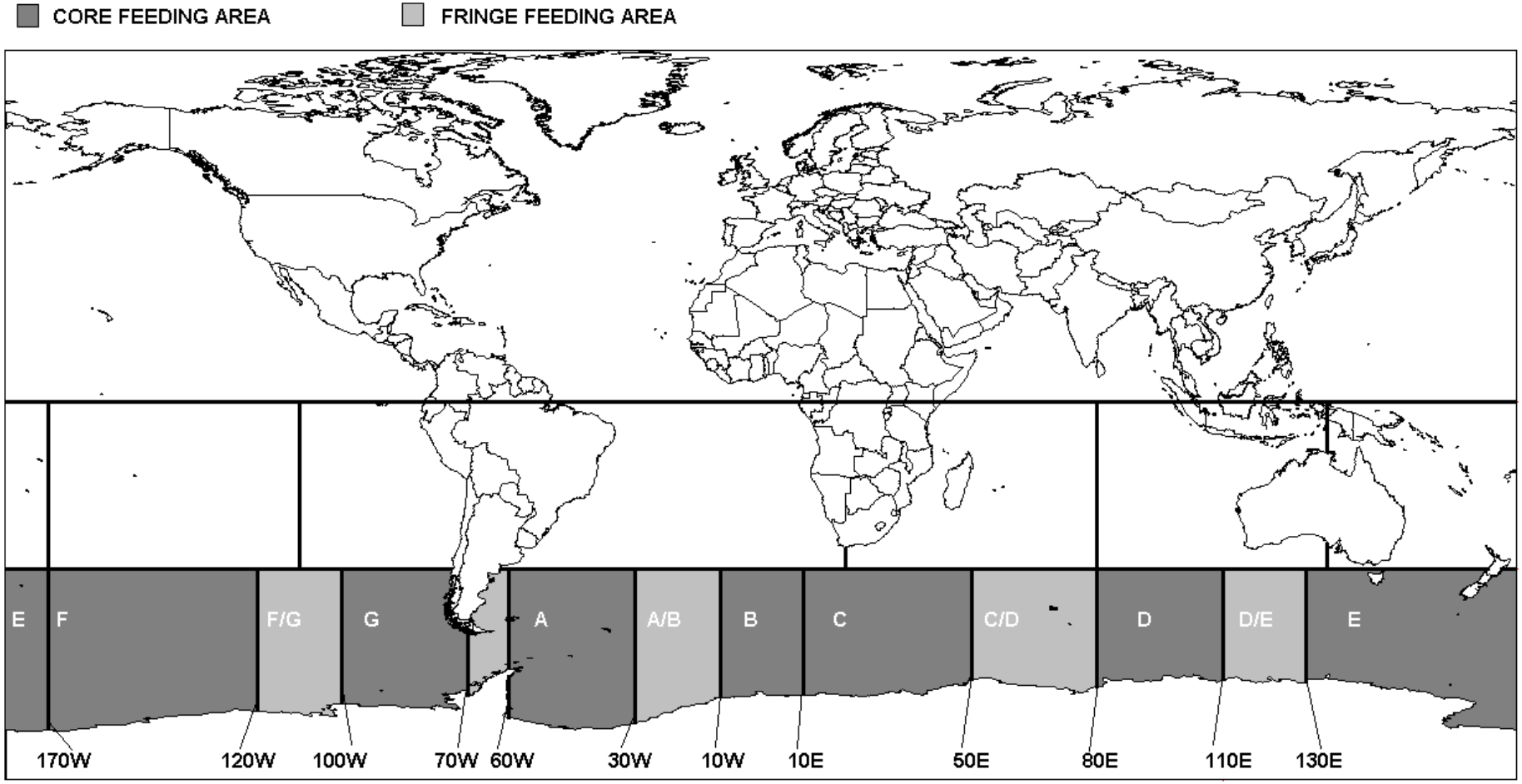

Figure 4. Areas of allocation of catches from feeding areas under the FRINGE model as presented in Appendix I. Breeding ground catches are as for Figure 3.

3. ALTERATIONS TO THE CATCH ALLOCATION AREAS (2000 – 2008)

As stated above, the three alternative models for allocating catches in high latitudes to these breeding stocks were accepted by the sub-committee, recognising that they were tentative and subject to revision as new information became available. A number of revisions and alterations have taken place and Appendix III provides a review of these by meeting. A summary of such changes follows:

1. SC/52 - 2000:

The boundary between feeding grounds for G and A stocks should be moved some 10-15° to the east;

Breeding stock E should be split into three sub-populations (Eastern Australia, New Caledonia and Tonga),

Breeding stock B should be split into two sub-stocks (Gabon and Angola),

Breeding stock C should be split into three sub-stocks (Mozambique, Comoros and Madagascar), and

Breeding stock F should be split into two or three sub-stocks (Cook Islands, French Polynesia and possibly Easter Island).

2. SC/53 -2001

The borders for Areas A and G feeding areas shifted 10° from 70°W to 60°W (all models)

3. SC/54 – 2002

The SC/54 sub-committee proposed that an intersessional working group summarize current knowledge regarding Southern Hemisphere humpback whales, by population or management area; identify major gaps in knowledge; and establish priorities for research to fill these gaps.

No changes to catch allocation areas.

4. SC/55 - 2003

The report of the intersessional working group on Southern Hemisphere humpback whales was presented.

It was suggested that the F ground may require subdivision into two elements (Cooks Islands and French Polyenesia).

5. SC/56 – 2004

A further report of the intersessional working group on Southern Hemisphere humpback whales was presented at SC/56. (new information summarised in Figure 5).

No changes to catch allocation areas.

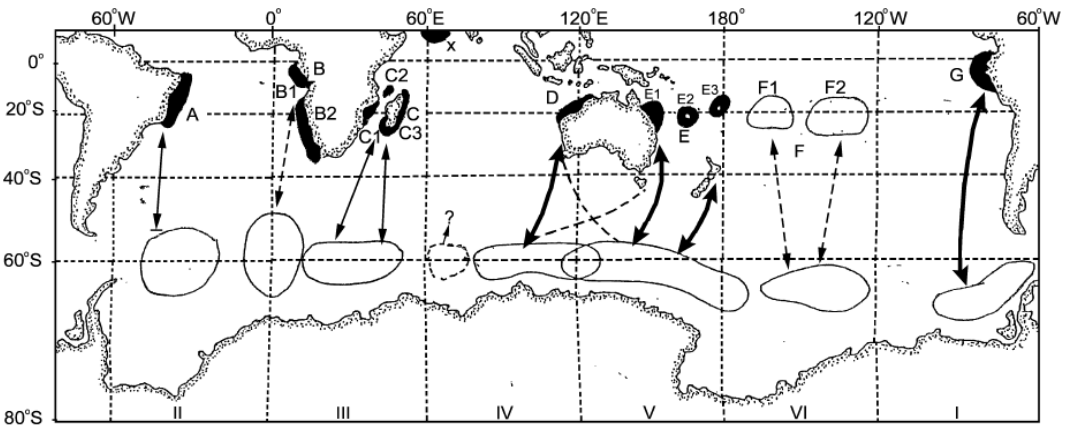

Fig. 1. New hypothetical stock structure for Southern Hemisphere humpback whales. This is for illustrative and discussion purposes only. The areas and sub areas identified reflect approximate, rather than necessarily exact, boundaries. A dotted line represents hypothetical connection, thin lines represent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

Figure 5. New hypothetical stock structure for Southern Hemisphere Humpback whales (from IWC 2004).

6. SC/57 – 2005

SC/57/SH11 (a further report of the intersessional e-mail group) presented an updated table of Southern Hemisphere humpback whale stocks as known prior to the start of SC/57.

Findlay reported on the sources and allocation of records used in compilation of the catch series for assessments of humpback whales carried out in previous meetings. This catch series, is now referred to as the "KF" series. An alternative catch series provided by the IWC (referred to as the "CA" series) was introduced and is used from here onwards.

SC/57/SH6 reviewed catches of humpback whales in the Southern Ocean during the period following World War II, with an emphasis on Areas IV, V and VI (the principal regions of illegal Soviet whaling on this species). The key remaining issue for the catch series is to assign the 1959/60 and 1960/61 catch information to the correct stocks. Currently, they have been allocated based on the proportion of the reported catches. It was noted that when these catches were correctly allocated and models were re-run, that the Fringe and Overlap models be run as well as the Naïve model, since the boundaries of the feeding stocks remain imprecise (IWC, 1998).

A working group was formed to discuss future steps to resolve and use catch history records for the Comprehensive Assessment and to define longitudinal borders of feeding stocks.

This Group believed that only the A/G border required modification. Two scenarios were suggested. The first apportions all catches to the west of 50°W and south of 60°S to breeding stock G, while the second apportions all catches to the west of 50°W and south of 50°S to G (see Figure 6). While the apportioning of the Falkland Island catches to G in the second option may be incorrect, these small catches are in some years included with the South Shetland and Chilean mainland catches. While the original "Fringe model" (IWC, 1998) included the 70°W - 60°W band as a fringe area (*KPF comment – it actually omitted this band in the definition of fringe areas*), it was decided that the 100°W - 70°W core area be extended eastward to 50°W under the two scenarios presented above.

