Annex H

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

Members: Jackson (Convenor), Bell (co-Convenor), Baba, Baker, Bannister, Branch, Brownell, Burkhardt, Butterworth, Cipriano, Clapham, Charrassin, Cheeseman, Collins, Cooke, Currey, De la Mare, Diallo, Double, Feindt-Herr, Findlay, Friedlaender, Fortuna, Fujise, Galletti Vernazzani, Garrigue, Genov, Iñíguez Bessega, Hielscher, Holm, Ivashchenko, Jimenez, Johnson, Kato, Kaufman, Kitakado, Lang, Lauriano, Leaper, Lundquist, Mallette, Matsuoka, Minton, McKinlay, Mogoe, Moronuki, Murase, Olson, Palka, Paniego, Pastene, S. Reeves, Reyes, Rodriguez-Fonseca, Rogers, Rosenbaum, Samaran, Siciliano, Sironi, Širović, Stachowitsch, Tamura, Thomas, Torres-Florez, Ulloa, Vermeulen, Wade, Walløe, Williams, Yasokawa, Yoshida, Zerbini.

1. INTRODUCTORY ITEMS

1.1 Opening remarks
Jackson welcomed participants.

1.2 Election of Chair
Jackson and Bell were elected Chair and co-Chair.

1.3 Appointment of Rapporteurs
Clapham, Findlay and Branch undertook the duties of rapporteuring.

1.4 Adoption of agenda
The adopted agenda is given in Appendix 1.

1.5 Documents available
Documents identified as containing information relevant to the sub-committee were: SC/66b/SH01-35, and Herr *et al.* (2016), Attard *et al.* (2016), Galletti Vernazzani *et al*. (2017), Olson *et al.* (2015), Torres and Klinck (2016), Jackson *et al.* (2015), Balcazar *et al.* (2015), Tripovich *et al.* (2015), Leroy *et al.* (2016), and Findlay (In press).

2. SOUTHERN OCEAN RESEARCH PARTNERSHIP

SC/66a/SH10 reports on the activity of the Southern Ocean Research Partnership (SORP) since SC/66a. Progress on the five primary IWC-SORP science programs (SC/66b/SH10 Annex 1-5) is summarised below.

SC/66b/SH10 Annex 1 described progress on the 'Antarctic Blue Whale Project'. The objective of this project is to improve understanding of the status of Antarctic blue whales following exploitation, to investigate the role of these whales in the Antarctic ecosystem, and to measure the circumpolar abundance of Antarctic blue whales and their rate of recovery from whaling. Over the last year, the project cooperated on a voyage to the western Antarctic Peninsula led by Argentina (SC/66b/SH15). Funding has also been secured funding for participation on the Antarctic Circumnavigation Expedition (ACE) voyage due to take place December 2016-March 2017 (SC/66b/SH07). Data from these research voyages are augmented with sightings information from ships of opportunity, which are contributed to the online reporting system[1].

Ongoing analyses of acoustic data from previous voyages continues. Analysis of movements of Antarctic blue whales has also been conducted producing 14 resights across years and 36 resightings within the same season (SC/66b/SH11). Further sub-committee discussion of this catalogue is given under Item 5.2.

SC/66b/SH10 Annex 2 reports on progress on the project to identify the 'Distribution, relative abundance, migration patterns and foraging ecology of three ecotypes of killer whales in the Southern Ocean'. Seven surveys were conducted in 2015/2016, around the west and northern Antarctic Peninsula, and in Terra Nova Bay. This project is of primary relevance to the Sub-committee on Small Cetaceans and their discussion can be found in Annex L.

SC/66b/SH10 Annex 3 summarised progress on the project to determine 'Foraging ecology and predator-prey interactions between baleen whales and krill: a multi-scale comparative study across Antarctic regions'. This project has completed a very successful Antarctic field season, with 196 biopsies collected from humpback whales and five from minke whales, and 21 satellite tags and three video-recording suction cup tags deployed on humpback whales and four limpet tags deployed on Antarctic minke whales. Analyses describing the migratory behaviour and patterns of humpback whales from the west Antarctic Peninsula continue, as do data arising from the multi-sensor video and LIMPET tags deployed. Further sub-committee discussion of this project is given in Annex K1.

SC/66b/SH10 Annex 4 reported progress on the project to 'Determine the distribution and extent of mixing of Southern Hemisphere humpback whale populations around Antarctica'. The primary output was a research voyage to Raoul Island, New Zealand, September-October 2015. During 13 days of fieldwork a cumulative total of 127 pods of humpback whales were encountered, comprising 235 adults and 37 calves. Twenty-four Wildlife Computers SPOT 5 satellite tags were deployed successfully; 18 transmitted for >21 days and one tag is transmitting at the time of this report being written. 85 tissue samples were collected from 78 individual whales. This included 24 tissue biopsy samples from tagged whales. 128 individual whales were photo-identified and 4 hours of song were recorded from 10 song samples throughout the field season. IWC-SORP gratefully acknowledges the South Pacific Whale Research Consortium (SPWRC) for their enormous contribution to this project. Further sub-committee discussion of this project is given in Item 3.1.3.

SC/66b/SH10 annex 5 summarised progress on the project to measure 'Acoustic trends in abundance, distribution, and seasonal presence of Antarctic blue whales and fin whales in the Southern Ocean'. This project represents a coordinated effort to collect new acoustic data using consistent spatial and temporal coverage, including the development of novel,

[1]*http://www.marinemammals.gov.au/sorp/sightings.*

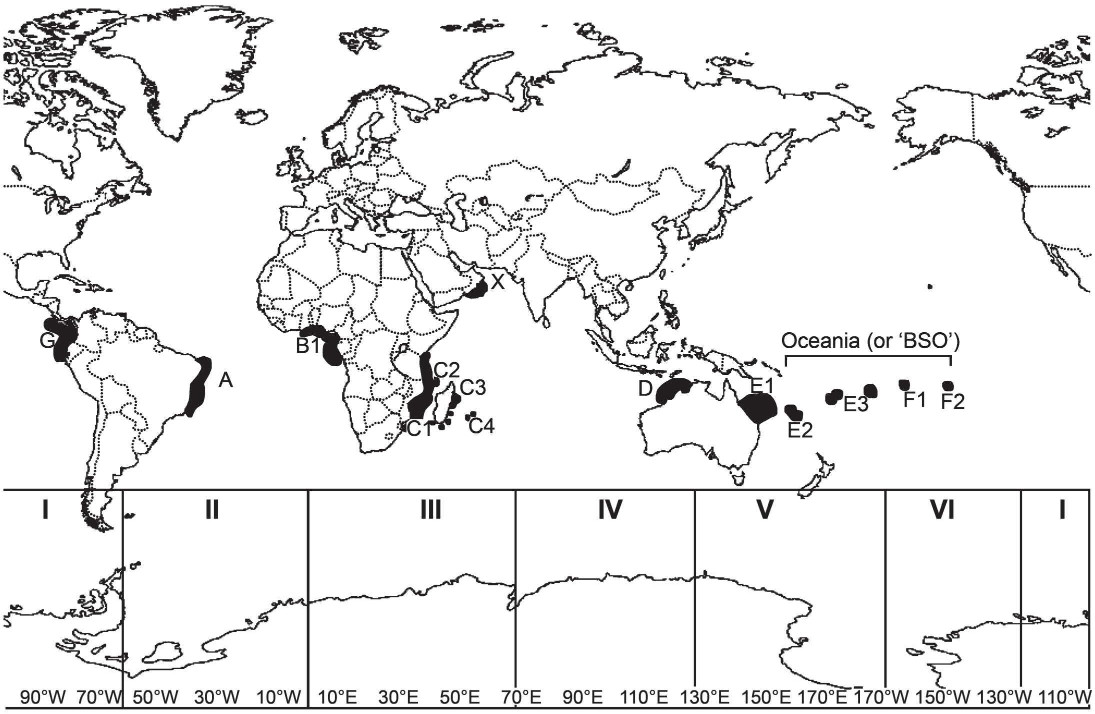

Fig. 1. Southern Hemisphere (A-G) and Northern Indian Ocean humpback whale (X) breeding stocks (black areas) and high latitude Antarctic Areas (I-VI) where substantial modern whaling catches were made.

sophisticated instruments and analytical methods. A focus of the project is the placement and maintenance of a circumpolar Antarctic monitoring system with at least one hydrophone in each of the six IWC *Management Areas*, i.e. implement the Southern Ocean Hydrophone Network (SOHN).

Guidelines and recommendations for instrument choice, hardware configurations and analysis methods to propose how data might be collected and analysed in a uniform manner to best address the specific research questions for both blue and fin whales have been and continue to be developed (e.g. Van Opzeeland *et al.*, 2014). Two (Areas II and IV) of the six IWC *Management Areas* have hydrophones deployed within them, with instruments on the margins of Areas I and III. Area V will be equipped at the end of 2017.

An Aural Autonomous Acoustic Recorder (AAR) was also deployed on the South African Mooring Buoy Array/South Atlantic Meridional Overturning Circulation (SAMOC) off the west coast of South Africa (34°23.6'S; 17°35.7'E) between September 2014 and December 2015. Antarctic blue whale 'D' and 'Z' calls were detected for the first time. Moreover, two instruments were deployed in December 2015 in the region to the west of Cape Town. These will be recovered in December 2016.

The researchers and students involved in project have published or are preparing numerous peer-reviewed papers and/or theses detailed in Annex 5. The upcoming Antarctic Circumnavigation Expedition (ACE) voyage will make a substantial contribution to this project (SC/66b/SH07).

At its 65th annual meeting (IWC/65), the IWC approved a contribution of £13,000 towards the salary of an IWC-SORP coordinator for the period 2014/15 and 2015/16. The contribution of these funds towards the salary of the incumbent coordinator (Dr Elanor Bell) was subsequently approved by the IWC-SORP Scientific Steering Committee. SC/66b/SH09 reports on expenditure against this contribution since 1 July 2014. The contribution was important in sustaining the momentum of IWC-SORP and ensuring the efficient delivery and communication of high calibre scientific research to the Scientific Committee, and leveraging funding and collaborative opportunities. The paper outlined a number of activities undertaken during the funding period. The IWC was thanked for its support.

The sub-committee strongly **commended** the many achievements of the IWC-SORP program. It was **recognised** that IWC-SORP is one of the best examples of collaborative research in the world, particularly in terms of the volume of new scientific information being generated and the new technologies being developed and applied to global cetacean management and conservation issues. The sub-committee therefore strongly **recommended** the continuation of this program.

It was noted in discussion that that the Australian Government has now committed to permanently supporting an IWC-SORP coordinator position, ensuring that IWC-SORP will not request further funding for coordination activities from the Scientific Committee; this in itself is a measure of the success of the Scientific Committee funding provided.

The sub-committee noted the importance of data contributed to IWC-SORP by the South Georgia Heritage Trust, CCAMLR and Happywhale.com, and ships of opportunity. The sub-committee also noted the importance of using ships of opportunity as research platforms. IWC-SORP thanked these contributors and the sub-committee encouraged the development of these collaborations with IWC-SORP and the wider Scientific Committee.

The sub-committee **commended** the researchers involved in IWC-SORP projects and thanked them for their contributions. It was noted that their efforts were key to the overall success of the Partnership, to the work of the IWC, and to the understanding of whales in general. The sub-committee thanked Bell for her coordination of IWC-SORP.

3. SOUTHERN HEMISPHERE HUMPBACK WHALES

The IWC Scientific Committee currently recognises seven humpback whale breeding stocks (BS) in the Southern Hemisphere (labelled A to G; IWC, 1998), which are connected to feeding grounds in the Antarctic. An additional population that does not migrate to the Antarctic is found in the Arabian Sea. An In-Depth Assessment of Southern Hemisphere humpback whales was concluded in 2015, but a few elements of this assessment remain unresolved. The most important outstanding element is the measurement of abundance in west Australia (BSD) which is required to conclude the assessment of this stock. The estimate currently available for BSD is a minimum abundance rather than representing the stock size. Therefore, in 2015 the Committee agreed intersessionally to: (i) continue work on abundance estimation for BSD; and to (ii) construct a prioritisation scheme to assist with developing an IWC Work Plan for strategic humpback whale research in advance of the next In-Depth Assessment of these stocks. These discussions are summarised in Items 3.2 and 3.3.

3.1 Review new information

3.1.1 Breeding Stock A

SC/66b/SH02 noted the paucity of data regarding the presence of humpback whales in the waters of Trindade Island, and its sister islet Martim Vaz, located at latitude 20°S about 1,140km east of Brazil in the Southern Atlantic Ocean; this is likely due to the remoteness of the area combined with the long-term difficulties in logistics. The authors reported 25 sightings of humpback whales around Trindade Island in the winters of 2012 and 2013 based on dedicated sightings both by ship and inflatable boat, and land-based surveys. Eight of the sightings involved mother-calf pairs, four were mother-calf and escort groups, two were groups of two whales and eleven were singletons. Including both new and published data, a total of 54 sightings of humpback whales with confirmed group compositions have been recorded off Trindade Island in recent years, strongly supporting the idea that the island is a destination for humpback whales from Breeding Stock A (BSA) that winter off Brazil. The study that was reported is part of a long-term project which will continue, subject to funding and vessel availability.

SC/66b/SH04 noted that the humpback whale population of the south-western Atlantic Ocean has shown signs of recovery from whaling over the last three decades and was recently down-listed in the official Brazilian Red List. Nevertheless, there is an apparent rise of new threats to the species, including entanglement in fishing gear and skin diseases. The authors reported seven confirmed cases of entanglement of humpback whales in Brazilian waters in 2015, including two juveniles found dead with attached gillnets on the southern coast. They also described a severe case of skin disorder in a live whale photographed in south-eastern Brazil, as well as the results from bacteriological analyses of stranded individuals from southern Brazil; the latter suggest exposure of the whales to untreated sewage in the coastal waters of Brazil. The authors concluded that although these records warrant serious attention, additional investigations are needed to understand if these threats have effects only on individuals or are significant at the population level.

The sub-committee welcomed this new information regarding the offshore distribution of BSA whales and noted that this initiative was part of a long-term project to collect population information on humpback whales off Trindade Island. It was noted in discussion that there was not enough photographic data from the offshore waters around Trindade Island to determine if these skin disorders were restricted to whales in the coastal waters of Brazil, but the authors noted that it would be interesting to do this in the future.

3.1.2 Breeding stock E1

SC/66b/SH21 reported on an eight-week, land-based survey of humpback whales conducted at Point Lookout on the eastern coast of Australia in June and July 2015. This survey was a continuation of the long series of surveys (19 in total) conducted at this site, the results of which form the basis of the relative and absolute abundance estimates of Breeding Stock E1 (BSE1) humpback whales. As with past surveys at this site, the survey was conducted across the peak of the whales' northward migration, over a 53-day period. The average number of whales passing per 10h over the peak four weeks of the northward migration was 160. When assessed in the context of previous surveys, the high long-term rate of population growth was maintained at 11.0% per annum (95% CI 10.6-11.3%). The authors noted that there was no evidence that the rate of population growth is slowing. Using an updated land-based correction factor for groups available but missed in 2004 and the updated rate of population growth, the estimate for 2015 absolute abundance is 24,545 whales (95% CI 21,631-27,851) suggesting that the population is 58-98% recovered. With continued exponential growth, however, it remains to be seen where the population will plateau.