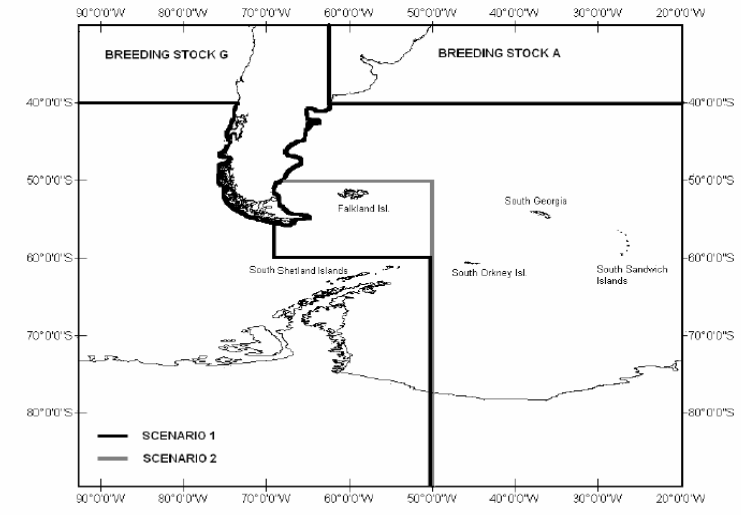

Fig. 1. Proposed delineation of feeding areas associated with breeding stocks G and A. Two scenarios are suggested. The first apportions all catches to the west of 50°W and south of 60°S to breeding stock G, while the second apportions all catches west of 50°W and south of 50°S to G.

Figure 6. Proposed delineation of feeding areas associated with breeding stocks A and G (IWC, 2005).

- There was discussion about Figure 1 in Annex H of IWC (2005, p. 236 reproduced as Figure 5), which appeared to present a new feeding ground at approximately 55°E, and whether this needed to be considered for the assessment. The sub-committee agreed that no action based on the figure needed to be presented at this time.
- It was suggested that an intersessional workshop would be the best way for scientists holding data on Southern Hemisphere humpback whales to choose the best estimates to use in the assessment.

6. IWC Comprehensive Assessment of Southern Hemisphere Humpback Whales Workshop - Hobart 2006

There was considerable 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.

KPF Comment – It is probable that this discussion may have introduced confusion as to the meaning of newly defined Core and Fringe models (sometimes referred to as the Fringe Minimum and Fringe Maximum), and in particular, confusion between these and the core and fringe areas within the FRINGE models. In the Core model the catches within a core area are used while in the Fringe model, catches from both the Core and Fringe areas are used, leading to further confusion between Core and NAÏVE models.

It is strongly recommended that such confusion be resolved. For example in Stock A below, no discussion is made on the NAÏVE model and it is assumed that the NAÏVE model borders of G would extend from 110 W to 50 W (with inclusion and exclusion of the Falklands Box), while the NAÏVE model borders of A would extend from 50 W (with inclusion and exclusion of the Falklands Box) to 20 W. Alternatively the NAÏVE models require replacing with the new Core and Fringe models.

Stock A

The Workshop agreed 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 - Figure 7 this document).

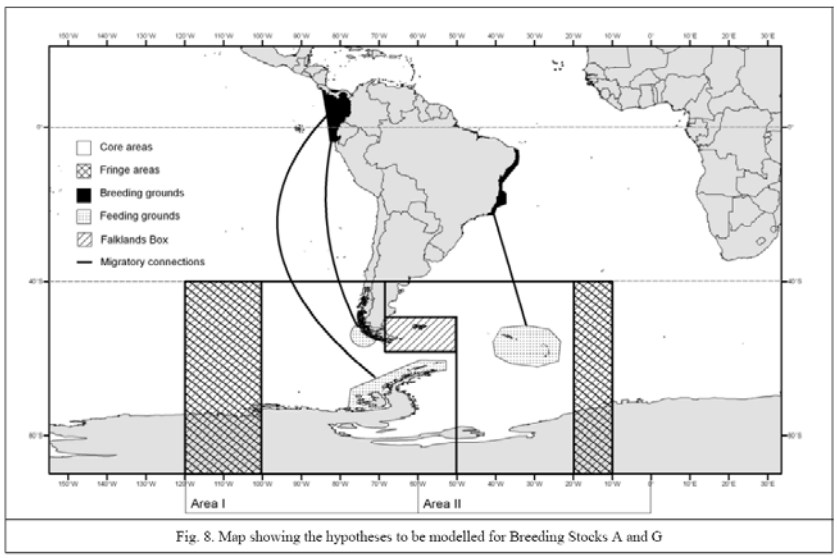

Fig. 8. Map showing the hypotheses to be modelled for Breeding Stocks A and G

Figure 7. Map showing hypotheses to be modelled for Breeding Stocks A and G (IWC 2006 Rep 5).

Stocks B and C

The Workshop agreed that, at the time 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

In relation to the discussion on the location for the core feeding grounds for Breeding Stocks D and E the Discovery mark data support the division between the two stock being moved 10° to the west. The previously agreed boundaries for the core area of the feeding grounds (*KPF comment – within the FRINGE model*) for Breeding Stock D are from between 80°E to 110°E with the fringe set as between 110°E to 130°E. The Workshop agreed that the core area of the feeding grounds for Breeding Stock D should be set at between 80°E and 100°E, with the fringe set as between 100°E to 130°E. The agreed options for boundaries for Breeding Stock D are given in Figure. 8 (*KPF comment which defines the 50 E to 80 E longitude band as a fringe area as well*).

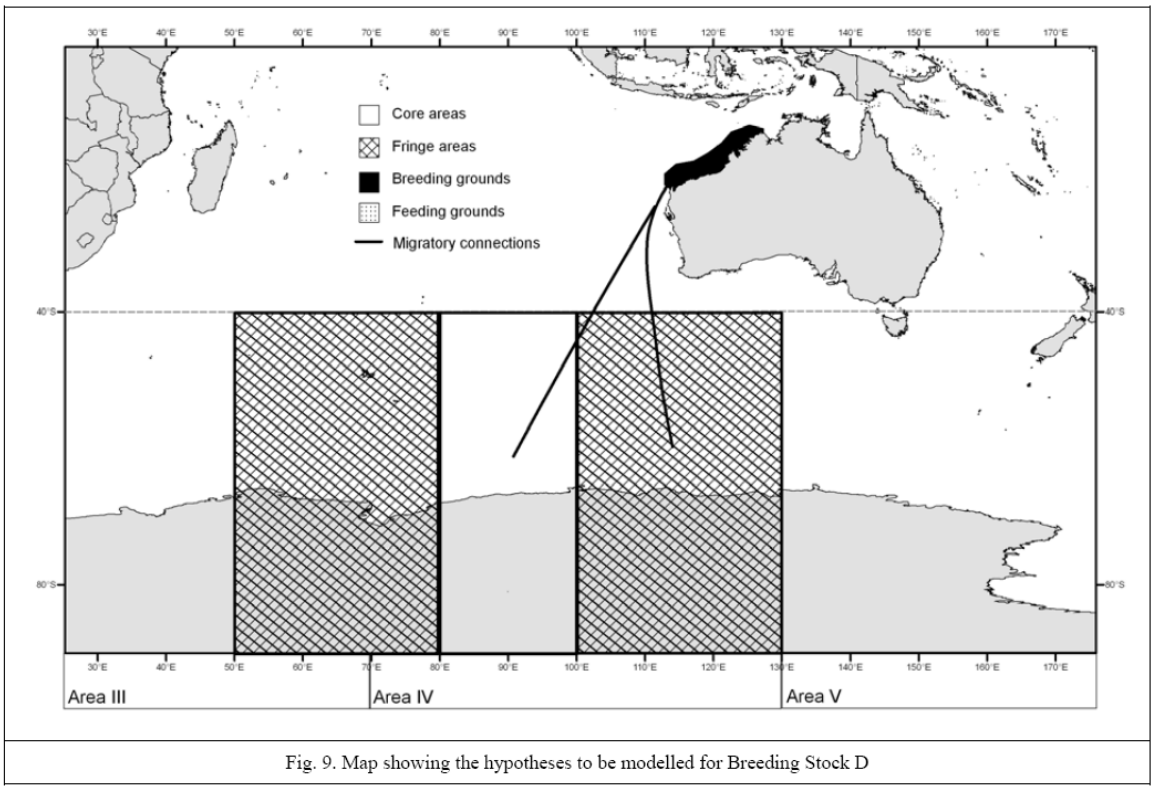

Fig. 9. Map showing the hypotheses to be modelled for Breeding Stock D

Figure 8. Hypotheses to be modelled for Breeding Stock D (IWC 2006 Rep 5).

Stocks E and F

The Workshop agreed that the situation for Breeding Stocks E and F is complex and currently unresolved, and therefore that it was not possible 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 Figure 7.

The Workshop agreed 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.

Conclusion

The Workshop agreed 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 agreed that high priority should be given to consideration of the new catch allocation hypothesis (Item 3.10 - KPF assumes this to be 3.9), - a new catch series should be produced from the IWC database and used in the assessment models.