The sub-committee noted that this update provides valuable data on the continued growth in size of the east coast humpback population. It was noted that this estimate of 24,545 whales was above the 95% CI of predicted 2015 abundance from the recent assessment of BSE1 (IWC, 2015), indicating that the population is growing at an even faster rate than was predicted by the assessment models. It was also noted that this estimate is now very close to the estimated BSE1 pre-exploitation abundance (26,133, 95% PI 21,605-29,033) predicted by multi-stock population modelling of BSD/BSE1/Oceania (IWC, 2015); this is difficult to reconcile with the continued rapid growth of BSE1. A revised assessment including this new abundance estimate is therefore likely to change outcomes, and perhaps necessitate a change in the assumptions underlying current models. It was recognised that the observed growth rate required biological parameters (calving interval, age at sexual maturity and survival) to be at extreme values across the population, and that the reported rate was close to the maximum plausible rate of growth for this species (Zerbini *et al.*, 2010). A question was also raised whether diet might positively influence life history traits associated with population growth, as isotope analyses suggest that BSE1 whales are not exclusively krill feeders (Eisenmann *et al.*, 2016). Kaufman stated that the reported high abundance was not consistent with what he had observed, and others had reported anecdotally, at various sites on the coast of eastern Australia, and suggested that double counting was potentially responsible. He suggested that future surveys at this site incorporate a photo-identification component to assess whether individuals were being repeatedly sighted and thus positively biasing the resulting estimates. Other members felt that the survey was well structured and that the reported numbers were likely reliable, noting that 'doubling back' behaviour could not account for the observed rate of increase unless this behaviour itself was increasing in frequency at a similar rate.

3.1.3 Breeding stock E2/E3/F

SC/66b/SH03 summarised boat-based observations of humpback whales collected between 1995 and 2015 (n=1,526) from two New Caledonia breeding grounds with very dissimilar environmental conditions: a large coastal reef complex (the South Lagoon) and an off-shore area of seamounts (the 'Southern Seamounts'). The research was intended to explore social segregation patterns in these two connected breeding grounds. Generalized Additive Models were applied to describe habitat relationships and Permissive Home Range Estimation was used to explicitly model spatial segregation resulting from these habitat preferences. In the South Lagoon, the number of groups with calves increased throughout the season and these groups always preferred shallow waters close to the coast. In contrast, no habitat segregation was observed between groups with and without calves in the Southern Seamounts. The proportion of groups with calves appeared higher in the Southern Seamounts (27%) than in the South Lagoon (16%). Examination of photographs of the degree of unfurling of dorsal fins in calves (a rough indicator of age) from both areas suggests that females with older calves are more likely to move to offshore, highly frequented areas. However, the lack of difference in scarring and shark bites between the two sites suggests that calves observed in the South Lagoon and the Southern Seamounts might belong to a single population moving between off-shore and coastal waters south of the New Caledonia mainland.

In response to a question regarding residency times in the two areas, the authors responded that they were not able to spend enough time on the seamounts to establish occupancy of individual whales there. The authors noted that seamounts appeared to be used for a variety of purposes, including reproduction, as a navigational marker and possibly for feeding, and highlighted plans to continue the work on these and possibly other seamounts, including acoustic monitoring. The sub-committee noted that understanding how humpbacks use these waters is useful for understanding distribution and timings of use by different demographic groups.

SC/66b/SH05 reported the results of a study to investigate the feeding grounds of humpbacks breeding in Oceania, through a research cruise to the Kermadec Islands in late September to mid-October 2015. The cruise deployed 25 satellite tags, collected 84 tissue samples for genetic analysis and photo-identified 124 individual whales. Eighteen tags transmitted for longer than 21 days and one tag continues to transmit over seven months post deployment; one tagged individual is estimated to have travelled approximately 8,600km between breeding and feeding areas. Preliminary data analysis found that whales migrating south past the Kermadecs originate from five different breeding grounds spanning ~3,600km of Oceania between New Caledonia and the Cook Islands. There were four genotype matches (including two tagged whales originally identified in Tonga from 2003 and 2005) and 13 photo-identification matches. To date there are no matches to mainland New Zealand (primarily whales on the northern migration) or east Australia. Once past the Kermadecs, the humpbacks stopped on feeding grounds spanning ~3,500km of the Southern Ocean between west of the Ross Sea region to the Bellingshausen Sea. While data analysis is incomplete, the results clearly demonstrate that Oceania humpback whales have feeding grounds spanning IWC Areas V, VI and I.

The authors were congratulated on this successful project and the significant new information obtained on migratory linkages within the Oceania region. This new report adds to a series of recent studies suggesting humpback whales in Oceania feed across a broad swathe of the Southern Ocean (Antarctic Areas IV to I, 70°E-120°W), and that at least one whale travelled east of the area used for catch allocation in the last assessment (IWC, 2015). In response to a question regarding why the photo-identification data from this study were not compared to other existing catalogues, the author commented that this was a preliminary comparison and that the catalogue from this project will shortly be curated with IWC-SORP and made available for additional matching by others. The sub-committee commented that it was interesting that most of the tagged whales avoided New Zealand despite this being an extension of the Kermadec Trench feature. It was noted that the breeding ground origin of the tagged whales was unknown so they may potentially have originated from multiple breeding areas.

3.1.4 Breeding stock G

It was noted that a one-day workshop has been proposed to bring together researchers from South America to discuss standardisation and integration of photo-identification catalogues for blue and humpback whales (see discussion in Item 5.3.1); this is an item of importance to assist with the assessment of Chilean blue whales because combining photo-identification catalogues is likely to improve regional abundance estimates. Similarly, the combination of photo-identification catalogues among humpback whale researchers in the region has led to identification of many migratory linkages (Acevedo *et al.*, In press); combining these catalogues into a single reconciled sightings database may have potential to enable a region-wide mark recapture analysis of abundance and movements within BSG. This workshop could be scheduled to happen just before the Latin American Marine Mammal meeting in November 2016 so that many regional participants could attend. This initiative would have funding implications for the Scientific Committee. The sub-committee **recommended** the development of this initiative.

3.1.5 Feeding grounds

SC/66b/SH06 reported on a project involving building and operating a web-based, marine mammal, photo-identification, crowd-sourcing platform named *Happywhale.com*. In the pilot season, the project processed in excess of 30,000 images contributed by citizen scientists, documenting 1,912 sightings containing 23 cetacean species. Individual identification efforts were focused on humpback whales, documenting 616 individuals, 126 of which were matched to existing catalogues in the northeastern North Pacific and off the Antarctic Peninsula. The project has developed automated and semi-automated image management systems and quality control standards to generate a dataset from publicly sourced images open for collaborative scientific use. The pilot season showed strong potential to effectively document marine mammal populations in areas such as the Antarctic and high Arctic frequented by wildlife tour vessels but where research cruises are limited, and to document populations, associations and movements at very high resolution in coastal areas with whale watching tour industries. Feedback to contributors has been a major feature of this project, which has often resulted in increased enthusiasm and improved data quality and quantity for subsequent submissions.

In discussion, the authors noted that working within the International Association of Antarctic Tour Operators (IAATO) has been central to the outreach effort in this project, and that this had resulted in numerous submissions of photographs and data. The project fits well with IAATO's desire to increase citizen science involvement, and is now included in the IAATO Field Operations Manual. The sub-committee **recognised** the potential value of this work, especially in terms of increasing information from platforms of opportunity in areas which typically have low directed research effort. It was noted that both Happywhale.com and IWC-SORP represented data repositories and conduits rather than catalogues. The sub-committee **recommended** further intersessional discussion to clarify relationships between these efforts and existing catalogues, and the role that they might play within the context of the IWC's use of photo-identification data generally (see Annex V).

SC/66b/SH24 reported on the Antarctic Humpback Whale Catalogue, which has been maintained (with funding from the IWC) by the College of the Atlantic since 1987. In 1998 the IWC approved funding to support the expansion of this catalogue to members of the IWC, with an aim to substantially improve the accessibility and organisation of the database. The collection has been internationally collaborative from its inception, with photographic contributions from 386 researchers and opportunistic sources. During the contract period, the Antarctic Humpback Whale Catalogue catalogued 863 photo-identification images representing 686 individual humpback whales from Antarctic and Southern Hemisphere waters, a growth of more than 27% over the previous year. These newly catalogued images were submitted by 62 individuals and research organisations. Photographic comparison of submitted photographs to the Antarctic Humpback Whale Catalogue during the contract period yielded 130 previously known individuals. These submissions bring the total number of catalogued whales identified by fluke, right dorsal fin/flank and left dorsal fin/flank photographs to 6,970, 414 and 408 respectively. Notable matches included: the first re-sighting between breeding group A and breeding group C; the first long-distance re-sighting of an individual between Brazil and 53°33'S; 41°37'W; many matches between the Antarctic Peninsula and Costa Rica, and sightings of five individuals from the Antarctic Peninsula to Panama; the movement of an individual between the west Antarctic Peninsula and South Orkney, helping to define the limits of that feeding aggregation.

In discussion, the sub-committee noted the importance of this long-term catalogue for collecting images from the Antarctic and lower latitudes. The value of the legacy and baseline data provided by this catalogue was recognised and the substantial body of work and understanding it has generated. The sub-committee noted the recent conclusion of the in-depth assessment of humpback whales and noted that while the Antarctic humpback whale catalogue has been a valuable and long-supported resource for IWC work, the research questions it can help to address for future IWC work need to be discussed and clarified. The sub-committee noted the value of periodically reviewing the utility of long-term projects and catalogues to ensure that they continue to provide new information with which to address questions important to the Scientific Committee. Continuation of the Antarctic Humpback Whale Catalogue has financial implications for the Scientific Committee (see Item 10.1). It was suggested that future funding be more strategically framed in terms of the specific scientific questions that this work can help to address and which geographic regions are highest priority for photo-identification matching for this sub-committee. An intersessional email group was convened under Zerbini and Olson to facilitate this (see Annex V).

Herr *et al*. (2016) provided evidence for horizontal niche partitioning between humpback and fin whales off the west Antarctic Peninsula. A dedicated aerial cetacean survey was conducted concurrent with a standardised net trawl survey for krill in order to investigate the relationships between the distribution patterns of large whales and different krill species. Distance sampling data were used to produce density surface models for humpback and fin whales. Abundance for both species was estimated over two strata in the Bransfield Strait and Drake Passage. Distinct distribution patterns suggest horizontal niche partitioning of the two whale species around the west Antarctic Peninsula, with fin whales aggregating at the shelf edge of the South Shetland Islands in the Drake Passage and humpback whales in the Bransfield Strait. Krill biomass estimated from the concurrent krill survey was used along with CTD data from the same expedition, bathymetric parameters and satellite data on chlorophyll-a and ice concentration to model krill distribution. Comparisons of the predicted distributions of both whale species with the predicted distributions of *Euphausia superba*, *E. crystallorophias* and *Thysanoessa macrura* suggest a complex relationship rather than a straightforward correlation between krill and whales. However, results indicate that fin whales were feeding in an area dominated by *T. macrura*, while humpback whales were found in areas of higher *E. superba* biomass. The survey resulted in an estimate of abundance for humpback whales in the Bransfield Strait of 3,024 (95 % CI 944-5015), without incorporation of a $g(0)$ correction.

Friedlaender commented that the Bransfield Strait appeared to be a boundary separating whales with different migratory destinations and that their ongoing deployment of telemetry devices on whales in this region could be used to produce an estimation for $g(0)$, which could be applied to this and other estimates of abundance.

3.2 Results of intersessional e-mail groups

3.2.1 Progress on abundance estimation of BSD

As described in Item 3, key data are still required in order to complete the assessment of west Australian humpback whale BSD. In 2015, the sub-committee strongly recommended the completion of three work items in order to conclude the Southern Hemisphere humpback whale assessment. Progress on these is described below.

(1) An evaluation of the available data and analytical approach used to measure mixing proportions of humpback whales in the Antarctic.

No progress was made on this item intersessionally. During SC/66b, the datasets necessary to complete these analyses were constructed. This work will now be completed in the next intersessional period and will be reported at SC/67a.

(2) Estimation of the minimum abundance of west Australian BSD humpback whales.

Recent discussions about abundance estimates, and subsequent population modelling of BSD, have mainly involved consideration of three aerial surveys (in 1999, 2005 and 2008), targeting the northward migration conducted along the west Australian coastline. Results of these surveys have been discussed at length by the sub-committee. Due to potential inconsistencies between those surveys, and the manner in which they were analysed, rates of increase that were originally estimated were beyond what is considered to be biologically plausible. Reanalysis by Hedley *et al.* (2011) of these aerial survey data in 2011 brought the results of each of the surveys to a point where they could be more reliably compared, producing a rate of increase of around 9.7% pa (CV=0.25) based on abundances of surface-available animals. Recent efforts with regard to obtaining absolute abundances for BSD have focused on the question of availability bias. Abundance estimates described by

Hedley *et al.* (2011) seem robust (particularly 2008), but include only surfacing animals, and make no correction for animals that dive out of view. There were initial field-based attempts (2005) to quantify availability bias estimates for northward migrating humpback whales involved using land-based surveys to try produce correction factors. These were problematic, however, due to milling of the animals. Later attempts using a similar method (in 2008) were also regarded as problematic because the land observers were not high enough to see all animals migrating past. An alternative solution to the availability problem was sought using focal follow data, providing an abundance estimate for 2008 of 28,830 (95% CI 23,710-40,100). However population modelling of BSD in a density dependent framework could not simultaneously fit both this abundance estimate and the 9.7% population trend estimated by the relative abundance series, suggesting inconsistencies between these estimates and the high latitude catch data, which are insufficient to explain the high abundance and growth rate seen off West Australia.

Kelly is in the process of reviewing these survey data. She was unable to attend SC/66b but provided a brief summary of her work to date. It is anticipated that Kelly will provide a fuller set of conclusions from this review intersessionally.

(3) Evaluation of the BSD sightings data reported in duFresne *et al*. (2014) with a view to determining the most appropriate survey method for measuring BSD abundance in the future. Kelly provided the following update on this work.

A series of land-based and aerial surveys were conducted in 2013 by duFresne *et al.* (2014) in order to test methods and to better quantify surface availability of whales in BSD along the Western Australian coastline, (i.e., these were geared directly to address the question of availability bias). In particular, these surveys involved methods such as land-based observations, and aerial survey techniques such as circle-back and cue-counting. Arising from this work, there are some recommendations for locations for land-based observations which will be useful for designing future surveys of BSD. In regards to aerial-based methods, the authors of this study suggest that cue-counting was a non-starter for this population (too many animals), but that circle-back remains a promising method for estimating availability bias. However the authors were not successfully able to estimate availability bias with these surveys.

The sub-committee thanked Kelly for this update and noted that her review of these two surveys will be completed intersessionally for reporting to the Scientific Committee during SC/67a.

In discussion, it was noted that a major issue with the BSD surveys was the influence of the non-standard way in which the abundance data were collected. It was also noted that the question to consider is how future abundance surveys should be designed, notably in light of the broad whale migration path that exists off the west coast of Australia. Sites for land-based surveys have been considered, but the primary survey method for this area is aerial survey. Land-based work can attempt to provide data on availability bias, although there are problems with this. Cue-counting from the aerial survey might be possible, though doubt was expressed regarding whether the ‘circle-back’ method was practical given the large number of groups found in the study area. Another problem raised by the sub-committee is that if animals are circulating (returning) or ‘milling’ it may result in whales being counted twice, relative to areas farther south where a steady northward migratory movement is evident. Photo-identification work in concert with abundance surveys could help to assess the degree to which animals are resighted over short periods; focal follows with drones might also provide useful information on availability bias.

Since these items of work are still outstanding to complete the Southern Hemisphere humpback whale assessment, they will remain open items and the sub-committee strongly **recommends** that they are completed before SC/67a (see Item 10.1). As a consequence, population modelling (population assessment of BSD/BSE1/Oceania) using abundance information from BSD was not conducted at SC/66b. The sub-committee **recommends** that this population modelling work be done intersessionally by Butterworth and colleagues when the review of BSD survey data is complete, using a £2,000 budget allocated for this purpose in 2014 (IWC, 2015).

3.3 Future directions for Southern Hemisphere humpback whale assessments

SC/66b/SH01 proposed criteria for determining priorities for future assessments of Southern Hemisphere humpback whales. The document reviewed gaps and uncertainties in the assessment process, their likely impact on current assessment outcomes, and the feasibility of obtaining resolved data for the next set of in-depth assessments. A summary of the unresolved questions and key data gaps remaining when the recent In-Depth assessment of Southern Hemisphere humpback whales concluded was provided by Jackson *et al.* (2015) at SC/66a. This list of data gaps formed the basis of the SC/66b/SH01 prioritisation document.