7. SC/58 – 2006

SC/58/Rep 5 summarized the results of the Hobart Workshop, the overall conclusion of which was that modelling options and possible completion of the Comprehensive Assessment were possible for stocks A, G and D, but that there was insufficient information to resolve conflicting hypotheses and ideas regarding breeding

stocks B, C, E and F. Therefore, the primary focus of intersessional work and of the SH Sub-committee at SC/58 should be on completion of assessments for stocks A, G and D.

Breeding Stock A

Allocation of Catches

For the purpose of the assessment, SC/58/SH2 allocated catches for breeding stock A according to the stock structure hypotheses defined in SC/58/Rep 5 ('Core' and 'Fringe' in Fig. 8, p. 33 – Figure 7 – this document) and also the 'Overlap' hypothesis defined by the IWC (1998, Appendix 4, p. 181). Uncertainty in the origin of whales taken in the Falkland Islands was also considered as suggested by IWC (2005).

Assessment

SC/58/SH2 fitted a deterministic sex- and age-aggregated population dynamics model to modern whaling catch data, absolute estimates of abundance and indices of relative abundance, with the goal of estimating pre-exploitation population size (K), the maximum net recruitment rate (r), the maximum depletion level (N_{min}/K), and other status indices. In addition, sensitivity analyses to various scenarios were conducted (details in SC/58/SH2) including six scenarios including a combination of the distribution of catches as specified.

In discussion, it was noted that while some variation was observed in model outputs depending on the prior or the data used, consistency was observed in almost all scenarios. The catch series had the highest impact on the estimate of K and therefore misallocation of catches or underreporting should cause bias in the estimate of status parameters. It was agreed that new model runs would be conducted including sensitivity analysis to Core and Overlap catch allocation hypotheses.

Breeding Stock G

Allocation of catches

Most of the catches occurred in the Antarctic Peninsula region and there is a relatively straightforward connection from there to Colombia and equatorial western South America (SC/58/Rep 5, p 35). The breeding location for animals feeding at Magellan Strait is unknown, but likely also lies within Breeding Stock G. Catch allocation for the Core hypothesis therefore encompasses the area 50°W-100°W. The Fringe hypothesis area only extends west from the Core (50°W-130°W). These areas are shown SC/58/Rep5, Figure 8 (Figure 7 – this document). There is very little difference in total catch between Core and Fringe areas of Breeding Stock G, making this a relatively unimportant distinction for this breeding stock.

Assessment

SC/58/SH23 presented a Bayesian stock assessment model incorporating updated historic catch series, current abundance and population trend information agreed in SC/58/Rep 5. This sex- and age-aggregated production model was run with both Core and Fringe historic catch area hypotheses, as well as both the SC/A06/HW13 and SC/A06/HW56 recent abundance estimates. It was agreed that new model runs would be conducted using the following data:

(1) Core, Fringe and an OVERLAP catch hypothesis scenario (80% of catches from Naïve area G, plus 10% from Naïve A and Naïve F).

Conclusions

Assessment modelling results for Breeding Stock G proved to be insensitive to the selection of catch allocation hypotheses.

Breeding Stock D

Allocation of catches

During the Hobart workshop, it was agreed that breeding stock D is most closely connected to Area IV, but that there is potential mixing with Areas III and V (SC/58/Rep 5, p 34). On the basis of *Discovery* mark data, the catch allocation areas for Breeding Stock D were re-defined at the workshop as 80°E-100°E (Core) and 50°E-

130°E (Fringe). The bulk of the catches came from breeding areas and there were nearly twice as many in the Fringe as the Core area (SC/58/SH23).

Assessment

SC/58/SH23 presented a Bayesian stock assessment model incorporating updated historic catch series, current abundance and population trend information agreed in SC/58/Rep 5. This sex- and age-aggregated production model considered both Core and Fringe historic catch areas.

Sensitivity analysis was performed on catch history values, the prior specified for *r* and the possibility of depensation. There was little sensitivity detected to historic catch history.

Conclusions

Assessment model results for breeding stock D were sensitive to catch allocation hypotheses and to recent absolute abundance estimates. Furthermore, the sub-committee noted its continuing concern about the potential for exchange with Breeding Stock E on the feeding ground. As noted above, previous models that incorporated mixed stocks on the feeding ground, and using similar data, led to much lower estimates.

8. SC/59 – 2007

No changes to catch allocation areas.

9. SC/60 – 2008

No changes to catch allocation areas.

The revisions that have been carried out in the interim are shown in Table 1. However such revisions do not appear to take into consideration the way the catch data are currently being allocated. This new allocation is best described using two new models, a Core (Fringe minimum) model and a Fringe (Fringe Maximum) model (which are described by the current longitudinal ranges of the FRINGE model in the Table 1 below). The Core model uses only the catches within the core feeding area, while the Fringe model uses all catches bounded by the fringe feeding area.

Table 1. Revisions to original catch allocation areas carried out since 1997.

NAÏVE Model		
Breeding Stock	***Original Longitude Range***	***Current Longitudinal Range***
A	70°W-20°W	50°W-20°W and Falklands Box
B	20°W-l0°E	
C	l0°E-60°E	
D	60°E-120°E	?????
E	120°E-170°W	
F	170°W-110°W	
G	110°W-70°W	110°W-50°W and Falklands Box
FRINGE Model Core Feeding Areas		
Breeding Stock	***Original Longitude Range***	***Current Longitudinal Range***
A	60°W-30°W	50°W-20°W and Falklands Box
B	10°W-l0°E	
C	l0°E-50°E	
D	80°E-110°E	80°E-100°E
E	130°E-170°W	
F	170°W-120°W	
G	100°W-70°W	100°W-50°W and Falklands Box
FRINGE Model Fringe Feeding Areas		
Breeding Stock	***Original Longitude Range***	***Current Longitudinal Range***
A and B	30°W-10°W	20°W-10°W
C and D	50°E-80°E	
D and E	110°E-130°E	100°E-130°E
F and G	120°W-100°W	
G and A	70°W-60°W	Eliminated

4. DISCUSSION AND WAY FORWARD

Although this intersessional working group report will provide a point of departure for clarification, it is strongly recommended that the issues be discussed further within the sub-committee. Two aspects are require addressing, namely the definition of the models in clear unambiguous terms and, the review of the catch allocation areas in relation to new mark return or tag data.

Definitions of the original NAÏVE, FRINGE and OVERLAP models

The largely semantic confusion between the original NAÏVE, FRINGE and OVERLAP models requires some resolution. In particular the core, fringe and overlap definitions within the FRINGE model require clarification. The following clarification is proposed:

In the NAÏVE model the longitudinal boundaries of feeding areas are common between contiguous breeding stocks. For example the feeding area associated with BSB extends from 20°W to 10°E, the feeding area fro BSC extends from 10°E to 60°E, while the feeding area associated with BSD should extend from 60°E to 120°E (although there appears to be confusion with this having been moved to 80E, leaving a gap of 20 degrees (60°E-80°E) from which catches remain unallocated. This confusion may result from the Fringe model core western boundary being set at 80°E.

The FRINGE model has core feeding areas separated by fringe feeding areas. It is strongly recommended that the term overlap areas not be utilised to describe the FRINGE model as it results in confusion with the OVERLAP model.

The catch allocation areas of the OVERLAP model are the same as those for the NAÏVE model, it is the division of catches within the area that differs from the NAÏVE model.

Definitions of the Core and Fringe models

No circumpolar definitions of the Core and Fringe models or the allocation of catch data by area within these two models has been defined. This has lead to NAIVE models being proposed for certain breeding Stocks and Core and Fringe models being proposed for other Breeding Stocks. To date no problems in the assessments of A, G and D and the preliminary assessments of B and C have arisen, apart from the overlap in the NAÏVE model used in C and the Fringe model used in D (50 to 60 E) or the gap of 20 degrees between the NAÏVE model used in C and the Core model used in D (60 to 80 E).

It is strongly recommended that the interrelationship between these models be reviewed.

New data

While many of the original catch allocation area boundaries were set using breeding to feeding area Discovery Mark returns, it is recommended that all tag returns (including natural marking and satellite tags) between the breeding grounds and feeding grounds be reviewed to ensure recent data in the allocation of boundaries. Furthermore, catch allocation area boundaries may benefit from a review of within feeding area and within breeding area movements.

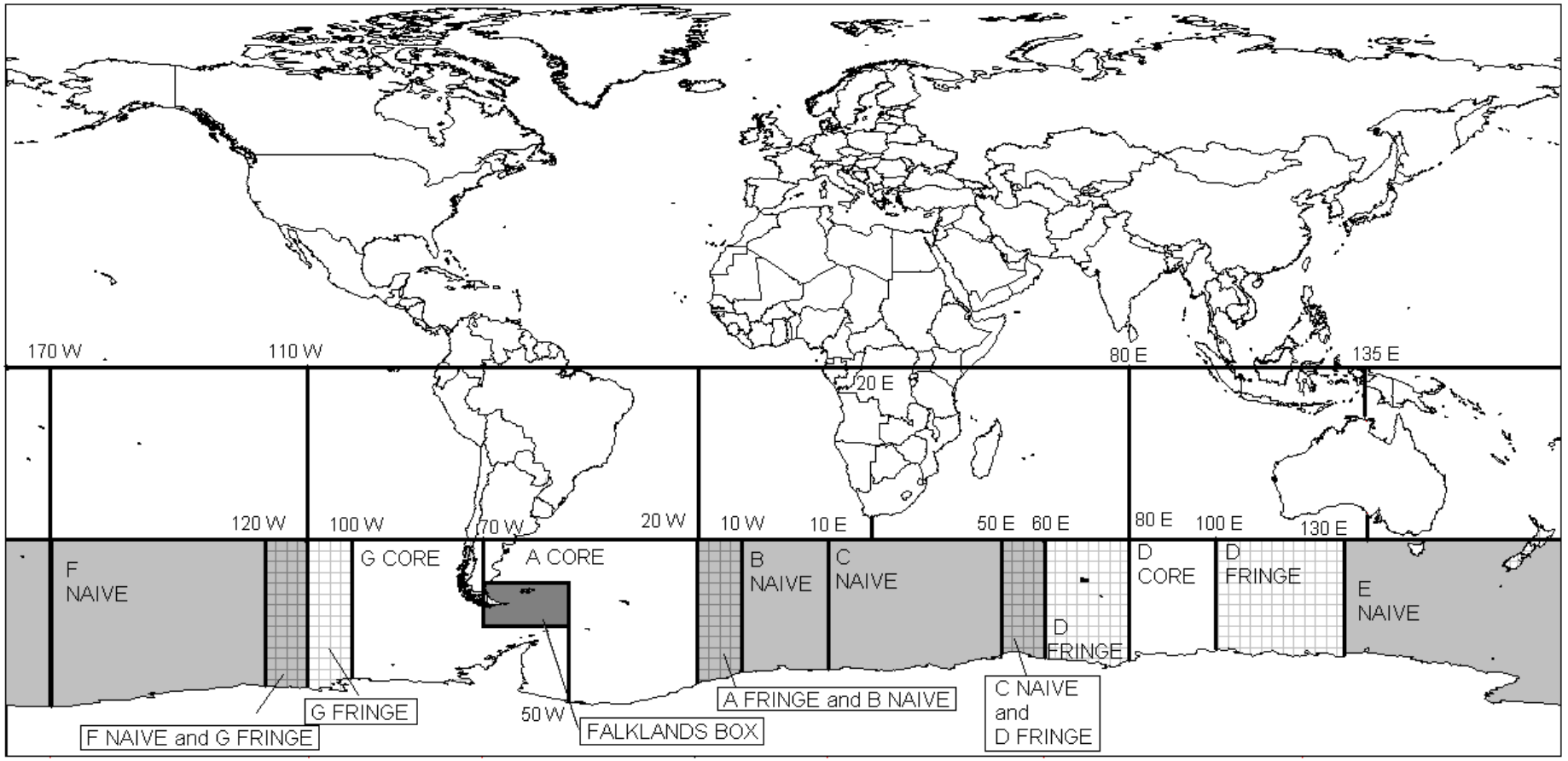

Figure 9. Current interrelationship between Core, Fringe and NAÏVE models. No attempt has been made to provide a similar diagram of Core, Fringe and FRINGE models.

5. LITERATURE CITED

Findlay, K.P., Cunningham, C.L., & Butterworth, D.S. (2000). A first step towards a preliminary assessment of Southern Hemisphere humpback whales. Paper SC/52/IA5 presented to the IWC Scientific Committee, June 2000, Adelaide Australia (unpublished).

International Whaling Commission 2005. Report of the Scientific Committee. Annex H Report of the Sub-Committee on Other Southern Hemisphere Whale Stocks. J. Cetacean Res. Manage, 7 (Suppl.), 235-246.

International Whaling Commission 2006. Report of the Scientific Committee. Annex H Report of the Sub-Committee on Southern Hemisphere Whale Stocks other than Antarctic Minke and Right Whales. J. Cetacean Res. Manage 8.

International Whaling Commission. 1997. Report of the Scientific Committee. Rep. int. Whal. Commn 47:59-258.

International Whaling Commission. 1998. Report of the Scientific Committee. Annex G. Report of the sub-committee on Comprehensive Assessment of Southern Hemisphere humpback whales. Rep. int. Whal. Commn 48:170-82.

International Whaling Commission. 2001. Report of the Scientific Committee. Annex G. Report of the Sub-Committee on the Comprehensive Assessment of Whale Stocks - In-depth Assessments. J. Cetacean Res. Manage. (Suppl.) 3:177-208.

International Whaling Commission. 2004. Report of the Scientific Committee. Annex H. Report of the Sub-Committee on Other Southern Hemisphere Whale Stocks. J. Cetacean Res. Manage. (Suppl.) 6:246-71.

International Whaling Commission. 2006. Report of the Workshop on the Comprehensive Assessment of Southern Hemisphere humpback whales, 4-7 April 2006, Hobart, Tasmania. Paper SC/58/Rep5 presented to the IWC Scientific Committee, May 2006, St. Kitts and Nevis,West Indies (unpublished). 25pp.

International Whaling Commission. 2007. Report of the Scientific Committee. Annex H. Report of the Sub-Committee on Other Southern Hemisphere Whale Stocks. J. Cetacean Res. Manage. (Suppl.) 9:188-209.

Johnston, S.J. and D.S. Butterworth. 2006. Updated assessments of Southern Hemisphere humpback whales from breeding stocks D and G. Paper SC/58/SH23 submitted to the IWC Scientific Committee, 21pp.

Johnston, S.J., Butterworth, D.S. and K.P. Findlay. 2001. Further results from a preliminary assessment of Southern Hemisphere Humpback whales. Paper SC/53/IA20 submitted to the IWC Scientific Committee,

APPENDIX 1 - INITIAL ALTERNATIVE HYPOTHESES FOR THE DISTRIBUTION OF HUMPBACK BREEDING STOCKS ON THE FEEDING GROUNDS (SC/47/ANNEXE G/APPENDIX 4).

I 'Naive' model

Whales from each breeding stock (see Fig. I for definitions of A,B ..) are, without overlap, restricted to fixed feeding areas as follows:

Table 1. Naive model feeding areas.

Breeding Stock	*Longitude range*
A	70°W-20°W
B	20°W-l0°E
C	l0°E-60°E
D	60°E-120°E
E	120°E-170°W
F	170°W-110°W
G	110°W-70°W

II 'Fringe' model

Again there is exact breeding stock -feeding ground correspondence, but only for certain core feeding areas, as in Table 2.

Table 2. Fringe model feeding areas.

Breeding Stock	*Longitude range*
A	6O°W-30°W
B	10°W-10°E
C	l0°E-50°E
D	80°E-110°E
E	130°E-170°W
F	170°W-120°W
G	100°W-70°W

The whales in the 'fringe' areas between these ranges contribute 50-50 to the two nearest breeding stocks (see Table 3).

Table 3. Fringe model overlap areas.

Longitude range	Breeding Stock
30°W-10°W	A and B
50°°E-80°E	C and D
110°E-130°E	D and E
120°W-100°W	F and G

III 'Overlap' model

As for the NAIVE model, but only 80% of the whales in the feeding area corresponding to a breeding stock belong to that stock. The remaining 20% belong 10% each to the nearest stocks to the east and the west. Thus, for example, the whales feeding between 700W-200W belong 80% to A, 10% to G and 10% to B.

Population modelling

1. Catch allocation

Historic catches south of 40^0S are allocated to breeding stocks as per the stock distribution model above under consideration. Catches north of 40^0S are allocated to the associated breeding stock in terms of the NAIVE model correspondence.

2. Abundance estimates

IDCR abundance estimates are' allocated' to breeding stocks in the same manner as indicated under hypothesis I-III above.

APPENDIX II - ALLOCATION OF CATCHES IN COMPILING THE KF CATCH SERIES USED UNTIL 2006.

A catch series of modern whaling catches of humpback whales in the Southern Hemisphere was compiled from the IWC held databases, including the Bureau of International Whaling Statistics (BIWS) database, catch records from the Olympic Challenger and catch records from the Soviet fleet between 1948/49 and 1972/73. No attempt was made to include any open-boat whaling catches of humpback whales in this catch series.

Modern whaling catches of humpback whales in the Southern Hemisphere can be grouped by their origin into a number of regions or eras.

Antarctic pre-1930 land station and floating factory catches, including catches from the Falkland Islands, the Kerguelen Islands, South Georgia, South Sandwich Islands, South Shetland Islands, the Area of West Antarctica and the South Orkney islands. Prior to the 1914/15 seasons there are a number of catches which are recorded as unspecified rather than to species. These have been apportioned to species on a pro-rata basis of catches of known species at that locality in that season. In cases where the total season catch for the locality was unspecified the catch has been allocated to species on a pro-rata basis of the preceding and following season's catches at the locality. Unspecified catches from the South Shetland Islands in 1907/08 season were ignored as many of these records were from the Chilean and Patagonian coasts.

Low - latitude land station and floating factory catches including catches from Brazil, the African coast (including the Cape grounds, Luderitz and Walvis Bay, Angola (Portuguese West Africa), Gabon (French Congo), the Natal whaling grounds, Mozambique (Portuguese East Africa) and Madagascar), Australian West Coast and East Coasts, New Zealand, Tonga, Chile (including all catches north of Cape Horn) and Peru. As with early Antarctic land station and floating factory catches, unspecified catches were apportioned to species on a pro-rata basis of specified catches from the preceding and following years. Catches of 130 unspecified whales in the Magellan Straits in the 1905/06 season were ignored as no humpbacks were recorded in the catches from the region the following year. BIWS catch records for the period 1908 to 1930 from the coast of southern Africa (Mozambique to the Congo) were supplemented by the catch series presented for this region by Best (1994).