In light of the fact that the initial exercise resulted in ten high-priority scores (one of nine and nine of eight), the sub-committee established a small working group under Jackson to recalibrate the prioritisation weightings in SC/66b/SH01 and to assemble items within each breeding stock so that they are ordered in terms of within-region priority. After discussion within this working group, scores were re-evaluated and the priority of data gaps reordered by likely impact on assessment, with additional consideration given to population modelling and the status of the population.

3.4 Conclusions and recommendations

A final set of priorities for work not completed during the first In-Depth Assessment is given in Table 1. The sub-committee agreed to **endorse** the recommendations for work associated with these priorities (detailed in Appendix 2). Other recommendations arising from the in-depth Assessment were compiled in 2015 and summarised in IWC (2016). The sub-committee **agreed** that they would consider in 2020 the feasibility of conducting a second in-depth assessment of Southern Hemisphere humpback whales.

4. ARABIAN SEA HUMPBACK POPULATION

4.1 Review new information

SC/66b/SH12 and SC/66b/SH14 provided an update on the progress of the Arabian Sea Whale Network (ASWN), which was formed during a workshop held in Dubai in January 2015. SC/66b/SH12 comprised a newsletter that showcases research and conservation work conducted by Network members in various Arabian Sea humpback whale range states. SC/66b/SH14 summarised progress made against the 11 core recommendations made during the January 2015 workshop, and finds that overall the Network is achieving its aims of promoting information exchange between members. However, a lack of funding at regional

Table 1

Scores summarising priority work for Southern Hemisphere humpback whale populations, considering: (i) the effect of this missing information on population assessment outcomes i.e. recovery status; and (ii) the recovery status of each stock. Priority actions within each breeding stock/sub-stock are ordered by level of importance.

Breeding stock	Assessment element	Impact on assessment outcomes	Population status from last survey	Priority score
BSA	Trend	5	3	8
	Catch	2	3	5
BSB1/B2/C1	Interchange	5	3	8
BSB1	Abundance and trend	5	2	7
BSC1/C3	Catch allocation	5	1	6
BSC1/C2/C3/C4	Population structure	3	3	6
BSC1N/C2/C3/C4	Abundance	1	3	4
BSD[1]	Abundance	5	3	9[1]
BSE1	Catch	1	2	3
Oceania	Abundance of breeding sub-stocks BSE3 (Tonga) and BSF2 (French Polynesia)	5	3	8
	Trend: for Oceania, BSE3 and BSF2	4	3	7
BSG	Abundance	5	3	8
	Population sub-structure across breeding ground	5	3	8
	Trend	4	3	7
Migratory connections		-	-	-
Identify breeding/feeding ground migratory linkages and connections		5	-	5
Population modelling		-	-	-
Power analysis for future surveys		5	-	5
Age-sex disaggregated models		3	-	3
Circumpolar population dynamics model integrating data from all Southern Hemisphere breeding stocks		5	-	5
Mixed-stocks used in population models		3	-	3
Alternate population dynamics framework		4	-	4
Include pre-1900 catches		3	-	3

[1]There is no agreed abundance estimate for BSD to date, so one point has been added to the total score as this goal is considered highest priority.

level has hindered progress on the envisaged collaborative data archiving and regional research projects. There were several research priorities identified at the workshop: first, to design and implement a regional online data platform based on Flukebook/Wildbook using relevant elements of other existing platforms, such as the IWC and IWC-SORP databases. This data platform is essential for allowing researchers in the Network to store and analyse data in the same format, and facilitate regional collaboration on data analyses for evidence-based conservation management. Second, to implement a region-wide passive acoustic study to detect the possible presence of humpback whales in previously unstudied but suspected humpback whale habitats off the coasts of Iran, Pakistan, India and Sri Lanka. Regional training workshops would allow expansion and replication of fisheries (bycatch) observer schemes. Increased use of platforms of opportunity, such as fishing or coast-guard vessels, ferries, etc. would further document cetacean sightings (either through training of vessel personnel, or placement of trained on-board observers). Finally, analysis of the existing genetic samples collected in the region is an important goal, as well as continued, targeted genetic sampling in countries where possible.

In discussion, it was noted that development of a standardised data platform was the highest priority for the ASWN for facilitating research and enhancing collaboration on the regional scale.

The sub-committee **commended** the authors of these two papers for working to establish and maintain such a network, which it recognises as important for the conservation management of this highly endangered population. The sub-committee also **endorsed** the recommendations arising from the workshop described in SC/66b/SH14, particularly that an online regional data archiving platform be developed for Arabian Sea whales to integrate different data types, and facilitate regional analyses and comparison of data between study sites. The sub-committee also **recommended** that the IWC Secretariat communicate the Committee's endorsement to the relevant range states.

SC/66b/SH28 reported on three surveys focusing on Arabian Sea humpback whales which were conducted from two field sites off the southern coast of Oman between February 2014 and December 2015. A summary was presented of boat-based survey data and satellite telemetry activities, which provided insight into the spatial ecology of Arabian Sea humpback whales and identified threats to the population. Ninety hours of on-effort vessel-based surveys resulted in 29 sightings of humpback whale groups involving 40 individuals. Tagging efforts resulted in successful deployment of nine satellite tags, six of which provided data on dive behaviour and vertical distribution within the water column. Tagged whales that were resighted (n=5) during subsequent surveys exhibited signs of healing following tag rejection. Satellite tracking data revealed whales ranging within a 1,150km corridor along the southern coast of Oman and northern Yemen, the first trans-boundary movement recorded for this population. Individuals spent an average of 83% (SD=17%) of their time engaged in localised or 'area restricted search' that is likely associated with foraging, breeding and resting behaviour. Tracked individuals spent much of their time over the continental shelf with 73% of satellite-derived locations attributed to waters <200m depth. Gathered dive data reveal that tracked whales spent 83% of time in the top 20m of the water column, most frequently (39%; SD=11%) engaged in dives with durations between 5 and 10 minutes. The average maximum depth recorded by the tags was 199m (SD=95m). Further spatial analysis indicated that 35% of location points in the study were within the Gulf of Masirah, habitat that co-occurs with emerging industrial activity (including shipping and oil and gas development), and existing artisanal fisheries. Dive behaviour in offshore waters beyond the continental shelf also likely indicates foraging activity.

In response to a question regarding the male-biased sex ratio in the sampling, the authors noted that photo-identification and genetic work shows an even sex ratio, for whales observed in the Gulf of Masirah, but a distinct male bias in whales observed in the southern survey site of Dhofar (Minton *et al.*, 2011, and results of genetic analyses presented at this meeting below). The authors also explained that females with calves were excluded from tagging in part because of concerns about harassment or injury to reproductive females. When questioned as to whether impacts of tagging had been monitored, the authors stated that some tagged individuals were resighted and that photographic evidence shows clean healing and there were no indications of infection or other issues at the tag insertion sites.

It was noted that there were sightings of humpback whales in areas other than Oman, but that connections among areas were unclear; this was the impetus for the membership base of the Arabian Sea Whale Network. In response to a suggestion that tagging occur at other sites (e.g. the Gulf of Kutch in Pakistan), the authors stated that not enough was known about the reliability with which humpbacks were found in other areas and the consequent difficulties associated with ensuring successful field operations. The sub-committee welcomed these results and **recommended** that satellite tagging work be continued in Oman, to target females and to cover seasons not included in work to date; and that tagging be considered in other range states if and when areas of continued and regular ASHW presence are identified.

SC/66b/HIM10 suggested priorities for addressing whale and vessel co-occurrence off the coast of Oman and in the wider northern Indian Ocean (NOI). The authors noted that satellite telemetry studies and habitat density mapping of the Endangered Arabian Sea humpback whale has revealed overlap with shipping off the coast of Oman. To date, the only other NIO study to determine the risk of mortality to whales (specifically blue whales) from shipping was completed in Sri Lanka (De Vos *et al.*, 2015). A demonstration exercise reviewing vessel traffic (from AIS data) passing through coarsely defined habitat reveals that container vessels may provide the highest risk to whales based on speed of vessels, notably given a three-fold increase in container traffic in the NIO region between 2004 and 2014. Traffic density heat maps show shipping routes are predominantly distributed around the periphery of the NIO area in close proximity to the continental shelf showing overlap with historical records of takes of blue, humpback, sperm and Bryde's whales during Soviet whaling between 1964 and 1966. The review presented a case for immediately commencing risk assessment work on humpback and ship co-occurrence in Oman while undertaking a wider spatial assessment of the region to determine priority areas for study. Given overlapping habitat use between species in certain areas, a multi-species approach to reviewing mitigation options was recommended by the authors.

The sub-committee **commended** the mitigation initiatives being undertaken by the Port of Duqm, which will have bearing on other port developments in the Arabian Sea, and **recommended** that more work be done to investigate and mitigate the potential impact of high densities of vessel traffic on Arabian Sea humpback whales (ASHW). The sub-committee also **recommended** that the IWC Secretariat should engage with the relevant port authorities with respect to development of proposed port operating procedures to mitigate ship strikes in the Arabian Sea.

SC/66b/SH32 reported on long-term acoustic monitoring of Arabian Sea humpback whales off Oman. The paper described the results from two yearlong deployments of three archival acoustic recorders in Hallaniyats Bay during 2011/12, and in the Gulf of Masirah during 2012/13. There was a strong seasonal component to the detection of song, primarily from November through May, congruent with the Northern Hemisphere breeding cycle. Singing was heard in both Hallaniyats Bay and the Gulf of Masirah, separated by approximately 400km, indicating that the population utilises both of these regions. However, there was a much stronger presence in Hallaniyats Bay, suggesting that the Hallaniyats Bay might serve as a more important habitat for breeding activity than the monitored region of the Gulf of Masirah. There also appeared to be a subtle northward shift in distribution of detections as the singing season progressed, both within Hallaniyats Bay, and from Hallaniyats Bay to the Gulf of Masirah, suggesting a seasonal shift in distribution for at least singing males and likely for the population as a whole. Previous boat-based survey data and satellite tracking data are congruent with these patterns. However, given the limitation in the duration of prior fieldwork the current acoustic dataset provides a more reliable indication of this population's breeding-related activity and distribution. During the summer and autumn months, very little song was detected. Nevertheless, sparse detections indicate that whales are present in both regions during at least some of this period. The authors recommended that similar acoustic monitoring be conducted in all range states of the population to elucidate spatiotemporal distribution throughout the Arabian Sea.

In discussion, the authors commented that this work was identified as a high priority by the Arabian Sea Whale Network workshop, and that some funding might be available to continue the project, including conducting acoustic monitoring off Pakistan. The sub-committee recognised the importance of this work in providing information about the distribution and behaviour of this endangered population and endorsed this continuing study, and **recommended** that every effort be made to collect acoustic data in other parts of the expected range in order to determine presence/absence of humpback whales elsewhere in the region.

SC/66b/SH34 summarised records of baleen whales from the Indian coast of the Arabian Sea (Gujarat, Maharashtra, Goa, Karnataka, Kerala and west Tamil Nadu) from June 2015 to May 2016. Sources included grey literature, vessel surveys and interviews with fishermen. Blue whales and Bryde's whales were reported, as well as a few records of un-identified whales from Gujarat, Maharashtra, Karnataka and Lakshadweep Islands. There were no reports from Goa, Kerala and western Tamil Nadu. There were seven sightings of blue whales between November and April, and several sightings of Bryde's whales. A number of animals were found stranded, and although the causes of mortality are not clear, the number raises some concern. The authors recommended that effort be made to conduct in-depth analyses of baleen whale carcasses to further examine the causes and seasonality of mortalities. Continued surveying efforts for Arabian Sea humpback whales and other baleen whales will remain the main objective of the work.

The sub-committee **encouraged** the collection of acoustic data from this region, noting the paucity of current data on NIO blue whale distribution and occurrence (see discussions in Item 5.1). The sub-committee expressed its appreciation to the Government of India, Maharashtra Forest Department and the local office of the United Nations Development Programme for their support of this work.

In response to a question, it was noted that genetic samples from carcasses were collected when possible, but that there were logistical difficulties associated with doing this in India. It was queried whether there had been an attempt to discriminate the species of Bryde's whale involved in the sightings and strandings but others noted the challenges of coordinating this work over a large coastal area in India, and that it was difficult to easily obtain such identifications in the field. The sub-committee **welcomed** the report of this important work, recognised the substantial effort involved in coordination of such research in logistically difficult circumstances, and **commended** the authors for their work. They **recommended** the continuance of this work and particularly urged the collection of genetic samples where possible as the population identity and structuring of many of these species is unknown.

The sub-committee received an update on genetic analyses of Arabian Sea humpback whales, including preliminary analysis of 49 new samples collected off the coast of Oman between 2005 and 2015; these were compared to samples collected between 1999 and 2004. Within the new dataset, seven duplicate samples were found. Five samples representing three individuals in the 2015 dataset registered as genotypic matches with animals sampled in the 2004 dataset. An additional nine samples involving six individuals that represent potential matches between the 2015 and 2004 dataset are being reviewed to determine if they represent inter-year recaptures. As the data were generated very recently, further checks to clarify issues with some microsatellite loci will be completed. Six samples failed to amplify consistently for sexing markers and need to be revisited. The genetic data were used to determine the sex of nine satellite-tagged humpback whales. Preliminary assessment of the new sexing data (although not yet fully complete) is providing valuable insight into possible difference in habitat use between the two primary study sites off the coast of Oman. Minton *et al.* (2011) documented a heavy bias toward males in Dhofar and a ratio near parity in the Gulf of Masirah. These results were based on the total number of photographic captures of known sex individuals. The combination of new and old sexing information allows for a more nuanced examination of this phenomenon: the male-female ratio based on individual whales for which sex was determined in each study site (regardless of how frequently they were observed) is 2:1 in Dhofar (n=30), while in the Gulf of Masirah this ratio was slightly biased toward females, with 45% of individuals of known sex observed in that study area being male, and 55% female (n=49). It was noted that additional samples from other areas of the Indian Ocean were required in order to better elucidate the genetic structure of this population, and that obtaining permits for export of samples from relevant range states was an important element of this. The three highest priorities for future work include clarifying taxonomic status of the population; examining relatedness and social structure, including an inbreeding assessment; and an analysis of health status through genetic examination of major histocompatibility complex (MHC) markers.

The sub-committee noted that a full report on this project would be received at SC/67a once all genetic analyses had been completed. The sub-committee **recommended** that collection of genetic samples take place either opportunistically from strandings and disentanglements or through targeted biopsy work in range states beyond Oman, and that the 92 existing Oman samples be further analysed to allow definitive determination of taxonomic status, kinship and the extent of possible inbreeding in the population.

With regard to Arabian Sea humpback whales generally, the sub-committee **welcomed** the new information on this Endangered population, **encouraged** the continuation of the research and **reiterated** its serious concern about the Endangered status of, and threats to, this distinct population.

4.2 Progress toward the development of a Conservation Management Plan and other conservation initiatives

Progress on a Conservation Management Plan for Endangered Arabian Sea humpback whales has stalled because the IWC had requested endorsement from range states, and this has not yet occurred despite a letter from the IWC Secretariat to the Omani commissioner requesting such endorsement. It was noted that the Arabian Sea Whale Network did not currently include any formal government representation, but that the Network could be used to further a Conservation Management Plan should Oman and others endorse it.

Last year the sub-committee recommended the formation of a Technical Advisory Panel along the lines of that established for western gray whales. It was subsequently suggested that this would focus initially on humpback whale conservation in the Gulf of Masirah given the imminent threats to the population in this area. It was felt that this Advisory Panel should be formed at the request of a relevant stakeholder in Oman, and noted that discussions are underway between the IUCN, WWF and the Environment Society of Oman. The sub-committee **agreed** to discuss the value and viability of a Conservation Management Plan and other conservation initiatives for this population at the forthcoming joint meeting with the Conservation Committee.