Antarctic pelagic catches reported to the BIWS (excluding Soviet and Olympic Challenger catches and including the early catches made in the Ross Sea).

Low latitude pelagic catches made off the Congo, Chile, Peru, West Australia and Madagascar. Considerable care was taken to ensure that these catches were not included in the low latitude land station and floating factory catches.

The Soviet Union operated four pelagic whaling fleets between 1946/47 and 1986/1987. The *Slava* fleet commenced in the 1946/47 season and operated until the 1965/66 season, the *Sovetskaya Ukrania* fleet operated between the 1959/60 and 1986/87 seasons, the *Yurii Dolgurukiy* fleet operated between the 1960/61 and 1974/75 seasons, while the *Sovetskaya Rossia* fleet operated between the1961/62 and 1979/80 seasons. Catches of humpback whales reported to the BIWS (in terms of Article VII of the International Convention for the Regulation of Whaling, 1946) were unreliable for the period 1948/49 to 1971/72 (Yablokov 1994) and reported and true catches were presented by Zemsky et al (1997) (Rep. int. Whal. Commn 47 pp 151). Catch positions are known for only a portion of the *Slava, Sovetskaya Rossia* and *Sovetskaya Ukrania* fleet catches. Daily (noon) catch positions submitted to the IWC showed the total catch series to include catches from north of the equator in the Indian Ocean, and from north of 40° S in other areas. Known Northern Hemisphere catches were removed from the *Slava* and *Sovetskaya Ukrania* fleet catches as there were no Northern Hemisphere catches recorded for the other two vessels. Total catches for the *Slava, Sovetskaya Ukrania* and *Sovetskaya Rossia* fleets were thereafter apportioned to IWC Areas I to VI on a pro-rata basis of known catch positions. Such pro-rated catches were then further apportioned to north or south of 40° S on the basis of known catch positions for each vessel to the north and south of 40° S. It should be noted that catches of known position to the north of 40° S amounted to less than 3% of all of the catches of known position. Catch positions of the *Yurii Dolgurukiy* fleet were known by latitude and IWC Areas and were allocated accordingly.

The *Olympic Challenger* whaling fleet operated in the Southern Ocean and off Peru, Chile and Ecuador between the 1950/51 and 1955/56 seasons (excluding the 1953/54 season), and major discrepancies exist between the catch records submitted to the BIWS and the true catch data (Barthelmess et al. 1997). Daily (noon) catch position records submitted to the IWC (Karl-Hermann Kock, in litt.) were used in the compilation of these catch

series. Where no daily catch position was recorded, the position used was approximated from the preceding and following recorded noon position.

Allocation of Catches to Breeding and Feeding Stocks

All catches to the north of 40° S were allocated to breeding stocks while all catches to the south of 40° S were allocated to feeding stocks, apart from catches from the coast of Chile which were allocated to breeding stock G regardless of the latitude at which they were made, and land based catches from New Zealand which were allocated to breeding stock E.

Breeding Stocks

Catches were allocated to breeding stocks as follows

A - Land and floating factory catches from Brazil, Soviet catches apportioned to Area II (north of 40° S).

B - Land and floating factory catches from the South African west coast, Luderitz and Walvis Bay, Angola (Portuguese West Africa), and land, floating factory and low latitude pelagic catches from Gabon (French Congo), 30/80 of Soviet catches apportioned to Area III (north of 40° S).

C -Land and floating factory catches from Durban, Mozambique (Portuguese East Africa) and land, floating factory and low latitude pelagic catches from Madagascar, 50/80 of Soviet catches apportioned to Area III (north of 40° S).

D - Land, floating factory and low latitude pelagic catches from the Australian West Coast, Soviet catches apportioned to Area IV (north of 40° S).

E - Land and floating factory catches from the Australian East Coast, New Zealand and Tonga, Soviet catches apportioned to Area V (north of 40° S).

F - No low latitude catch data were available for the central Pacific Ocean.

G - Land, floating factory and low latitude pelagic catches from “the west coast of South America”, Chile and Peru and the Olympic Challenger catches of 1954 from the west coast of South America.

A total of five individuals taken in the central Indian Ocean by the Soviet fleet were divided between breeding stocks C and D.

Feeding stocks

Catches were allocated to feeding stocks under the three different models.

Naïve model

Catches are allocated to seven feeding areas by year, each of which correspond to a single breeding stock

70° W - 20° W : the 70° W - 20° W BIWS catches, Soviet catches apportioned to Area II (south of 40° S), land station catches for the Falkland Islands, South Georgia, South Sandwich Islands, South Shetland Islands, the Area of West Antarctica and the South Orkney Islands, and the Olympic Challenger catches for 70° W - 20° W.

20° W - 10° E : the 20° W - 10° E BIWS catches, 30/80 of the Soviet catches apportioned to Area III (south of 40° S), and the Olympic Challenger catches for 20° W - 10° E.

10° E - 60° E : the 10° E - 60° E BIWS catches, 50/80 of the Soviet catches apportioned to Area III (south of 40° S), and the Olympic Challenger catches for 10° E - 60° E.

60° E - 120° E : the 60° E - 120° E BIWS catches, Soviet catches apportioned to Area IV (south of 40° S), early Kerguelen Island catches, and the Olympic Challenger catches for 60° E - 120° E.

120° E - 170° W : the 120° E - 170° W BIWS catches, Soviet catches apportioned to Area V (south of 40° S), the early Ross Sea catches, and the Olympic Challenger catches for 120° E - 170° W

170° W - 110° W : the 170° W - 110° W BIWS catches, Soviet catches apportioned to Area VI (south of 40° S), and the Olympic Challenger catches for 170° W - 110° W.

110° W - 70° W : the 110° W - 70° W BIWS catches, Soviet catches apportioned to Area I (south of 40° S).

Fringe model

Catches were allocated to core feeding areas (from Table 2, Appendix I) and fringe areas between feeding grounds (Table 3, Appendix I). A further fringe area was defined between 70 W and 60 W. Allocations to the core feeding areas were as follows

60° W - 30° W : the 60° W - 30° W BIWS catches, 30/50 of the Soviet catches apportioned to Area II (south of 40° S), land station catches for the Falkland Islands, South Georgia, the South Sandwich Islands, and the South Orkney Islands and the Olympic Challenger catches for 60° W - 30° W.

10° W - 10° E : the 60° W - 30° W BIWS catches, 20/80 of the Soviet catches apportioned to Area III (south of 40° S) and the Olympic Challenger catches for 60° W - 30° W.

10° E - 50° E : the 10° E - 50° E BIWS catches, 40/80 of the Soviet catches apportioned to Area III (south of 40° S) and the Olympic Challenger catches for 10° E - 50°.

80° E - 110° E : the 80° E - 110° E BIWS catches, 30/60 of the Soviet catches apportioned to Area IV (south of 40° S) and the Olympic Challenger catches for 80° E - 110° E.

130° E - 170° W : the 80° E - 110° E BIWS catches, 40/50 of the Soviet catches apportioned to Area V (south of 40° S), early Ross Sea catches and the Olympic Challenger catches for 80° E - 110° E.

170° W - 120° W : the 170° W - 120° W BIWS catches, 50/60 of the Soviet catches apportioned to Area VI (south of 40° S) and the Olympic Challenger catches for and the Olympic Challenger catches for 170° W - 120°W.

100° W - 70° W : the 100° W - 70° W BIWS catches and 30/40 of the Soviet catches apportioned to Area I (south of 40° S).

Catch allocations to the fringe areas between the core feeding areas were as follows

30° W - 10° W: the 30° W - 10° W BIWS catches, 10/50 of the Soviet catches apportioned to Area II (south of 40° S), 10/80 of the Soviet catches apportioned to Area III (south of 40° S), and the Olympic Challenger catches for 30° W - 10° W.

50° E - 80° E: the 50° E - 80° E BIWS catches, 0/80 of the Soviet catches apportioned to Area III (south of 40° S), 20/60 of the Soviet catches apportioned to Area IV (south of 40° S), and the Olympic Challenger catches for 50° E - 80° E.

110° E - 130° E: the 110° E - 130° E BIWS catches, 10/60 of the Soviet catches apportioned to Area IV (south of 40° S), 10/50 of the Soviet catches apportioned to Area V (south of 40° S), and the Olympic Challenger catches for 110° E - 130° E.

120° W - 100° W: the120° W - 100° W BIWS catches, 10/60 of the Soviet catches apportioned to Area VI (south of 40° S), 10/40 of the Soviet catches apportioned to Area I (south of 40° S).

70° W - 60°W (Area not defined in Table 3 of Appendix I) : the 70° W - 60° W BIWS catches, 10/50 of the Soviet catches apportioned to Area II (south of 40° S) and the Olympic Challenger catches for 70° W - 60° W.

Overlap model

The overlap model was as for the Naïve model except that only 80% of the whales in the feeding area correspond to the associated breeding area. The remaining 20% belong 10% each to the nearest stocks to the east and west.