5. ASSESSMENT OF SOUTHERN HEMISPHERE BLUE WHALES

5.1 Southern Hemisphere population structure

In preparation for Southern Hemisphere pygmy blue whale assessments, it was recommended at SC/66a that an intersessional e-mail discussion be initiated to identify and summarise datasets (acoustic and genetic) relevant to assessing population structure among pygmy-type blue whales in the Southern Hemisphere. Documents submitted to the meeting relevant to Southern Hemisphere population structure were reviewed in a joint session of this sub-committee and the Stock Definition Working Group (Annex I).

SC/66b/SH35 reports on the results of the group tasked with identifying and summarising acoustic data relevant to assessing pygmy-type blue whale population structure in the Southern Hemisphere. The point of departure for the summary was the study by McDonald *et al.* (2006) summarising the biogeography of all blue whale songs and identifying clear regional separation of song types. The group used the term 'song type' as defined by McDonald *et al.* (2006), considering songs with units that are slightly modified (e.g. shifted frequency) as variants. When different units were present they were classified as different songs. The McDonald numbering system was not found to be ideal because it is hard to expand. The system was therefore extended by adding letters to the song type numbers that occur in the same geographical regions, e.g. 2A and 2B for different areas within the southeast Pacific Ocean. Not all songs were visually confirmed to be from blue whales; for three proposed song types the assumption of blue whale was based on characteristics of individual call units and repetitive

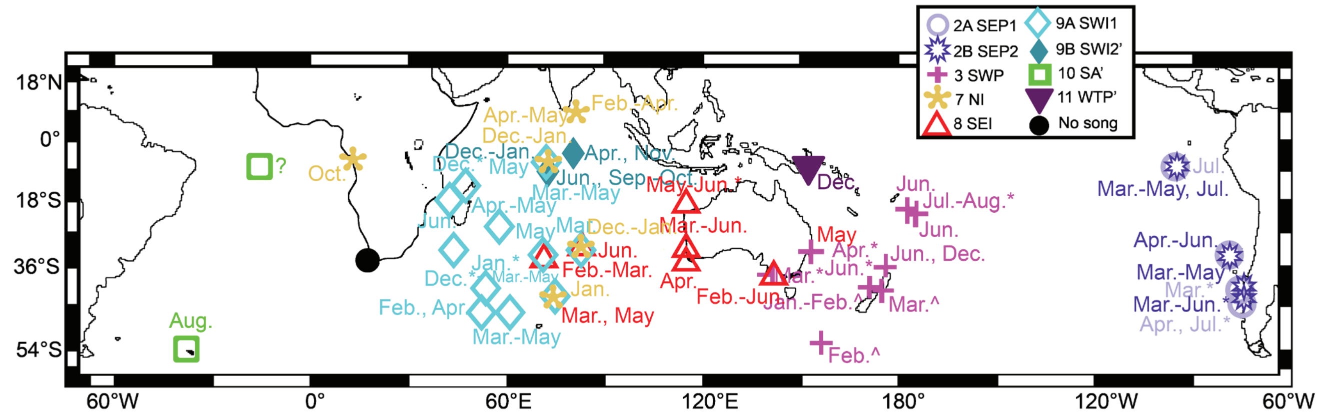

Fig. 2. Locations of non-Antarctic blue whale songs reported for the Southern Hemisphere (between the equator and 60°S) in the literature. Each symbol and colour denote a song type. Months included for each site indicate peak months of detection. In most cases year-round recordings were available. If three or more month of recording were missing per year, those peak months are marked with *. At locations marked with ^, recordings were collected with sonobuoys or dipping hydrophones and generally data were only available during indicated month(s). The black dot marks a location where full year of recording exists and no non-Antarctic blue whale songs were recorded.

patterns in the song. It was assumed that these songs are produced by males and have a reproductive function based on patterning, since male-only production of these songs has been confirmed in northeast Pacific blue whales.

Based on song types, McDonald *et al.* (2006) hypothesised five Southern Hemisphere pygmy blue whale populations. This review found a possible nine song types (Fig. 2). In the Atlantic, one song type (song type 10 (SA)) has been reported off Sub-Antarctic islands between about 54°-55°S, 36°-38°W in the austral winter and also occurs at Ascension Island at, as of yet, an unknown time of year. Notably, this song type has not been detected off Africa. In the Indian Ocean, there are four possible song types; in the North Indian Ocean, song type 7 (NI) occurs in summer as far south as 40°S and during the autumn and winter further north around India and Sri Lanka. A new, possible blue whale song (song type 9B (SWI2)) was recorded only in the very northern parts of Indian Ocean, with seeming migratory movements between the two detection sites. In the western Indian Ocean, song type 9A (SWI1) is detected from Madagascar and the Mozambique Channel in the east, Diego Garcia in the north, through the central Indian Ocean off Amsterdam Island, and south to the Kerguelen Plateau. There is no clear migration pattern from the recordings of type 9A. In the eastern Indian Ocean, song type 8 (SEI) traces migratory movements along the coast of Australia with detections in late summer in Bass Strait and along western coast during the autumn. This song type extends out to central Indian Ocean, overlapping with song types 9A (SWI1) (spatially and temporally) and 7 (NI) (only spatially). A possible new blue whale song has been detected once in the Solomon Sea (song type 11 (WTP)) but the timing indicates it could be a Northern Hemisphere population. Further east in the south Pacific Ocean there are three song types. Song type 3 (SWP) occurs around New Zealand and eastern Australia. Few year-round recordings exist in this area, but song type 3 (SWP) occurs off Tonga in the winter and along New Zealand in summer/autumn. There is some overlap with song type 8 SEI, but the two are generally separated by the Australian continent. Two songs were recorded in South East Pacific, both off Chile and in the Eastern Tropical Pacific. Song types 2A (SEP1) and 2B (SEP2) generally occur in the same locations and at the same time, but song 2B (SEP2) is more common. Appendix 3 provides the origins of all the blue whale song types recorded in the Southern Hemisphere. In this report we utilise the term song to describe the particular structure and pattern of the vocalisation, while call or unit is used to describe an individual vocalisation.

The sub-committee welcomed this effort and noted its important acoustic contribution to the understanding of pygmy blue whale stock structure.

Since the two song types recorded off the west coast of South America (2A SEP1 and 2B SEP2) are detected off Chile and in the eastern Tropical Pacific, it was queried whether these song patterns suggest any trans-equatorial movement of blue whales. In response, it was noted that northeast Pacific songs are acoustically distinct (see Stafford *et al.*, 1999) and have not been recorded further south than the Galapagos/Costa Rica Dome, showing a clear separation of southeast Pacific and northeast Pacific song types.

The provenance of the Solomon Islands song type (11, WTP) was discussed. It was noted that this song was detected by Frank and Ferris (2011) from seismic recorders, and is consistent with Japanese sightings records from this region in 1957, but that blue whale sightings in this region are currently scarce, and the song may be from a North Pacific whale. However, it was noted that this song type differs from those associated with the central and western Pacific Ocean.

It was queried whether song types 9A (SWI1) and 9B (SWI2) might represent the same whales detected at different times in the season. It was explained that these two song types are quite distinct in terms of both frequency characteristics and theme structure. Song type 9A (SWI1) has two parts, while 9B (SWI2) has one part and longer inter-call intervals (McDonald *et al.*, 2006). Both song types have been recorded in the same locality, and song types 9A (SW11) and 9B (SW12) are at least as different from each other as the southeast Pacific blue whale song types 2A (SEP1) and 2B (SEP2) are, if not more. It was noted that song type 9B (SWI2) was only recorded close to the equator over a narrow geographic range, with acoustic detections indicating seasonal movements towards the equator in summer and away from the equator in winter. This song type is quite different from those in the northern Indian Ocean (song type 7, NI). This song type has not been recorded in the presence of an animal but is assumed from its structure to be a blue whale. The possibility of this call being made by an Omura's whale was discounted since the recordings of Omura's whale are more similar to Bryde's whale calls (Cerchio *et al.*, 2015). It was also noted that no recording effort reported from the western Arabian Sea to date includes blue whale song. Efforts to conduct more acoustic work on

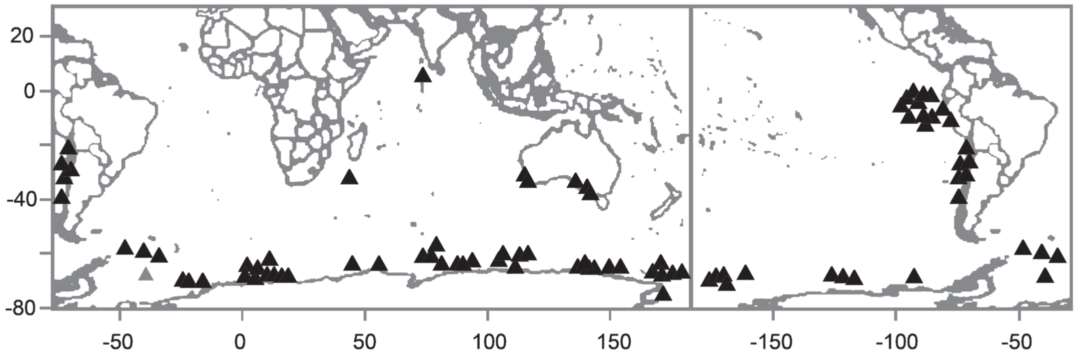

Fig 3. Locations of analysed samples collected from blue whales in the Southern Hemisphere and northern Indian Ocean and archived in the SWFSC tissue collection database.

the western side of the Northern Indian Ocean to collect data on whale calls were **encouraged**, including analysing the acoustic records off Oman that were collected and reported in SC/66b/SH32.

The source of the 10 (SA) song type recorded in the region of Sub-Antarctic islands between about 54°-55°S, 36°-38°W received some discussion. It was noted that the Antarctic convergence in this region meant that the presence of pygmy blue whales is a distinct possibility, and both pygmy and Antarctic blue whales have been photo-identified in this area. While very few of the blue whales caught in this area were likely to have been pygmy blue whales (<1.5%) based on length data (Branch *et al.*, 2007a), during the early whaling period in that region, length measurements were rounded up, which could falsely indicate larger whales than were actually being caught. A recent genetic analysis of whalebones collected from the area also identified one probable pygmy blue whale within the bone collection (among 18 blue whales identified), further suggesting some degree of past presence. Only one stranding and three catches have been made off Brazil and their subspecies identity is not known. In summary, the sub-committee noted that while past catches at high and low latitudes in the South Atlantic suggested that pygmy blue whales were not regularly present in this region, the limited recent sightings data suggest the possibility of current pygmy blue whale presence, perhaps following a temporal change in their distribution as a consequence of changing oceanographic conditions.

The overlap of the 2A (SEP1) and 2B (SEP2) song types in the southeast Pacific Ocean was questioned and it was noted that despite the 2B (SEP2) song type being dominant (with the 2A (SEP1) theme less common), these two song types were always detected at the same localities. It was commented that there have been biopsy surveys done while whales were vocalising both song types, so whales of both types are likely to have been genetically sampled. No genetic differentiation within the samples was detected, suggesting that these differences in song structure are not associated with genetically distinct groups. The single record of a Sri Lanka song (type 7, NI) off the coast of Angola was believed to be an out-of-range occurrence (Cerchio *et al.*, 2010).

Balcazar *et al.* (2015) used automated detector methods to identify 'acoustic populations' of blue whales producing region-specific song types from passive acoustic data collected at five sites spanning over 7,370km across the southeast Indian Ocean and southwest Pacific Ocean from 2009 to 2012. Blue whales were located in previously undocumented locations, including the far southwest Pacific Ocean, in the Tasman Sea off the east coast of Australia, and along the Lau Basin near Tonga, although not all sites had as many records. The Australian continent acts as a geographic boundary, separating Indonesia/Australia and New Zealand blue whale acoustic populations at the junction of the Indian and Pacific Ocean basins (Tasmania). Between 2009 and 2012 there was some, but very little (one day of detections) interchange between populations.

The authors were thanked for this contribution and it was noted that these acoustic reports provide good context for upcoming discussion of genetic evidence.

Lang presented the results of complementary intersessional work to review the genetic evidence for blue whale stock structure in the Southern Hemisphere and northern Indian Ocean. Fourteen published studies have contributed information regarding genetic diversity and structure of these populations to date, using samples distributed across the Southern Hemisphere as shown in Fig. 3. The summary evidence from these studies is detailed in Appendix 4. When using genetic data to inform understanding of stock structure, she cautioned that the genetic samples for pygmy blue whales in the Southern Hemisphere have all been collected from feeding grounds or transiting areas (with the exception of the breeding area(s) located in the ETP) (Table 1 of Appendix 4), and that at least some of these sampling locations are also used by Antarctic blue whales. Since diagnostic genetic differences have not been identified between Antarctic and pygmy blue whales (nor between pygmy blue whales using different feeding grounds), it is possible that stratification of samples by geographic location for genetic analyses could be confounded by inclusion of Antarctic blue whale samples, and that the genetic differences revealed by these studies are not necessarily representative of breeding populations.

The intersessional group were thanked for their considerable effort to review studies by different research groups, noting that the exercise has identified many data gaps. Lang highlighted the problem that breeding ground locations for these species, potentially yielding samples representative of breeding stocks, are poorly known, with the exception of the eastern Tropical Pacific (ETP). A presumed calving ground has been identified in the Banda and Molucca Seas by satellite tracking whales migrating from feeding grounds in the Perth Canyon, west Australia (Double *et al.*, 2014). Genetic samples obtained from these satellite-tracked animals are therefore known to be associated with this breeding ground, but sample sizes are very small. Similarly, small sample sizes off the western Indian Ocean (Madagascar) and northern Indian Ocean prohibit a robust analysis of differentiation.

It was noted that whales off Chile are as genetically differentiated from the Indian Ocean region (this includes samples from Madagascar (*n*=6), west Australia (*n*=28) and the Northern Indian Ocean (2)) as they are from Antarctic blue whales (LeDuc *et al.*, 2007), supporting past proposals that they are a distinct subspecies (Branch *et al.*, 2007a). In reviewing these genetic and acoustic differences, it was commented that within the four subspecies of blue whales that are currently recognised in the Southern Hemisphere and Northern Indian Ocean, the type specimen of *B. m. brevicauda* is the Madagascar form but was taken off the coast of South Africa.

Few genetic samples are currently available for describing any population structure in the Atlantic and Indian Oceans (including the Northern Indian Ocean, Fig. 3), although a limited number of samples have been collected. Further genetic sampling from the NIO may be possible in the future, although the remoteness of other areas (e.g. the South Atlantic, around the Kerguelen feeding grounds) meant little prospect for further sample collection in these areas. The sub-committee noted that although a number of blue whale stranding events have been reported along the coasts of India or Pakistan there were considerable issues in obtaining CITES permits to transfer such samples to laboratories, although it was reported that the situation in India has improved on a regional basis. The sub-committee **strongly encouraged** biopsy sampling of whales in these areas to collect genetic information, and also **recommended** and encouraged the Secretariat to facilitate the expediting of such sample transfers. Furthermore, the sub-committee **encouraged** sample collectors to submit their samples to the Southwest Fisheries Science Center in an attempt to increase sample availability and maintain an archive.

Noting the large repositories for genetic samples and DNA sequence data (e.g. *GenBank*), it was noted that there is no similar structure for the archiving of blue whale call or song types. Developing such a database would need to be done carefully because many calls can be temporo-spatially specific and accompanying metadata on date and location would need to be supplied. However, it was also considered a beneficial development to have a single place where recordings of all key song types could be made available. The sub-committee **recommended** this be developed.