APPENDIX III _ REVIEW OF THE ALTERATIONS TO THE CATCH ALLOCATION MODELS (2000 – 2008)

5.1. 2000 - SC/52 Meeting

A first step towards an assessment of Southern Hemisphere humpback whales was presented in SC/52/IA5 in 2000. The sub-committee noted that SC/52/IA5 focused attention on what information and additional work was necessary for a fuller assessment. Discussions centred on what revisions of the analysis of SC/52/IA5 might be carried out in future, and the sub-committee suggested that any re-runs of the model of SC/52/IA5 should include the following changes:

- the boundary between feeding grounds for G and A stocks should be moved some 10-15° to the east;
- stock E should be split into three sub-populations (Eastern Australia, New Caledonia and Tonga),
- stock B should be split into two sub-stocks (Gabon and Angola),
- stock C should be split into three sub-stocks (Mozambique, Comoros and Madagascar), and
- stock F should be split into two or three sub-stocks (Cook Islands, French Polynesia and possibly Easter Island).

New runs assuming a single circumpolar stock were not considered useful. Stock-specific runs would not be possible for stocks B and F because no suitable abundance estimates are available. Decisions on the most appropriate sub-division of stocks need to be addressed in order to use the new information on stock structure and catch in runs of the model of SC/52/IA5. A Working Group was set up to address this issue before the meeting in 2001.

5.2. 2001 - SC/53 Meeting

SC/53/IA20 presented in 2001 included slight changes to the catch series:

(1) New catch data included for breeding stocks D and E for the period 1912-1915.

(2) The borders for Areas A and G feeding areas shifted 10° from 70°W to 60°W as requested at the 2000 meeting of the Scientific Committee.

A working group report (Appendix 13) evaluating the progress made to the Southern Hemisphere humpback stock assessments (with respect to suggested work raised at the 2000 Scientific Committee meeting) noted that work that was requested at SC/52 but not yet achieved included:

(1) Alternate divisions between stocks – no suggestions put forward.

(5) Breeding stock E should be spilt into three sub-populations: should try to split the feeding ground catches using Chittleborough and Dawbin's marking data; Soviet catch data; and information from SC/53/IA18. Individual abundance estimates are available for each sub-population. At a later stage, given appropriate genetic information, such modelling might be extended to take into account possible dispersal between such breeding grounds (breeding stocks B and C might offer similar possibilities).

(8) Linked models i.e. links between feeding and breeding grounds using age-aggregated production models might be an extension of what has been achieved.

(9) Use the IWC/IDCR SOWER data to obtain estimates of humpback estimates of abundance, and investigate its utility for providing information on stock distribution on the feeding grounds.

5.3. 2002 - SC/54 Meeting

The SC/54 sub-committee proposed that an intersessional working group summarize current knowledge regarding Southern Hemisphere humpback whales, by population or management area; identify major gaps in knowledge; and establish priorities for research to fill these gaps.

5.4. 2003 - SC/55 Meeting

The report of the intersessional working group on Southern Hemisphere humpback whales was presented at SC/55. It was noted that some further subdivision of certain breeding stocks were suggested, notably the F ground may require subdivision into two elements (Cooks Islands and French Polyesnia). Breeding grounds were reasonably well known for most groups except for the F ground. Migrations routes were quite well known for four groups (B, C, D and E(i)), while feeding grounds were well-defined for only one group (D, eastern Indian Ocean) and either poorly defined or not defined at all for the remainder. There were moderately good estimates of abundance for four groups (A, C, D and E(ii)1), but only poor estimates, or none at all, for the others. Moderately good estimates of trends existed for only the D and E groups, and only poor estimates, or none at all, for the remainder. Most catch histories are more or less complete with the exception of the central Pacific (BS E (ii) 2 – F), where the catch record coverage is generally poor.

5.5. 2004 - SC/56 Meeting

A further report of this intersessional working group on Southern Hemisphere humpback whales was presented at SC/56. The sub-committee recommended that an updated version of the table summarising current knowledge for Southern Hemisphere humpbacks be placed on the IWC website at www.iwcoffice.org. Figure 5 was updated to include the more recent information.

5.6. 2005 - SC/57 Meeting

SC/57/SH11 (a further report of the intersessional e-mail group) presented an updated table of Southern Hemisphere humpback whale stocks as known prior to the start of SC/57.

Findlay reported on the sources and allocation of records used in compilation of the catch series for assessments of humpback whales carried out in previous meetings. This catch series, which was slightly modified for the assessments reported in SC/57/SH15, SC/57/SH16 and SC/57/SH17, is now referred to as the "KF" series. He also introduced an alternative catch series provided by the IWC (referred to as the "CA" series). Differences in these two catch series were ascribed to different sources used in their compilation (see also item 6.7).

SC/57/SH6 reviewed catches of humpback whales in the Southern Ocean during the period following World War II, with an emphasis on Areas IV, V and VI (the principal regions of illegal Soviet whaling on this species). Legal and illegal Soviet catches were summarized by year, area and factory fleet, and information was also given on takes by other nations. Soviet humpback catches between 1947 and 1973 totalled 48,702 and break down as follows: 649 (Area I), 1,412 (Area II), 921 (Area III), 8,779 (Area IV), 22,569 (Area V) and 7,195 (Area VI), with 7,177 catches not assignable to area. The key remaining issue for the catch series is to assign the 1959/60 and 1960/61 catch information presented in SC/57/SH6 to the correct stocks. Currently, they have been allocated based on the proportion of the reported catches. It may be possible at some point in the future to break catches down by longitudinal bands. While the IWC has held the data in Yablakov (1995) for a number of years, only with the considerations contained in SC/57/SH6 and discussions with the original Soviet scientists could the most recent level of detail be obtained. The most important remaining task at this point is to check with Mikhalev to determine whether the 7,177 unassigned catches could be assigned to the correct stocks, but it is doubtful that this is possible. Using the tracklines of the vessels, which exist and were unlikely to have been falsified, may be helpful in his task. It was noted that when these catches were correctly allocated and models were re-run, that the Fringe and Overlap models be run as well as the Naïve model, since the boundaries of the feeding stocks remain imprecise (IWC, 1998). A working group was formed to discuss future steps to resolve and use catch history records for the Comprehensive Assessment and to define longitudinal borders of feeding stocks.

This Group reviewed the delineation of the feeding stocks and in light of the information provided to date believed that only the A/G border required modification. Two scenarios were suggested. The first apportions all catches to the west of 50°W and south of 60°S to breeding stock G, while the second apportions all catches to the west of 50°W and south of 50°S to G (see Figure 5). While the apportioning of the Falkland Island catches to G in the second option may be incorrect, these small catches are in some years included with the South Shetland and Chilean mainland catches. While the original "Fringe model" (IWC, 1998) included the 70°W - 60°W band

as a fringe area (*KPF comment – it actually omitted this band in the definition of fringe areas*), it was decided that the 100°W - 70°W core area be extended eastward to 50°W under the two scenarios presented above.

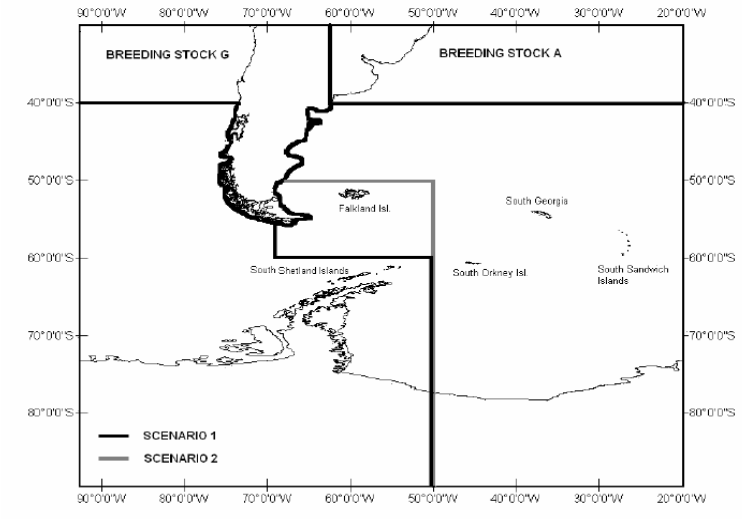

Fig. 1. Proposed delineation of feeding areas associated with breeding stocks G and A. Two scenarios are suggested. The first apportions all catches to the west of 50°W and south of 60°S to breeding stock G, while the second apportions all catches west of 50°W and south of 50°S to G.

Figure 10. Proposed delineation of feeding areas associated with breeding stocks A and G.

There was discussion about Figure 1 in Annex H of IWC (2005, p. 236 reproduced as Figure 5), which appeared to present a new feeding ground at approximately 55°E, and whether this needed to be considered for the assessment. The chair of the sub-committee at SC/56, suggested that the revised figure was presented only to stimulate and generate discussion about possible divisions. It was not intended to be conclusive. The sub-committee agreed that no action based on the figure needed to be presented at this time.

It was suggested that an intersessional workshop would be the best way for scientists holding data on Southern Hemisphere humpback whales to choose the best estimates to use in the assessment.