On the basis that song types and themes can identified and distinguished, it was questioned whether blue whale calls could be classified in a manner that might identify relatedness between populations (e.g. Garland *et al.*, 2015). It was reported that although this is yet to be carried out, the fine-scale variability in North Pacific songs (e.g. the variability of the call contours by region) is being investigated for relatedness patterns. A quantitative metric of song relatedness could be developed in a manner similar to that of the genetic differentiation measure F_{ST} which is used to measure comparative differences within and between populations. If differences in acoustic song types proportionately reflect genetic differentiation then multivariate statistics could perhaps be used to analyse both genetic and acoustic data. It was noted that blue whale songs are simple compared to some other species, but do vary in their complexity and that there should be sufficient information in the calls to develop a relatedness metric. While such a metric could be informative about differentiation levels between blue whale populations, it was noted that genetics can also be used to measure population interchange. To date, acoustic data have proved challenging to use in this context for other species (e.g. humpback whales, Garland *et al.*, 2015) but blue whale song evolves comparatively slowly relative to humpback whales and may therefore show more static and interpretable patterns.

The sub-committee noted some general concordance between the patterns observed in the acoustic and genetic data across the Southern Hemisphere, but noted that direct comparisons between acoustics and genetics are difficult because the mode of evolution and transmission of songs is unknown. For example, the two southeast Pacific song types are found completely concurrently; the reason for this is unknown.

On reviewing Fig. 2, six ‘acoustic’ populations were identified: Antarctic blue whales, Chilean blue whales, and pygmy blue whales from the Northern Indian Ocean, New Zealand, the Australia/Indonesia region and the southwest Indian Ocean. It was noted that the Chilean blue whale population represents a special case because two song types are always co-occurring temporo-spatially, and therefore for the purposes of this assessment we consider it a single population. It was also noted that the acoustic distinctions seen between the Australia/Indonesia and New Zealand regions are not reflected in the mtDNA patterns, with these analyses showing no genetic differentiation between the two regions. However, these two song types do co-occur temporo-spatially. It was noted that mtDNA reflects patterns of female dispersal while song is assumed to be male-only, so these contrasting patterns may reflect some kind of sexual selection. However, analyses to date are preliminary and based on a low sample size that did not access all available Australian data. It was noted that genetic sample sizes were low in most parts of the Southern Hemisphere, and that for this reason it would initially be better to consider the acoustically defined regions as distinct populations for the purposes of assessment, because this would provide a better-resolved set of hypotheses to be tested. Furthermore, it was noted that although use of the song type presents some challenges in being male-only and potentially subject to rapid change, it should be sufficient for generating hypotheses. The sub-committee therefore agreed that until more genetic data are available they will use acoustically defined regions to delineate the pygmy blue whale populations for assessment, while **strongly recommending** additional genetic sampling of pygmy blue whales across the Southern Hemisphere, especially in areas of potential overlap.

It was noted that for three song types (namely the South Atlantic type 10 (SA), the SW Indian Ocean type 9B (SWI2), and the Solomon Sea type 11 (WTP)), there has been no concurrent visual confirmation of the species producing the call, and that visual confirmation of these types should be attempted. The sub-committee **recommended** that this be undertaken.

Branch presented results examining Southern Hemisphere blue whale catch lengths and seasonality, and their implications for population separation (Appendix 5). Catches from Chile peaked in summer, but catches in South Africa, Namibia, and Angola peaked in winter. Whaling from land-stations in western Australia was in winter, but blue whale catches were lowest in mid-winter. In all Antarctic regions, including whaling stations, catches peaked in summer. The proportion of blue whales among all catches declined by 67% off Chile, 99.6% off Saldanha Bay, and 97% off Durban, implying much less depletion off Chile, while the depletion in South African waters mirrored that in the Antarctic (Branch *et al.*, 2004). Examination of sexually mature females demonstrated that Chilean blue whales are intermediate between Antarctic blue whales, and pelagic catches of pygmy blue whales throughout the Indian Ocean. Length frequencies of blue whales of all maturity status and sex demonstrated that pygmy blue whale catches were constrained to the region east of 20°E and north of 52°S; catches in Saldanha Bay and Durban comprised mostly immature individuals, with all sexually mature individuals being of Antarctic blue whale length; and that Chilean blue whales were again intermediate in length. Antarctic blue whales were found further north between 60°W eastward to 120°E, where many catches were taken between 52°S and 60°S; but at longitudes 120°E eastward to 60°W, there were only five blue whale catches in the entire 20th century between 52°S and 60°S - all of the Antarctic blue whale catches were south of 60°S. Finally, there was a substantial gap in catches between the Antarctic and Chile, with very few caught between 60°S and 40°S. Taken as a whole, seasonality, depletion, and length frequencies all support separate Antarctic, Indonesia/Australia, and Chile populations, and are consistent with Antarctic blue whales being caught in both South African locations (Durban on the east coast and Saldanha Bay on the west coast).

The sub-committee welcomed this work. Based on differences in acoustics and catch lengths it was suggested that it would also be useful to further investigate differences between southwestern and southeastern Indian Ocean animals in the catch analysis, particularly in view of the fact that the type specimen for pygmy blue whales originates from a location southeast of South Africa and is, therefore, probably from the population of blue whales found off Madagascar. Branch proposed to conduct an in-depth investigation of all available catch data held in the IWC database to see if stocks can be delineated. The sub-committee also requested that Branch contact Pastene regarding the availability of the original catch data of blue whales taken off Chile in the 1960s, as these data need to be checked against the IWC database.

Fig. 1 of Appendix 5 shows whaling effort over the entire South Atlantic and strengthens the idea that pygmy blue whales were not found in the South Atlantic. If the song type 10SA was not made by a pygmy blue whale, then the question as to its identity remains. The call has features similar to other blue whale calls, but could be from sei whales which have a large variation in their calls. Branch noted that Mackintosh and Wheeler (1929) had examined over a thousand blue whales from the South Atlantic and had found the same sized blue whales between Saldanha and the Sub-Antarctic islands between about 54°-55°S, 36°-38°W, with no evidence of pygmy blue whales. It was noted that the catch length data presented is consistent with acoustic data, apart from the odd song type (9B SWI2) recorded at the centre of the Indian Ocean.

SC/66b/SH26 presents advances on the progress of Southern Hemisphere Blue Whale Catalogue (SHBWC) between June 2015 and May 2016. Currently the SHBWC includes a total of 1,381 individual blue whale photo-identifications that include areas off Antarctica, Chile, Peru, Ecuador-Galapagos, Eastern Tropical Pacific, Australia, East Timor, New Zealand, Madagascar and Sri Lanka. In 2015-16, the catalogue increased 30% with the addition of new photo-identifications. Regional matching process within Australia and New Zealand region has been finalised with all photo-identifications received prior to 2016. Five whales were re-sighted within all three areas of Australia but no matches were found with New Zealand blue whales. Details are given in SC/66b/SH27. Between-region comparisons of Antarctica, the ETP and South East Pacific have also been completed and no matches were found. Over the years the IWC has made a set of recommendations to the SHBWC and in response major improvements have been implemented in the software. Future work should include the initiation of the matching process with new photo-identifications received and comparisons between regional catalogues from: (1) Australia, Indonesia and New Zealand; and (2) the Eastern Tropical Pacific, Antarctica and southeast Pacific.

As the Southern Hemisphere Blue Whale Catalogue grows, there is growing potential to use within-region catalogues for mark recapture modelling of population abundance. This may now be possible for Australia given the size of the regional catalogue. However such an effort will require the input of the regional co-ordinators and uploading of the data and location metadata that was not made available under the previous data-sharing agreement. New Terms of Reference for the SHBWC have been proposed and agreed by the Database Working Group. Changes have also been made to the catalogue so that the date and location metadata can be uploaded. The sub-committee **recommends** that the revised Terms of Reference are sent to all catalogue contributors for agreement.

The sub-committee made some recommendations for improvements to the SHBWC during SC/66a. Progress was reported on these items.

(1) Updated Terms of Reference (described above).
(2) Creation of a discussion forum for users having technical difficulties. Barbara Galletti has set up a wiki forum for this purpose and is receiving support from the IWC Secretariat to activate this forum.
(3) Update the English users manual. This work was progressed during SC/66b.
(4) Migrate the catalogue to the IWC for hosting on a server at the IWC Secretariat. However, the computing platform differs between the SHBWC and IWC servers so a new server will need to be purchased to accommodate the catalogue, with a cost implication for the sub-committee. Once the server has been migrated to the IWC Secretariat the IWC and the CCC IT staff will review the cost required to convert the catalogue to PHP for greater flexibility and consistency with other IWC databases. The sub-committee encouraged this transfer as it is believed that it will greatly advance the submission of data.

It was noted that the Australian ARWPIC catalogue (constructed in PHP) is available to the IWC if required.

5.2 Antarctic blue whales

5.2.1 Review new information

Attard *et al.* (2016) presented analysis using the largest genetic dataset to date for Antarctic blue whales (142 individuals, 20 microsatellites, and a 414bp fragment of the mtDNA control region) to assess population structure in this subspecies. The 142 individuals were collected from the Antarctic during IDCR/SOWER cruises. The analysis excludes replicate samples, those genetically identified as pygmy blue whales and individuals of admixed ancestry to both subspecies. Bayesian clustering of microsatellite data revealed evidence of three genetic clusters which occur in sympatry in the Antarctic and that may represent three populations. The genetic findings are supported by similar patterns of differentiation using mtDNA sequences. The findings are consistent with movement data from Discovery marks, photo-identifications, and satellite telemetry as these show large-scale movements across multiple IWC Management Areas as well as small-scale movements. For population structure to be confirmed requires locating the breeding grounds and migratory routes of Antarctic blue whales through satellite tagging in the Antarctic. Tagged blue whales could be simultaneously biopsied to allow genetic analyses with biologically reasonable a priori groupings based on breeding ground locality and to provide a baseline for comparative genetic analyses of samples collected off Antarctica.

In discussion it was noted that 'delta K' analyses of the relative support of the data for different numbers of populations cannot assess whether the data support one population over multiple populations. The delta K method has been used to identify three populations within the data but each individual has been assigned a mixture of the three populations. Some felt that the evidence for more than one population was not convincing and that the data had been over-fitted by STRUCTURE, although they agreed that there was some heterogeneity in the data, with for example 80-90% of individuals being assigned to one population with >50% probability. Some evidence in support of the possible populations was that overall F_{ST} levels were high enough that STRUCTURE is functionally able to detect population structure. In addition mtDNA data provided an independent comparison with the population structure observed with nuclear DNA, and showed similar differentiation, of similar magnitude, between the putative populations. It was noted that the genetic data are from the feeding ground for Antarctic blue whales. If these whales travel long distances to feed, for example to access high density prey aggregations as is seen in the North Pacific (Calambokidis *et al.*, 2009), but still have relatively discrete breeding grounds, assignment plots could look like a longitudinal mixture of multiple populations as observed in the STRUCTURE plot. However, it was noted that if these populations were distinct each individual might be more strongly assigned to one of the three populations than is seen here, even if such individuals are not clustered together because of latitudinal movements. Another observation was that the three distinct breeding populations had been assigned similar numbers of samples each, suggesting equal sampling of each population. It is likely that populations in different oceans were subjected to different levels of depletion and such an even distribution is so surprising as to suggest that the assignments may be an artefact. It was pointed out that there are some differences between the levels of mtDNA differentiation found in this study among the six Antarctic Areas and those reported by Sremba *et al.* (2012) with similar mtDNA data. Sremba *et al.* (2012) found some significant mtDNA differences between Areas which were not seen in the current study.

The sub-committee found the evidence for three populations of Antarctic blue whales inconclusive and noted that there are more robust methods for analysis. They suggested that the authors (who were not present at SC/66b) consider exploring other ordination-based clustering methods with their data because these can have more discriminatory power than STRUCTURE.

Branch reviewed available information on long-distance movements by blue whales. Indirect evidence comes from acoustics and catches of Antarctic blue whales, assuming that they return to feed in the Antarctic each year. If true, acoustic detections near the equator imply movements of >6,300km (Stafford *et al.*, 2004), while a catch in the Congo implies a movement of 5,388km. Mark-recapture data give only a start and end location, but the minimum distance spanned can be calculated as-the-whale-swims. Photo-identification recaptures included 5,200km, 5,677km and 6,650km movements (Torres-Florez *et al.*, 2015; SC/66b/SH11), and the longest movement comes from a *Discovery* mark that was recovered 170° around the Antarctic for a movement of 8,013km. In addition, *Discovery* mark data showing circumpolar movements around the Antarctic (Branch *et al.*, 2007b), suggest that Antarctic blue whales are likely to be a single population, albeit with some genetic structure. The acoustic, catch, photo-identification, genetic, and *Discovery* mark data are total distance spanned over multiple years. In contrast, satellite tag data measures distance swam, but includes meanders and back-tracking, producing swimming distances of >7,000km (SC/66b/SH16), and up to 19,203km over three migration legs in California. In addition, a satellite tag recorded a distance as-the-whale-swims spanning 6,300km from the Bonney Upwelling to Indonesian waters.

In discussion, it was noted that humpback whales occasionally undergo movements of similar distance, for example between breeding grounds (e.g. Pomilla and Rosenbaum, 2005; Stevick *et al.*, 2011) but still have significant breeding ground population structuring. However, it was also noted that there is a wealth of data showing long-distance movements by blue whales while these are rarer for humpback whales, and that humpback whales have relatively high long-term fidelity to breeding sites which underscores this population structure.

Leroy *et al.* (2016) examined six years (2010 to 2015) of continuous acoustic recordings at up to seven different locations in the Central and Southern Indian Basin to assess the peak periods of presence, seasonality and migration movements of Antarctic blue whales. An automated method was used to detect the Antarctic blue whale stereotyped Z-call. Detection results are analysed in terms of distribution, seasonal presence and diel pattern of emission at each site. Z-calls are detected year-round at each site, except for one located in the equatorial Indian Ocean, and display highly seasonal distribution. This seasonality is stable across years for every site, but varies between sites. Z-calls are mainly detected during autumn and spring at the sub-Antarctic locations, suggesting that these sites are on the Antarctic blue whale migration routes, and mostly during winter at the subtropical sites, indicating the likely presence of a breeding area at these latitudes. In addition to these seasonal trends, there is a significant diel pattern in Z-call emission, with more Z-calls in daytime than during the night. This diel pattern may be related to blue whale feeding ecology.

Noting the peak in calls everywhere during the months of April to Sept (including in the Antarctic) it was questioned whether this is more a reflection of seasonal calling behaviour than of distribution or abundance. In response it was noted that published work from California identified two different song types which are used at different times of the year by the same population (Oleson *et al.*, 2007). A behavioural change is likely in autumn (when the peak occurs) as whales appear to produce one song type more often.

SC/66b/SH11 described the movements of Antarctic blue whales based on photo-identification. Identification photographs were collected from the IWC IDCR/SOWER cruises, IWC-SORP voyages, the Institute of Cetacean Research, and naturalists and collegial scientists working in the Antarctic region, 1991-2016, and compiled into the Antarctic Blue Whale Catalogue. This is 14-18% of the most recent accepted estimate of abundance of 2,280 in 1997/98 (CV=0.36, Branch, 2007). The total number of identified whales was 416, represented by 315 left sides and 306 right sides. There were fifteen inter-annual re-sights of fourteen whales, with sighting intervals of 1-12 years, and distances ranging from 19 to 6,650km between sighting locations. The distance of 6,650km over a six-year period is the longest movement of an Antarctic blue whale recorded to date.

The small sample size of re-sights here does not shed light on a specific pattern as both small and large inter-annual movements are represented; there is evidence for both site tenacity and wide-ranging movements. Within-season sighting rates from five survey years ranged from 7-22%. The minimum daily movement of Antarctic blue whales ranged between 1.5 and 162km/day. This is generally consistent with foraging and transiting behaviours as observed for blue whales in the North Pacific and for two satellite tagged Antarctic blue whales in 2013. A cornerstone of the Antarctic Blue Whale Project under the IWC-SORP program is to generate new estimates of abundance using photo-identification data for capture-recapture analysis. The most recent accepted estimate of abundance is based on line-transect data now over 18 years old. The continued collection of identification photographs from the Antarctic will provide data toward a set eventually large enough to obtain new estimates of abundance.

SC/66b/SH10, annex 5 reported on the deployment of an Aural 128s Autonomous Acoustic Recorder (AAR) instrument deployed on the South African Mooring Buoy Array/South Atlantic Meridional Overturning Circulation (SAMBA/SAMOC) mooring off the west coast of South Africa (34°23.63'S; 17°35.66'E) for almost 15 months between in 2014 and 2015 in water depths of 1,118m with the instrument at 182m (although this varied with current speed). Some 3,489.75 total hours of recordings were made on a duty cycle of 20 mins per hour per day. Antarctic blue whale Z-calls and D-calls were detected in September 2014 and December 2014 and between May 2015 and August 2015 with peak densities of Z-call presence (within 20 minute recording blocks) in June and July 2015. Fin whale calls were detected between September 2014 and November 2014 and between May 2015 and November 2015. Call numbers are currently being enumerated. A further instrument deployed further inshore at 800m depth for six months in 2014 yielded no blue whale calls, but fin whale calls were recorded. Two further instruments deployed in December 2015 are currently soaking in the region to the west of Cape Town. These will be recovered in December 2016.

The value of this work was noted, particularly in relation to the extensive catches of Antarctic blue whales off South Africa, Namibia and Angola prior to 1930.

A large number of blue whale baleen plates are accessioned in the Smithsonian Institution in Washington, DC. During SC/66a, a pilot project was established to attempt to extract DNA from these, although their provenance in terms of location still requires confirmation. The plates arise from Japanese catches and data from Japan is required to link the plates to catch locations. An inventory of their origin is required as two factory ships were operational in the particular period of operation (1946/47 and 1947/48). The plates need to be assigned to a particular factory ship to get location information, and to be sampled to allow for transfer of material to SWFSC.

In response to a question of whether DNA is likely to be extractable from these plates, it was reported that this was being tested as a pilot study. However, DNA has been extracted from other plates held under worse conditions that these held in a museum collection. The sub-committee looks forward to further results from this pilot project.

During SC/66a, the sub-committee recommended a review of sightings data from the post-CPIII IDCR/SOWER surveys to determine whether the data are any good for informing on Antarctic blue whale trend or abundance. This intersessional work was convened under Kelly, who was unable to attend SC/66b but provided a brief update on her progress on this topic.

After the completion of the third circumpolar survey, the IWC-SOWER programme continued for another six seasons (2004/05-2009/10); three seasons in Area III and three in Area IV, with most survey effort occurring in south of the IWC-SOWER survey regions, close to the summer sea ice edge. The main aim of these last six surveys was to conduct a series of experiments to both augment analyses towards circumpolar abundance estimates for a range of species, and to test and refine new survey methods that may be used in future IWC survey efforts. The surveys were not specifically designed to return regional design-based abundance estimates (although the intent was to provide very localised abundance estimates for Antarctic minke whales during attempts to collaborate with surveys inside ice regions in the years 2004/05, 2007/08, 2008/09 and 2009/10; and for fin whales in a research area ~55°S in 2005/06 and 2006/07). Although these six survey years yielded over 100 sightings of Antarctic blue whales, all but three sightings (four individuals) were encountered outside track-lines that could support regional design-based abundance analyses, a number far too small to consider proceeding with such analyses. However, with approximately 12,000 n.miles of primary search effort, across the six seasons, Kelly advised that there is potential for regional model-based abundance estimates for Antarctic blue whales, particularly in areas close to the sea ice boundary in Area III and Area IV. Analyses are underway to obtain model-based abundance estimates.

It was noted that Kelly would be continuing with these analyses. The sub-committee welcomed the analyses, **recommended** their continuation and noted that it was very encouraging to maximise these data opportunities given the difficulties of the data collection.

5.3 Pygmy type blue whales

5.3.1 Southeast Pacific blue whales

5.3.1.1 REVIEW NEW INFORMATION

Findlay (In press) provided an overview of the 1997/98 Chilean blue whale cruise carried out on the *Shonan Maru* and the *Shonan Maru* No.2 in December 1997 and January 1998 (see Fig. 4). The objective of the cruise centred on the differentiation of Antarctic blue whales from south-eastern Pacific Ocean pygmy blue whales so that maximisation of blue whale encounters was a priority rather than to survey the area on a random basis in classic line-transect methodology. Totals of 179h 23m of search effort (2,065.4 n.miles of trackline) and 210h 35m of search effort (2,388.5 n.miles of trackline) were conducted by the *Shonan Maru* and the *Shonan Maru* No.2 respectively on the cruise, during which 22 sightings of 22 individual blue whales and 17 sightings of 25 individual blue whales were made from the *Shonan Maru*, and the *Shonan Maru* No.2 respectively, along with one sighting of one 'like' blue whale made from the *Shonan Maru*. These blue whale sightings were distributed throughout the proposed survey area between Iquique and Talcahuano; only after the initial 14-day survey period was a region of higher relative sighting rates identified between 26° and 33°S. This concentration of blue whales was well to the north of more recent observations of blue whales in the region of Isla de Chiloé and the Gulf of Corcovado, although it may well have been affected by the strong *El Niño* conditions at this time. Branch *et al.* (2007c) used line-transect methods to estimate a population abundance of Southeast Pacific blue whales of 452 individuals from the

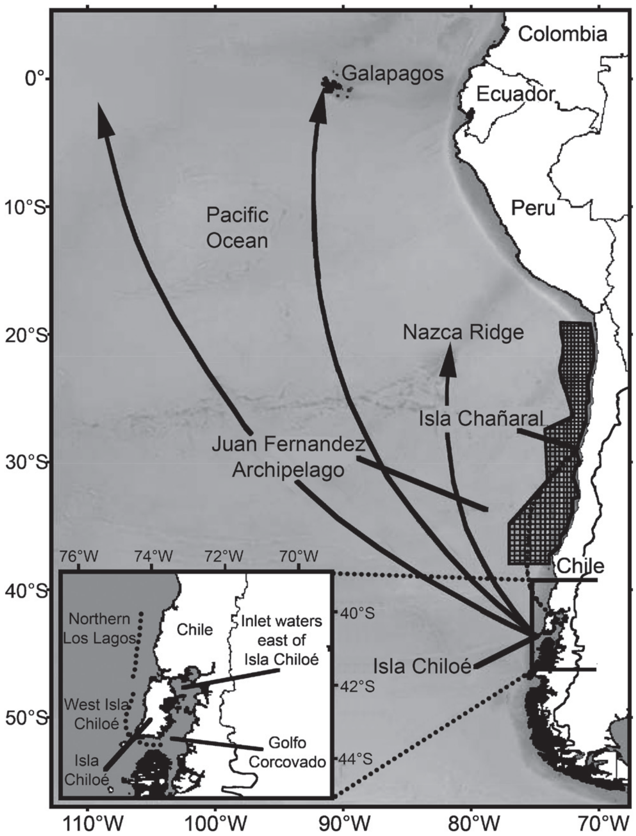

Fig. 4. Feeding ground of the Chilean blue whale, with inset showing summer survey areas off Isla de Chiloé and Golfo Corcovado. The hashed box shows the 1997 IDCR-SOWER survey (Findlay, In press), and black arrows show migratory linkages between Chiloé and lower latitude areas. A dotted line connects Isla de Chiloé and Isla Chañaral, representing a single whale re-sighted in both regions (Galletti Vernazzani *et al.*, 2017).

sightings and effort from this cruise. Williams *et al.* (2011) used the sightings data in a spatial modelling framework in the estimation of abundance of 303 (95% CI 176-625) within the study area, but noted that this was in all likelihood a minimum estimate as the entire range of the distribution was not covered in the survey. The data generated on this cruise have generated considerable outputs on blue whale taxonomy and distribution, acoustics, photo-identification (with further potential for the use of the photo-identification data in broader population assessment studies although the images are some 20 years old), population genetics and the at-sea differentiation of blue whale subspecies). It was noted that SC/66b/SH10 provides information on the song type 2B (SEP2) recorded on the sonobuoys deployed on this cruise.

In response to a question on the photo-identification images collected on the 1997 IWC SOWER cruise, it was noted that 14 left side and 9 right side blue whales were identified and added to the Southern Hemisphere blue whale catalogue. One match has been recorded between these images and the catalogue from Isla Grande de Chiloé. It is understood that the original film images are currently held by researchers in Australia where they were digitised and it is **recommended** that the Secretariat retrieve these images.

SC/66b/SH16 reports on the satellite tagging of seven blue whales in the feeding ground of northern Patagonia, Chile, during mid-April 2015. Minimum distances travelled ranged between 80 and 4,010 n.miles and the longevity of the tags extended between 21 and 162 days. The blue whales initially moved in a wide range of directions which aligned with a general NW movement in the direction of the Galapagos Islands and westward of there. Switching state space modelling showed Area Restricted Search (ARS) behaviour within the protected waters of the Chiloe inner sea, along open waters of the Corcovado Gulf and west of Guafo Island. Furthermore, ARS behaviour (together with deep dives [350m]) was also recorded south of the Galapagos Archipelago by one whale which remained in the area over the period mid-July to late-September, when transmissions ceased. Transit behaviour was noted between feeding areas in the Chiloense Ecoregion feeding ground, but became more evident during offshore and alongshore movements, indicative of migration. It was also reported that funding has been secured for more tagging studies in the region in the next few years.

In discussion, it was mentioned that a concentration of blue whale sightings were made in the region to the west of the Galapagos Archipelago. To the north, there is a latitudinal gap in records between the Galapagos and the Costa Rica Dome, suggesting potentially three independent sub-stocks of blue whales may be found in the eastern central Pacific, namely: those off Baja California, the Costa Rica Dome and off the Galapagos-Peru-Chile region, and in addition to the subspecies of Antarctic blue whales that have been recorded at 8°S west of South America (Stafford *et al.*, 1999).

Seasonal mixing of the whales from the northeast Pacific and southeast Pacific likely occurs within the ETP and matches of whales have been made between California and the Costa Rica Dome, between the Galapagos and the Costa Rica Dome, and between the Galapagos and Isla Chiloe-Golfo Corcovado region. It was also noted that genetic differentiation between southeast Pacific and northeast Pacific blue whales was less than the differentiation between the southeast Pacific and Indian Ocean blue whales, suggesting there may be occasional gene flow across the equator (LeDuc *et al.*, 2007). In contrast, the southeast Pacific blue whales are more differentiated from Antarctic blue whales than they are from the northeast Pacific blue whales, despite some apparent sympatry of these two subspecies in the same breeding area; acoustic data in the southern ETP showed Antarctic blue whales to be present in July, but detected both 2A (SEP1) and 2B (SEP2) songs associated with Chilean blue whales all year round.

SC/66b/SH25 reported on the temporal patterns of Chilean blue whale songs recorded between 2003 and 2015 off Juan Fernandez Island (33°S, 78°W), compared with the pattern of calls detected at acoustic stations to the north and south. Call rates confirm the increasing body of evidence that Chilean blue whales feed in southern cooler waters during the austral summer off the coast of Chile and migrate to tropical waters further north to breed. The similarity between the seasonal patterns of the Chilean blue whale calls and the Indonesia/Australia blue whale calls by latitude suggests that despite being from different acoustic populations, the migration patterns of pygmy blue whales in the southeastern Indian Ocean (Indonesia/Australia) are similar to those in the southeast Pacific Ocean.

It was also queried whether changes in calling behaviour, like a change in calling rate, would compromise the study. The author clarified that they were not attempting to predict numbers of whales from numbers of whale calls. Rather, this research aims to examine drivers (abiotic and biotic) coincident with blue whale behaviour, specifically their use of temperate/tropical waters. To this end, the presence of whale calls (either high or low) were used as a proxy of whale presence in order to examine seasonal timing within temperate and tropical waters, and how this changes across years.

Galletti Vernazzani *et al.* (2017) reported on photo-identification surveys conducted in the waters off Isla Grande de Chiloé, southern Chile from 2004-12 and Isla Chañaral, northern Chile in 2012 (see inset, Fig. 4). Over this time, 1,070 blue whales were encountered yielding, after photo-quality control, 318 and 267 unique photographs of the left and right lateral flank respectively. Using mark-recapture analysis of these left and right photographs collected from Isla Grande de Chiloé over the period 2006-11, open population models estimate that ~550-720 whales are feeding seasonally in this region. POPAN super-population abundance estimates for the feeding ground in 2011 are 711 (95% confidence intervals, CI=573-849) and 549 (95% CI 441-657) for left and right aspect datasets respectively, very similar to the results from the closed population models. Estimates of trend revealed strong annual variation in abundance, peaking in 2009 and suggesting a fluctuating use in the survey area over time, likely related to prey densities. High inter-annual return rates suggest a degree of site-fidelity of individuals to Isla Grande de Chiloé although the number of whales using this feeding ground is relatively small compared to the estimate using the single year data from Isla Grande de Chiloé and Isla Chañaral from 2012.

In discussion it was noted that the abundance estimate reported from the model was roughly double the number of individuals included in the mark re-sight dataset. There was some discussion about what these abundance estimates represent. Since nearly all photo-identification data were collected from Chiloé they provide a relatively accurate measure of the abundance of Chilean blue whales in the Chiloé area, but this is only part of their feeding ground distribution so could not be considered representative of the abundance of the Chilean blue whales as a whole. Previous surveys made to the north of this area and offshore of the coast in 1997 (Findlay, In press; Williams *et al.*, 2011) have yielded a similar abundance of animals, but used different survey methods in a different area, and may represent a different proportion of the population; the connectivity between the two survey areas is unknown, but telemetry tracks reported in SC/66b/SH16 suggest Chiloé blue whales do travel through this area.

The authors noted that they investigated the single year of photo-identification effort off Isla Chañaral (central Chile) in 2012 (n=22) and found no re-sights with the Chiloé mark resight catalogue, in strong contrast to the high inter-annual resight rate (30%) found within the Chiloé catalogue. They highlighted that one abundance estimate had been calculated using mark resight data from both Chiloé (southern Chile, 2006-12) and Chañaral (central Chile, 2012) in an open population model framework, yielding much higher abundance estimates of 1,000-1,400 whales, but mark recapture assumptions of spatially equivalent survey through time were violated with this estimate and it is likely biased high. The sub-committee **agreed** that this was not an appropriate approach for measuring abundance, but that the estimate from Chiloé alone was not likely to represent the whole population, providing at best a minimum abundance.

In discussion of the inter-annual fluctuation in abundance seen in the Isla de Chiloé dataset, it was noted that the resightings data showed a skew typical of a transient/resident mixture and that the abundances of blue whales from Isla Grande de Chiloé might be more appropriately modelled using mark-resighting framework that explicitly accounts for residency and transience. During the meeting Cooke reanalysed the data with a model (used e.g. in SC/66b/BRG25) that allows for this. The results indicated a strong signal of a variable availability of transients by year. The best population estimate for the mid-year (2008½) was 450 animals (CV 0.17) for an open population or 576 (CV 0.16) for a closed population. Annual survival was not precisely estimated (0.89 with an SE of 0.05). Fixing the survival at 0.96 would increase the open population estimate to about 530. The estimated proportion of residents was 40-45% (see Appendix 6). This analysis yielded abundance estimates very similar in magnitude to those presented by Galletti Vernazzani *et al.,* (2017) but better accounts for differing proportions of residents and transients using the area in each year.

5.3.1.2 PROGRESS ON POPULATION ASSESSMENT

SC/66b/SH23 reconstructed the population trajectory and recovery status of Chilean blue whales using a Bayesian population dynamics model incorporating multiple data sources, including two alternate catch series (catches only from Chile and catches from the Southeast Pacific as summarised by Williams *et al.* (2011), and two abundance estimates as described by Galletti Vernazzani *et al.* (2017): 'Isla de Chiloé' (based on a mark resighting series from only the Isla de Chiloé region), and 'Chiloé and Chañaral' (based on a mark resight abundance estimate generated using photo-identifications from both regions). Two alternate population growth scenarios were explored: one with an informative prior on r_{max} (a normally distributed prior of 6.2%, SD 2.9%), and another using the mark resighting data from 2006-11 to inform the population trend. The effect of including a N_{floor} constraint on population bottleneck abundance was also explored. Median pre-exploitation abundance was estimated at 2,100-3,600 whales, with the population recovery status varying considerably between the two population abundance scenarios but not varying substantially between the differing catch, population bottleneck and population growth rate scenarios.