5.7. IWC Comprehensive Assessment of Southern Hemisphere Humpback Whales Workshop - Hobart 2006

The Workshop 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 and 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;

In the allocation of feeding ground catches to breeding stocks, the workshop noted that 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. 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 'Fringe minimum' and 'Fringe maximum') to provide for suitable examination of the effect of uncertainty in catch allocation on assessments. 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.

KPF comment - there is considerable stock specific information within the review of stock structure, distribution and movements within the Hobart report. It is recommended that the original document be referred to, and only the feeding ground conclusions are presented here.

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 these 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, 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 agreed 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 - Figure 7 this document).

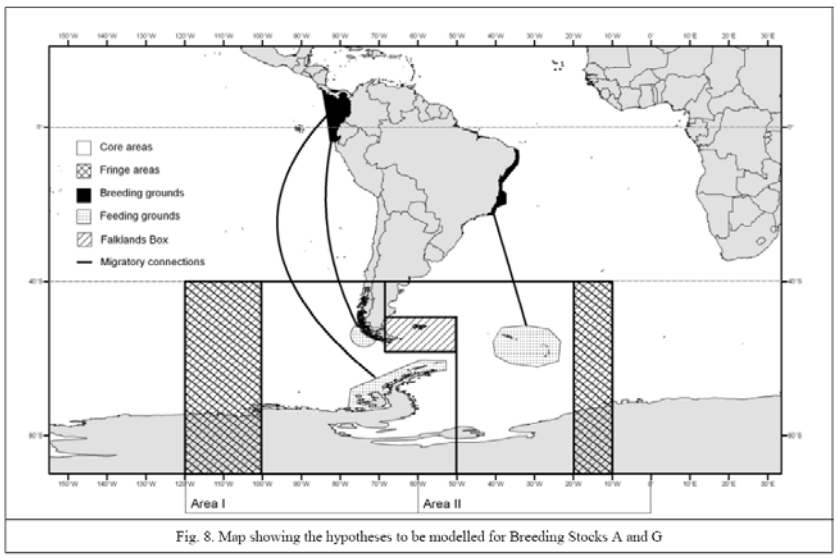

Fig. 8. Map showing the hypotheses to be modelled for Breeding Stocks A and G

Figure 11. Map showing hypotheses to be modeled for Breeding Stocks A and G.

Stocks B and C

The Workshop agreed that, at the time 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 agreed that the available information was 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 stock being moved 10° to the west. 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 fringe set as 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% the recoveries) were recorded moving from Area V into Area IV. 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 fringe set as between 100°E to 130°E. The agreed options for boundaries for Breeding Stock D are given in Figure. 8.

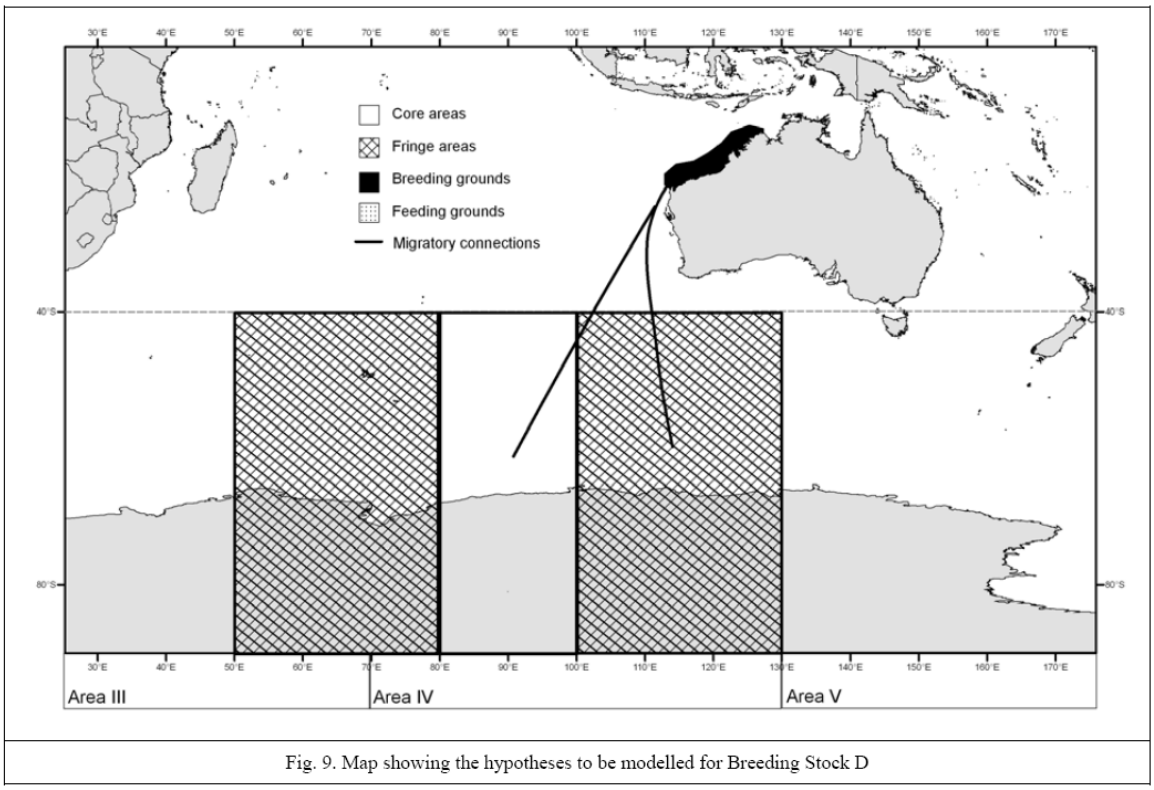

Fig. 9. Map showing the hypotheses to be modelled for Breeding Stock D

Figure 12. Hypotheses to be modeled for Breeding Stock D.

Stocks E and F

The Workshop agreed that the situation for Breeding Stocks E and F is complex and currently unresolved, and therefore that it was not possible 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.

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.

Catch Series

As regards the catch database, SC/A06/HW47 summarised the work of Allison and the Secretariat computing department on 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;

(2) the 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. 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). 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 know some operation: 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 vast falsified catches of the USSR 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 (refs) 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 reasonable reliable (although inevitably the allocated catches were more widespread).

The Workshop also considered SC/A06/HW53 that presented information on humpback whales killed by 19th century open-boat whaling. The Workshop agreed 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.

Conclusion

The Workshop agreed 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 agreed that high priority should be given to consideation of the new catch allocation hypothesis (Item 3.10 - KPF assumes this to be 3.9), - a new catch series should be produced from the IWC database and used in the assessment models.

5.8. 2006 - SC/58

SC/58/Rep 5 summarized the results of the Workshop held at the Australian Antarctic Division in Hobart, Tasmania, between 4 and 7 April 2006. After considering all the data, the overall conclusion of the Workshop was that modelling options and possible completion of the Comprehensive Assessment were possible for stocks A, G and D, but that there was insufficient information to resolve conflicting hypotheses and ideas regarding breeding stocks B, C, E and F. Therefore, the primary focus of intersessional work and of the SH Sub-committee at SC/58 should be on completion of assessments for stocks A, G and D.

Breeding Stock A

Allocation of Catches

As noted in the Hobart Workshop, allocation of catches to breeding stock A is relatively simple because of the straightforward connection with Area II. Details are given in SC/58/Rep 5, p. 33. For the purpose of the assessment, SC/58/SH2 allocated catches for breeding stock A according to the stock structure hypotheses defined in SC/58/Rep 5 ('Core' and 'Fringe' in Fig. 8, p. 33 – Figure 7 – this document) and also the 'Overlap' hypothesis defined by the IWC (1998, Appendix 4, p. 181). Uncertainty in the origin of whales taken in the Falkland Islands was also considered as suggested by IWC (2005).

Assessment

SC/58/SH2 fitted a deterministic sex- and age-aggregated population dynamics model to modern whaling catch data, absolute estimates of abundance and indices of relative abundance, with the goal of estimating pre-

exploitation population size (K), the maximum net recruitment rate (r), the maximum depletion level (N_{min}/K), and other status indices. In addition, sensitivity analyses to various scenarios were conducted (details in SC/58/SH2) including six scenarios using a combination of the distribution of catches as specified.

In discussion, it was noted that while some variation was observed in model outputs depending on the prior or the data used, consistency was observed in almost all scenarios. The catch series had the highest impact on the estimate of K and therefore misallocation of catches or underreporting should cause bias in the estimate of status parameters. It was agreed that new model runs would be conducted including sensitivity analysis to Core and Overlap catch allocation hypotheses.

Breeding Stock G

Allocation of catches

Most of the catches occurred in the Antarctic Peninsula region and there is a relatively straightforward connection from there to Colombia and equatorial western South America (SC/58/Rep 5, p 35). The breeding location for animals feeding at Magellan Strait is unknown, but likely also lies within Breeding Stock G. Catch allocation for the Core hypothesis therefore encompasses the area 50°W-100°W. The Fringe hypothesis area only extends west from the Core (50°W-130°W). These areas are shown SC/58/Rep5, Figure 8 (Figure 7 – this document). There is very little difference in total catch between Core and Fringe areas of Breeding Stock G, making this a relatively unimportant distinction for this breeding stock.