In response to a question on the spatial extent of the catch series, it was reported that there were two major catch areas off central and northern Chile and off Peru, and that the current feeding ground range is far larger that the geographic range of the Isla Grande de Chiloé estimate.

Discussion of this assessment then focussed on the influence of the two alternative abundance estimates on the status outcomes for this population. The 'Isla de Chiloé' dataset provides a minimum abundance that represents whales regularly sighted in southern Chile only, so it is spatially limited relative to the feeding range of the Chilean blue whale population. Isla de Chiloé abundance levels are not much higher than those previously reported by Williams *et al.* (2011) in 1997 (n=303, 95% CI 176-625). Using the 'Chiloé and Chañaral' estimate increases population recovery substantially, for example changing increasing median recovery from 0.26 to 0.74 with the Chile-only catch series and from 0.18 to 0.56 with the southeast Pacific catch series. However the sub-committee noted that this higher abundance estimate was less methodologically sound due to violations of the mark resight model as discussed above, and **agreed** that at present all that could be concluded is a minimum population status estimate for this population.

Further discussion followed about how photo-identification and biopsy sampling of whales might be geographically extended, particularly given the high resighting rate seen at Chiloé. Alternative approaches to measuring population abundance can be provided by genetic markers, which can be used to estimate effective population size for example. Torrez-Florez *et al.* (2014) measured effective population size to be 62 individuals (95% CI 52-

105) within the Gulf of Corcovado region for example; however this estimate is also most applicable to the Chiloé/ Corcovado feeding region rather than the entire population using the Chilean coast. The sub-committee highlighted the urgent need to collect photo-identification data from other areas along the Chilean coast north of Chiloé, particularly including areas of blue whale aggregations such as Isla Chañaral, as well as to reconcile photo-identification catalogues among all survey areas. The sub-committee **recommended** that this work be done and **agreed** that a regional workshop should be held during the Conference of the Latin American Society for Aquatic Mammals (SOLAMAC, Sociedad Latino Americana de Mamiferos Aquatics) in Valparaiso, Chile in November 2016. The goal of the regional workshop would be to encourage marine mammal scientists working in the eastern South and Central Pacific to reconcile their photo-identification catalogues in order to obtain more robust information on population connectivity and estimation of abundance for blue (and other) whales in the region.

5.3.2 Indonesia/Australia blue whales

SC/66b/SH27 reports on results from Southern Hemisphere Blue Whale Catalogue (SHBWC) on comparisons of photo-identification data collected from the Australia and New Zealand regions. Photo-identification of 431 blue whales from four different research groups working in the Perth Canyon (west Australia), Geographe Bay (west Australia), Bonney Upwelling (southern Australia) and around New Zealand were compared and provided five whales resighted between different areas and years. Matches have been found within all three areas of Australia, but no matches have been found with New Zealand blue whales. Blue whales sighted in Perth Canyon, Geographe Bay and Bonney Upwelling have been resighted later in any of these areas, representing a high level of connectivity between these areas and thus, strengthening the hypothesis of one distinct population for Indonesia/Australia whales. These results are consistent with genetic data that shows blue whales from Perth Canyon, Bonney Upwelling and Geographe Bay are part of the same stock. While genetic analyses and morphological descriptions have found that New Zealand blue whales are similar to those found off Indonesia/Australia, the authors have found no matches. However, the small sample size from New Zealand still prevents conclusions being drawn about possible isolation from the Indonesia/Australia population.

As the catalogue grows, there is growing potential to use within-region catalogues for mark-recapture modelling of population abundance. This may now be possible for Australia given the size of the regional catalogue as reported in SC/66b/SH27. Australian and NZ scientists were thanked for their contribution to this effort and **encouraged** to keep up photo identification efforts and submissions to the SHBWC in order that a regional population abundance estimate can be developed for this population using resight data.

Tripovich *et al.* (2015) examined recordings from a 15-month (May 2009-July 2010) continuous acoustic data set collected from a bottom-mounted passive acoustic recorder at a sample frequency of 6 kHz off Portland, Victoria, Australia (38°33'01"S, 141°15'13"E) off southern Australia. Analysis revealed that songs from both subspecies (8 [SEI] and 6 [ANT]) were recorded at this site, and general additive modelling revealed that the number of calls varied significantly across seasons. Antarctic blue whales were detected more frequently from July to October 2009 and June to July 2010, corresponding to the suspected breeding season, while Indonesia/Australia blue whales were recorded more frequently from March to June 2010, coinciding with the feeding season. In both subspecies, the number of calls varied with time of day; Antarctic blue whale calls were more prevalent in the night to early morning, while Indonesia/ Australia blue whale calls were detected more often from midday to early evening. Using passive acoustic monitoring, it was shown that each subspecies adopts different seasonal and daily call patterns which may be related to the ecological strategies of these subspecies. This study demonstrates the importance of passive acoustics in enabling us to understand and monitor subtle differences in the behaviour and ecology of cryptic sympatric marine mammals.

Double presented a compilation of cetacean sightings data from 40 seismic surveys conducted off Australia. This information has been provided to the sub-committee following a recommendation during SC/66a that seismic survey observations of blue whales off New Zealand and Indonesia/Australia be investigated to find out if these data might be useful for better understanding their habitat use and distribution.

Substantial discussion was held around the potential of these data to be useful for addressing this question. A number of caveats were raised with respect to using data of this type. Firstly some potential observer error in identification was noted because Australian marine mammal observers are not required to have experience or specialist training in cetacean identification. For species such as blue whales where discrimination between pygmy and Antarctic blue whales in the field is difficult even for experienced naturalists, these data cannot be relied upon for accurate discrimination of the two subspecies. Even if the identification of subspecies is not considered a problem, an additional challenge for identification is that many sightings are made at a reasonable distance from the ship, with prescribed distances at which shutdown is initiated varying by species. Given that these identifications are usually made at a distance, photographs accompanying the sighting can sometimes be useful for confirmation of species but are rarely useful for photo-identification of individuals.

Effort data were also discussed to understand whether these data represent presence only records or whether presence and absence could be determined. It was reported that some effort data may be available but could potentially be compromised by the elements described above, as well as potential effects of seismic operations on cetacean behaviour, since many species change course to avoid a seismic survey operation from a reasonable distance away. An additional consideration is the timing and location of seismic surveys and what information they will consequently provide about seasonal distributions. For example seismic surveys are often scheduled to occur during periods of low seasonal abundance of particular seasonal species in order to mitigate detrimental effects. In response it was noted that such seasonal mitigation is seldom used for blue whales in Australian waters, although it is applied for other species such as right whales.

In response to a question on whether any Passive Acoustic Monitoring (PAM) by MMOs could be utilised to address this question, it was noted both that PAM is not utilised extensively in the Australian monitoring system and that flow noise and background noise would preclude adequate detection of blue whale calls.

It was commented that the 'Joint Industry Programme' is currently conducting a similar compilation of marine mammal sightings from their global databases (particularly New Zealand, Australia and UK) to find out if their whale sightings are useful for understanding more about cetacean distribution. The sub-committee was interested to hear about the progress of this initiative. The sub-committee also noted that they had received a scientific proposal with funding implications to conduct blue whale habitat modelling using MMO sightings data from seismic surveys around New Zealand and Australia. This could provide useful new information on pygmy blue whale distribution and foraging hotspots in a region where their distribution is poorly known. However, they also noted the many challenges of working with such data, as discussed above.

5.3.3 Madagascar blue whales

SC/66b/SH33 reports on the detection of song type 9A (Madagascar-type) calls of pygmy blue whales off the northwest coast of Madagascar during the months of November and December 2015. This represents the northernmost documentation of the Madagascar song phrase close to the east African coast. The timing is slightly asynchronous with other acoustic data which suggests these animals should be further south at this time of year. The authors suggest that the blue whales documented off the northwest coast of Madagascar during November and December may be migrating south in the Mozambique Channel from a more northern breeding range to feeding grounds to the south (i.e., on the Madagascar Plateau; Best *et al.*, 2003). Alternatively, the breeding range may extend into the northern Mozambique Channel and detections may represent the tail end of occupancy in the breeding area.

It was proposed that these whales may be linked to past catches off Somalia. It was noted that foetal lengths in the catches off Somalia are different from those in the Northern Indian Ocean, suggesting separation from this area and a link between Somalia and Madagascar. The sub-committee **recommends** the continuation of this project, and given that there are few biopsy samples from Madagascar song type 9A blue whales, the sub-committee **encouraged** the collection of biopsy samples during this and other projects.

5.3.4 New Zealand blue whales

SC/66b/SH08 and Olson *et al.* (2015) were presented together since SC/66b/SH08 is an update to Olson *et al.* (2015). The basis for the research arose from the 2013 IWC-SORP Antarctic Blue Whale Voyage that departed from and returned to New Zealand (Double *et al.*, 2015). Blue whales were detected both visually and acoustically in New Zealand waters during the voyage and it was confirmed that the animals producing the New Zealand song type 3 were indeed blue whales (Miller *et al.*, 2014). Photo-identifications were collected during the 2013 voyage and were pooled with photographs collected ancillary to their other research projects to produce a total of 38 individuals from seven months of the year and from locations all around New Zealand. Two of the 38 whales were re-sighted inter-annually (in Cook Strait in June 2011 and then again in March 2013 and in Cook Strait in June 2008 and June 2015) which suggests that there is a small population of blue whales that repeatedly visit or are resident in New Zealand waters. Torres *et al.* (2015) reported another re-sighted whale: between Hauraki Gulf in November 2010 and the South Taranaki Bight in January 2014. Of the total three re-sighted individuals to date, two of the re-sights have been inter-seasonal (June-March; November-January) suggestive of residency. Blue whales have now been documented in all four seasons, and in 11 months of the year in New Zealand waters. Feeding has been observed in multiple areas around New Zealand. An interesting addition to the collection of photo-identified individuals is a blue whale that was photographed during IWC-SORP humpback research conducted at the Kermadec Islands in October 2015 (SC/66b/SH05; SC/66b/SH10). New Zealand type blue whale calls have been recorded in the winter months in Lau Basin, approximately 1,000km to the north of Raoul Island (Balcazar *et al.*, 2015). The observed New Zealand and Indonesia/Australia whales were similar to one another, but noticeably different from Antarctic blue whales. The differences were in head shape, tailstock, surfacing pattern, and skin condition, as well as overall body length. Sremba *et al.* (2015b) also found New Zealand and Indonesia/Australia whales to be genetically similar.

While this photo-identification catalogue is growing, its small size does not currently allow for mark-recapture analysis of population abundance, an important goal for assessment of this regional population. It was noted that there are two nascent groups constructing New Zealand photo-identification catalogues and that there are a number of photo-identifications from the New Zealand region yet to be uploaded to the Southern Hemisphere blue whale catalogue. Given that abundance of this population is currently unknown and essential for conducting population assessment of this regional population, the sub-committee **recommended** these catalogues be reconciled through the Southern Hemisphere blue whale catalogue to enable mark recapture analysis of regional pygmy blue whale abundance. This recommendation is also raised in the discussions of the Databases Working Group (Item 3.2, Annex R).

Torres and Klinck (2016) provide a report on their recent field surveys of the Taranaki Bight, New Zealand during 20 January and 10 February 2016. This survey collected data on blue whale ecology including details on distribution, residency, abundance, behaviour, health and population parameters. During the 2016 season, five hydrophones were deployed and ~1,500 miles were surveyed, yielding 22 blue whale sightings of 33 individuals. The distribution of whales in this area varied from 2014, likely due to El Niño conditions in 2015. Twelve biopsy samples and 8 faecal samples were collected to examine population structure, foraging ecology and health. In addition, 4,000 photographs were captured to contribute towards ongoing photo-identification analysis. A second field season is planned in this region during January and February 2017.

The sub-committee recognised the importance of this project in providing a population identification of New Zealand blue whales and an understanding of their use of the Taranaki Bight area. It was noted that another research group has also deployed six new buoys throughout the area which will provide information on the seasonality of blue whale migrations through the Cook Strait.

5.3.5 Northern Indian Ocean blue whales

Brownell presented an update on intersessional work to gather photo-identifications taken in this region. Data collection is in progress. The biggest data gap at present is the lack of information on population size. He noted the significant size and likely impact of Soviet catches on this population. Olson observed that she is working on the available collections of blue whale photos in the Northern Indian Ocean; there are at least six organisations that have been identified as having identification photos of blue whales. The sub-committee noted that Brownell and De Vos have developed a regional stranding database for large whales which will include information on ship strikes off Sri Lanka. However there are problems with accurate identification to species. The sub-committee strongly **encouraged** continued initial work identifying photo collections for possible future analyses. They also noted that there are a few whale-watch operators working in the region and the potential: (i) to develop regional training and guidance schemes to assist data collection; and (ii) to develop citizen science initiatives to garner additional photo-identification data.

5.4 Conclusions and future directions

Work towards an in-depth assessment of Southern Hemisphere pygmy blue whales continues. The Chile/Peruvian and Australia/Indonesia blue whale stocks remain highest priority for population assessment, with the sub-committee strongly in support of continued data gathering in all regions to better understand stock structure and identity in areas where data are sparse such as the southwestern Indian Ocean and northern Indian Ocean.

6. SOUTHERN HEMISPHERE FIN WHALES

Herr *et al.* (2016) summarised the results of a dedicated distance sampling helicopter survey from the *R/V Polarstern* for fin whales around the western Antarctic Peninsula between 25 January and 11 March 2013. During the survey, there were 117 fin whale sightings (337 individuals). The majority of sightings were reported north of the South Shetland Islands resulting in a model based abundance estimate of 4,898 (95% CI 2,221-7,575) fin whales.

The sub-committee welcomed this information, noting that there are very few other fin whale abundance estimates available from the Southern Ocean. They noted that there is no correction for $g(0)$, which makes this a minimum estimate of fin whale abundance in the survey area.

At SC/66a the sub-committee had recommended an inspection of post-CPIII sightings data collected for fin whales, similarly to the work done for Antarctic blue whales and reported in Item 5.2.1. This work was conducted intersessionally by Kelly, who was unable to attend SC/66b and provided a short report on her progress. Her thoughts to date were summarised as follows:

(a) A complete circumpolar, south of 60°S abundance estimate for fin whales for SOWER CPIII remains to be estimated, although the abundance estimates presented by Branch and Butterworth (2001) for CPIII do apply to some 280º of longitude of the circumpolar region.

(b) A circumpolar, south of 60°S abundance estimate for fin whales from CPIII, and selected regional (or even more local) abundance estimates from the post-CPIII years are also possible, given the numbers of sightings.

(c) As with Antarctic blue whales (see Item 5.2.1), abundance estimates from the post-CPIII SOWER data would likely be better derived within a model-based framework. However since it is thought that some unknown proportion of fin whales may distribute further north of 60°S in the summer months, any abundance estimates from IDCR/SOWER are likely to be an under-estimate of the total. Kelly concluded that what needs to be discussed is whether abundance estimates that are limited to south of 60°S, and which are thought to be negatively biased to some unknown degree, are still useful for any future assessment of Southern Hemisphere fin whales.

The sub-committee noted that JSV data suggests that the IDCR/SOWER surveys south of 60°S likely under-estimate fin whale abundance by a factor of 4.8-8.7, since most fin whales are north of 60°S (Butterworth *et al.*, 1994; Butterworth and Geromont, 1995). Furthermore, most historical catches of fin whales were largely south of 60°S, and thus whaling may have preferentially removed the more southerly fin whales, resulting in a change in distribution. It was also noted that there are additional abundance estimates for fin whales from the JARPA surveys (e.g. Matsuoka *et al.*, 2006), but that these have high associated rates of increase. For all of these surveys, estimates of $g(0)$ are required. Finally, additional useful information exists in the JSV data and in the more than 30 years of IDCR/SOWER transit legs to and from the Antarctic.