Assessment

SC/58/SH23 presented a Bayesian stock assessment model incorporating updated historic catch series, current abundance and population trend information agreed in SC/58/Rep 5. This sex- and age-aggregated production model was run with both Core and Fringe historic catch area hypotheses, as well as both the SC/A06/HW13 and SC/A06/HW56 recent abundance estimates. It was agreed that new model runs would be conducted using the following data:

(1) Core, Fringe and an overlap catch hypothesis scenario (80% of catches from Naïve area G, plus 10% from Naïve A and Naïve F).

Conclusions

Assessment modelling results for Breeding Stock G proved to be insensitive to the selection of catch allocation hypotheses.

Breeding Stock D

Allocation of catches

During the Hobart workshop, it was agreed that breeding stock D is most closely connected to Area IV, but that there is potential mixing with Areas III and V (SC/58/Rep 5, p 34). On the basis of *Discovery* mark data, the catch allocation areas for Breeding Stock D were re-defined at the workshop as 80°E-100°E (Core) and 50°E-130°E (Fringe). The bulk of the catches came from feeding areas and there were nearly twice as many in the Fringe as the Core area (SC/58/SH23).

Assessment

SC/58/SH23 presented a Bayesian stock assessment model incorporating updated historic catch series, current abundance and population trend information agreed in SC/58/Rep 5. This sex- and age-aggregated production model considered both Core and Fringe historic catch areas.

Sensitivity analysis was performed on catch history values, the prior specified for r and the possibility of depensation. There was little sensitivity detected to historic catch history.

Conclusions

Assessment model results for breeding stock D were sensitive to catch allocation hypotheses and to recent absolute abundance estimates. Furthermore, the sub-committee noted its continuing concern about the potential

for exchange with Breeding Stock E on the feeding ground. As noted above, previous models that incorporated mixed stocks on the feeding ground, and using similar data, led to much lower estimates.

5.9. 2007 - SC/59

The Chair appointed a Working Group to review research requirements to complete the assessment of Southern Hemisphere humpback whale breeding stocks B and C. The terms of reference of this group were:

(1) identify key issues regarding stock structuring;

(2) identify necessary steps towards the provision of revised abundance estimates;

(3) determine other parameters which merit further exploration in the upcoming assessment models; and

(4) identify and prioritise tasks needed and those who could undertake the work for the assessment to be completed by SC/60.

Stock structure in the feeding grounds

SC/59/SH24 provided estimates of the genetic structure of feeding aggregations of humpback whales in the southern ocean using 10 microsatellite loci and mitochondrial control region data. Genetic structuring was explored using Fst and fst scoring both between Management Areas and between the Naïve/Core feeding areas associated with each humpback whale breeding stock (IWC, 1998; 2006). Fst scores did not detect significant differentiation between feeding areas corresponding to breeding stocks B and C, and between areas corresponding to stocks C and D. Lack of genetic structure among the neighbouring feeding grounds associated with breeding stocks B and C and C and D (feeding grounds associated with breeding stocks B and D were significantly different for Fst only) may reflect interchange of breeding stocks on the feeding grounds, as well as poorly understood migratory processes occurring between breeding and feeding stocks across regions. This research is concordant with a recent genetic capture-recapture of a whale between breeding stocks B and C, which suggests that inter-annual migration of animals from one breeding stock to feeding grounds associated with other stocks may be more common than has been detected by demographic analyses. Lack of structuring between feeding grounds associated with breeding stocks C and D is also an interesting result as the potential for mixing between these Indian Ocean stocks has not been previously or sufficiently examined. The genetic evidence suggests this should be an area for closer scrutiny, and clearly has implications for catch allocation, trend estimates, and estimates of abundance from the feeding grounds in the Antarctic.

Additional lines of evidence for breeding stock mixing on feeding grounds were discussed. The sub-committee agreed that boundary allocation for different feeding grounds associated to breeding stocks remains uncertain and a more complete understanding will probably require better knowledge of humpback whale distribution, movements and habitat (e.g. oceanography, sea-ice extent) in high latitudes. Given the availability of genetic data from both breeding and feeding grounds, an alternative genetic approach was suggested; development of a mixed demographic model accounting for the observed genetic proportions of each breeding population in the feeding grounds. The authors of SC/59/SH24 explained that further genetic studies on the connectivity of the Southern Hemisphere breeding and feeding grounds are ongoing and have the potential to better inform as to appropriate historical catch allocation and feeding ground mixing. A study of the degree of connectivity and interchange between these regions is planned, and results will be presented next year provided sufficient funding is secured. The sub-committee was informed of a developing collaboration effort among researchers working on feeding grounds associated with breeding stocks C and D (Rosenbaum and colleagues and the Australian Antarctic Research Program), as interchange between these populations merits further investigation.

Martin reported on recent work conducted in collaboration with the Humpback Whale Institute, Brazil. Photographs of individually identified humpback whale from the South Sandwich Islands (25 individuals) were compared with photographs from Bouvet Island (32 individuals) and from Brazil (2,387 individuals). No matches were obtained between Bouvet and Brazil and between Bouvet and the South Sandwich Islands. However, four whales were matched between the latter and Brazil, confirming previous migratory connections between these two areas (Stevick et al., 2006; Zerbini et al., 2006a). It was noted that no comparison with West Africa has been done at the present time and the sub-committee agreed this should be pursued.

The group also recommended that genetic data from breeding grounds be compared with genetic data from their associated feeding grounds in order to determine levels of stock mixing on feeding grounds.

5.10. 2008- SC/60 Meeting

Stock structure on the feeding grounds and catch allocation

Mitochondrial DNA analyses of southern hemisphere breeding stocks and feeding areas (SC/60/SH11 reported elsewhere in SC/60/Annex H) detected no maternal differentiation between feeding areas associated to BSB and BSC, and between feeding areas associated to BSC and BSD. This may reflect interchange of breeding stocks on the feeding areas, or poorly understood migratory processes occurring between breeding and feeding Stocks across the regions.

The feeding area associated with BSB (20°W – 10°E) showed significant differentiation from breeding sub-stocks B1, C2 and C3, but not from sub-stocks B2 and C1. The feeding area associated with BSC was significantly different from BSA and BSB, but not from BSC. Also, all models found the feeding area associated with BSD to be significantly different from BSB, whereas only the Naïve model revealed significant differentiation between the feeding area associated with BSD and BSC.

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

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

APPENDIX IV - SC/57/SH11 - INTERSESSIONAL WORKING GROUP ON SOUTHERN HEMISPHERE HUMPBACK WHALES: REVISED TABLES BY BREEDING STOCK (AS AT 1 MAY 2005) J. L BANNISTER (CONVENOR).

Feeeding Ground Information

Breeding Stock A

Originally thought to be IWC Management Area II (Weddell Sea)1,2 but satellite tagging now shows probable feeding grounds near South Georgia and South Sandwich Is3.

Breeding Stock B

Suggested as Area IIE and Area III1 Preliminary connection demonstrated by satellite telemetry2

Genetic analysis comparing breeding and feeding for B and C and Areas II and III underway3

Some mixing with C and A being tested

Breeding Stock C

Suggested Antarctic 0-50°E, centred on 10-40°E.

Possible mixing with B stock1

Two mark returns from Area III to South Madagascar2

Genetic analysis linking breeding and feeding for B and C and Areas II and III underway13

Possible connection/ exchange with northern Indian Ocean, but further analyses needed3

Breeding Stock D

Antarctic Area IV, 80-110°E; some mixing with E(i)1

Breeding Stock E

E (i) - Antarctic Areas IV-V, 110°E -?

E (ii) 1 - Antarctic Area V ?-?°E

E (ii) 2 - ?

Breeding Stock F

?

Breeding Stock G

Antarctic Area I, 60-120ºW,

Recommended shift of eastern limit to 58°W.Strait of Magellan possibly Perú and northern Chile

APPENDIX V - SOUTHERN HEMISPHERE HUMPBACK WHALE COMPREHENSIVE ASSESSMENT, HOBART, APRIL 2006: TABLE 1 (SC/57/SH11 REVISED) J. L BANNISTER (CONVENOR).

Feeeding Ground Information

Breeding Stock A

Originally thought to be IWC Management Area II (Weddell Sea) but genetic comparisons, photoidentification matches and satellite tagging now shows feeding grounds near South Georgia and South Sandwich Is

Breeding Stock B

Suggested as Area IIE and Area III

Preliminary connection demonstrated by satellite telemetry

Genetic analysis comparing breeding and feeding for B and C and Areas II and III underway

Some mixing with C and A being tested

Breeding Stock C

Suggested Antarctic 0-50°E, centred on 10-40°E.

Possible mixing with B stock1

Two mark returns from Area III to South Madagascar2

Genetic analysis linking breeding and feeding for B and C and Areas II and III underway13

Possible connection/ exchange with northern Indian Ocean, but further analyses needed3

Breeding Stock D

Antarctic Area IV, 80-110°E; some mixing with E(i)1

Breeding Stock E

E (i) - Antarctic Areas IV-V, 110°E -?

E (ii) 1 - Antarctic Area V ?-?°E

E (ii) 2 - ?

Breeding Stock F

?

Breeding Stock G

Antarctic Area I, 60-120ºW,

Recommended shift of eastern limit to 58°W.

Strait of Magellan possibly Perú and northern Chile