In discussion regarding the utility of acoustic data for determining stock structure in Antarctic fin whales, it was noted that there are persistent differences between the fin whale calls in the western Antarctic Peninsula and the East Antarctic, indicating two distinct populations. It was cautioned that fin whale call interpulse intervals are known to change over time (Morano *et al.*, 2012; Oleson *et al.*, 2014). However, the higher frequency components remain relatively stable over time and could therefore potentially be used for abundance estimation.

The sub-committee noted that Kelly will complete her review of these data intersessionally and provide a report to SC/67a. The sub-committee **recommended** that abundance estimates of fin whales be obtained from the full CPIII set of surveys from IDCR/SOWER, and subsequent surveys.

SC/66b/SH22 and SC/66b/SH29 together provided information regarding a line-transect distance sampling survey conducted on board a Chilean fishing vessel operating around the South Orkney Islands and Elephant Island. The survey was conducted over 10 days during February 2016 and sighted 41 fin whale groups (61 individuals). Concern was expressed that trawling activity occurred at least twice within a confirmed feeding aggregation of a mixed cetacean group including calves of both humpback and fin whales, and other marine mammal and seabird species. The authors urged that this be discouraged. Minimum abundance estimates were obtained of 528±362 fin whales around Elephant Island and 796±516 fin whales around the South Orkney Islands.

In discussion it was noted that fin whales often form very dense and patchy aggregations, for example, being focused only at one end of an acoustic array of recorders separated by 60 miles. While these surveys indicate substantially more fin whales than expected given the results of the IDCR/SOWER surveys, this might either be due to high variability in encounter rates, or the result of more fin whales moving south of 60°S to occupy a new 'hotspot', or expand into their historic range, around the west Antarctic Peninsula and surrounding island groups.

The sub-committee **recommended** that in light of multiple smaller surveys being conducted in various places around the Antarctic, the results of these surveys should be compiled. They **recommended** that this, and an intersessional synthesis of these data and other potential data sources of use for future assessment of Southern Hemisphere fin whales to the Scientific Committee next year. The sub-committee **agreed** to form three intersessional e-mail groups (see Annex V for members and Terms of Reference) to: (1) summarise the fin whale information available from the west Antarctic Peninsula region; (2) develop a proposal for a dedicated fin whale survey (both convened under Herr); and (3) examine fin whale stock structure (convened under Jackson).

SC/66b/SH30 outlined a concept for a proposal for a ship-based survey around the western Antarctic Peninsula, with a focal area around the South Shetland Islands. Survey plans included visual surveys complemented by UAV (multicopter ARF Okto XL and fixed-wing Bormatec), concurrent with a standardised krill survey. The survey would include opportunities for biopsy sampling and photo-identification of fin whales and fin whale call recordings would be obtained using passive acoustic recordings together with behavioural observations. Initially, funding and 3-4 weeks of ship time on a suitable research vessel would be sought.

In discussion, it was noted that fin whales in the Antarctic have been observed to be very clearly marked and with distinctive external morphology, and thus have great potential for photo-identification matches. It was also noted that there is currently no post-whaling fin whale genetic data available from the South Atlantic, although analyses of bones from the Sub-Antarctic islands between about 54°-55°S, 36°-38°W have identified a number of fin whales present there before the 1930s (Sremba *et al.*, 2015a).

The sub-committee was reminded that for the next seven years the Argentinean vessel, *RV Tango*, is potentially available for this kind of work in the west Antarctic Peninsula, including South Orkney, under the auspices of IWC-SORP (see SC/66b/SH10 and SC/66b/SH15).

The sub-committee **recognised** the importance of collecting fin whale data, in particular genetic samples, from this region and **encouraged** the collaborative development of this proposal, if possible with an expanded longitudinal and latitudinal scope.

7. REVIEW OF SOUTHERN HEMISPHERE ABUNDANCE ESTIMATES

The sub-committee provided an updated list of abundance estimates (see Annex S).

8. GENETIC DATABASES ARISING FROM ASSESSMENT WORK

Two mitochondrial DNA genetic databases have been constructed following the completed In-Depth population assessments of Southern Hemisphere humpback whales (IWC, 2015) and to help develop population structure hypotheses for pygmy blue whales (Item 5.1). Summaries of these papers are given below.

SC/66b/SH18 reviewed published records of mtDNA control region sequences of Southern Hemisphere humpback whales as a first step in developing a validated register of haplotypes for future analyses of interest to the Scientific Committee. The initial review was restricted to sequences submitted to GenBank as ‘population datasets’ and accompanied by references to six publications in peer-reviewed journals. The sequence variation for all of these submissions was compared using a standard segment of 465 base pairs in length, where available, to identify unique haplotypes, many of which were reported in more than one publication. A small number of likely sequencing errors in some submissions were identified and it was noted that many haplotypes were represented by multiple GenBank accession numbers and haplotype codes assigned by individual authors. From the review, a means was provided to cross-reference the different internal codes and redundant GenBank codes, resolving 223 haplotypes. A standardised nomenclature was presented for ‘internal codes’ and GenBank codes based on precedent of publication. The review concluded that GenBank was not well suited for hosting a standardised register, and suggested instead further computational development to automate matching of haplotypes, similar to the species identification program DNA Surveillance, and to include spatially explicit information on the location and frequencies of haplotypes, similar to the existing searchable database for the North Pacific humpback whales.

The sub-committee thanked the authors for their useful review, and noted that the proposals therein would be considered by the Scientific Committee in the broader context of database coordination. The dataset and standardised nomenclature provided by the authors is anticipated to be lodged with the IWC Secretariat and made available through the IWC website. However before this dataset is completed, substantial additional sequence data will be supplied by Rosenbaum, providing the most complete mtDNA dataset for Southern Hemisphere humpback whales and representing all data used to contribute to the Southern Hemisphere humpback whale in-depth assessment.

SC/66b/SH17 reports on progress made by an intersessional e-mail group that was formed last year in preparation for the pygmy blue whale assessments. The objectives of this group were to: (1) establish a common nomenclature for SH pygmy blue whale mtDNA control region haplotypes; and (2) identify haplotype sequences that have been submitted to GenBank and are identical over at least the region common across submitted datasets. Although these objectives were identified to further the Southern Hemisphere pygmy blue whale assessments, in discussion the group agreed that mtDNA sequences from blue whales in the eastern North Pacific should also be included given that some haplotypes are shared between this region and the Southern Hemisphere. A total of 133 sequences were downloaded from GenBank, including datasets from six population-level studies that were used in the construction of a reference haplotype library. After these sequences were trimmed to include only a segment that was common across all six datasets (327bp in length), they were compared to each other to identify unique sequences. Eighty-nine unique mtDNA haplotype sequences were identified, and the nomenclature first assigned to each sequence, based on GenBank submission dates, was retained for the library. Based on the 327bp-standardised segment, 34 haplotype sequences were represented more than one time, such that 44 sequences were considered duplicates. The construction of this haplotype library, and the identification of submitted sequences that are identical over the consensus region, will facilitate building a combined dataset in the future if needed for assessments of pygmy-type blue whales. In completing this exercise, the need for a unique sample identifier (voucher number), and if possible location data, to be included in GenBank submissions was noted, and the authors recommended that future studies sequence at least the 327bp consensus and reference the haplotype nomenclature established here.

9. OTHER

The sub-committee **endorsed** a proposal developed by Skaug to organise an open presentation on new epigenetic developments for measuring whale age (e.g. Polanowski *et al.*, 2014) for the IWC next year at SC/67a, introducing IWC scientists to the concept and methodological developments of this technique. This sub-committee has previously welcomed updates on this topic (e.g. IWC, 2015) and also welcomed this proposal, **recommending** that it be organised for SC/67a. This would require the sub-committee supporting Dr Simon Jarman to attend the IWC as an Invited Participant to present this work and contribute to discussions in other groups (EM, BRG and SD).

SC/66b/SH19 summarised efforts to calibrate underwater sound levels from calibrated year-long continuous recordings made by custom autonomous recording devices deployed at two Antarctic sites off east Antarctic in 2014 (IWC Management Area IV). The Southern Ocean Hydrophone Network (SOHN) was formed under the auspices of IWC-SORP with the goal of better standardising and coordinating a circumpolar network of Southern Ocean acoustic recording devices for monitoring of marine mammals. The use of ambient noise levels and long-term spectral averages as a preliminary means to identify bands of energy potentially attributable to ice, wind, and known vocalisations from marine mammals was investigated. Remotely sensed observations of wind-speed and ice cover were used to conduct a preliminary investigation of the relationships among ambient sound levels and physical environmental processes. Such investigation is particularly suited to Antarctic waters where noise from shipping is minimal. Quantifying the relationships among ambient sound levels and noise-generating physical processes may help to address abiotic environmental factors that can cause site-specific variability in detections of marine mammals and may facilitate comparison of acoustic recordings from different instruments, locations, and times. A cursory and non-exhaustive list of marine mammal detections from these recordings included calls from Antarctic blue whales, fin whales, minke whales, killer whales, sperm whales, humpback whales, leopard seals, Weddell seals, and crabeater seals.

The sub-committee welcomed these efforts, noting the importance of calibration for assessing variability in acoustic detections and improving comparability of acoustic data.

SC/66b/SH31 described a small, juvenile rorqual live-stranded on Qeshm Island, Iran, in the northern Strait of Hormuz (Persian Gulf) in September 2007; the first record of *B. omurai* in Iran, the Persian Gulf and in the NW Indian Ocean. The cause of the stranding remains unknown but the whale (QE22.09.2007) showed no severe traumatic injuries nor was it emaciated. Based on at least seven morphological features, considered diagnostic in combination, the animal was positively identified as an Omura's whale, *Balaenoptera omurai*. Features included diminutive body size (397cm); a large number of ventral grooves (*n*=82) extending behind the umbilicus; a strongly falcate dorsal fin; asymmetric colouration of the head (especially lower jaws) reminiscent of fin whale, including unilateral dark eye, ear and flipper-to-flank stripes; faint/incomplete lateral rostral ridges; and a low number of short, broad baleen plates (204 in right jaw). The existence of a local *B. omurai* population in the eastern Persian Gulf or northern Arabian Sea is more likely than the separation of a very young animal or mother/calf pair from any of the known distribution areas in the eastern Indian Ocean or Madagascar.

The authors were not present to discuss their paper. However, the sub-committee welcomed this information and noted that the possibility of *B. omurai* occurring in the region should be kept in mind when identifying stranded whales and during sighting surveys.

SC/66b/SH15 reported on sightings of sei whales in sub-Antarctic and Antarctic waters off the north Antarctic Peninsula from ship-based line transect surveys during the austral summers from 2013 through 2016. Of 778 encounters of cetaceans, 4% were sei whales. Eighty individuals were observed in 32 groups, of which 37% were in Scotia Sea, 31% in the southern region of Drake Passage, 28% in the entrance to the Beagle Channel (BC), and 3% in Mar de la Flota/Bransfield Strait. No sei whales were observed in the Estrecho de Gerlache/Gerlache Strait. Most of the sightings were between 60° and 61°S. Dispersal movements of sei whales has been described in the past, and it is possible that larger aggregations of this species during austral summer occur further north of the study area, around the Sub-Antarctic islands between about 52°-55°S, 36°-58°W, while some adults continue further south towards the proximities of the South Orkney Islands and the Antarctic Peninsula. Groups with calves were seen only in the Beagle Channel on two occasions. The presence of many seabirds around some of the sei whales sighted in the area during these surveys could be indicative of the presence of fish schools. Historic and current information on the distribution and abundance of sei whales in the South West Atlantic and Southern Ocean is limited, and the extent to which this species has recovered since it gained full protection in 1979 is still uncertain. Whether these observations of sei whales are indicative of rising numbers in the Southern Hemisphere or dispersal movements is unknown and will require further studies in these areas.

SC/66b/SH20 reviews the distribution of sei whales based on literature and new records from the southwest Atlantic Ocean and reports on sightings from surveys conducted on Vitória-Trindade Seamount Chain, Brazil, between 2011 and 2015. Thirteen groups of sei whales were recorded during the expeditions. The group size ranged from one to five individuals, including adults and calves. These new records and the presence of newborn individuals indicate that Trindade Island and Martin Vaz Archipelago represent the winter concentration and breeding area for the species in the southwest Atlantic. This provides important new information about a possible calving area for sei whales.

In discussion it was noted that identifying a sei whale calving ground would represent significant news for this poorly known species. There was some debate about other evidence that sei whales occur in this area. It was noted that sightings have recently been made on a Brazilian whaling ground, where 3,600 sei whales were previously killed during the modern whaling period (Andriolo *et al.*, 2010). However sightings of this species along the coast are rare. It was observed that sei whales may shift in distribution depending on the climate, for example they were sighted in very tropical waters in the 1960s. In response to a question as to whether Bryde's whales could be mistaken for sei whales, it was clarified that sei whales were consistently caught off Brazil for a decade and catches over time were relatively stable, suggesting a consistent presence over time. It was noted that there may be a transition area around about 22°S between Bryde's whales and sei whales. The sub-committee encouraged further work in this region to understand the nature of this wintering ground.

10. WORK PLAN AND BUDGET CONSIDERATIONS

The sub-committee assessed and prioritised funding requests for the biennial period, 2016/17 and 2017/18, against Scientific Committee criteria and sub-committee priorities identified during the course of this meeting. Sub-committee recommendations for funding are detailed in the following work plan (unless otherwise indicated).

10.1 Humpback whales

10.1.1 Southern Hemisphere humpback whales

At SC/65b the sub-committee identified key work items which were important for concluding the 2014 assessment of Australia and Oceania (BSD/BSE1/BSO). These were not completed intersessionally and were retained in the work plan for SC/67a.

(1) Measurement of the minimum abundance of BSD used in the assessment of humpback breeding stocks BSD/BSE1/Oceania (convened by Kelly). The £5,000 GBP budget for this activity was allocated in 2014/15 and is retained from the previous funding cycle to enable completion of this activity.
(2) Work to evaluate the available genetic data, assumptions and analytical approaches for establishing mixing proportions of breeding stocks in the Antarctic (convened by Jackson).

The sub-committee also **recommended** the completion of a re-analysis of the sightings data reported in DuFresne *et al*. (2014) in order to determine the most appropriate survey method for measuring BSD abundance in the future. This work commenced in 2015 and will be completed by SC/67a. Kelly acted as Convenor for this group.

The sub-committee strongly recommended these tasks to be completed by SC/67a. Work will be progressed by two intersessional email groups. Terms of reference of these groups and their membership are provided in Annex V.

Modelling work will be undertaken by Butterworth and colleagues to provide revised population assessments following completion of (1) and (2) above, and to develop a metaprior on r_{max} derived from Southern Hemisphere line transect abundance surveys and mark-recapture data. The £2,000 GBP budget for this activity was allocated in 2014/15 (see Item 7.1.1 in IWC, 2015) and is retained from the previous funding cycle to enable completion of the assessment of BSD.

Following the humpback whale synthesis review discussed in 2015 (Item 3.2.2, IWC, 2016), the sub-committee **recommended** a number of field, modelling and analytical activities that would fill key data gaps identified at the conclusion of the in-depth assessments of Southern Hemisphere humpbacks in 2014. In this context, the sub-committee recognised the importance of modelling analyses to address specific needs identified by the sub-committee for future assessments of Southern Hemisphere humpback populations (see Item 3.3). The modelling work will be undertaken by Butterworth and colleagues with a budget allocation of £2,500 GPB in 2016/2017 and £2,500 GPB in 2017/18.

The sub-committee recognised the long-term value of photo-identification catalogues to support future assessments and **recommended** that work continue on the Antarctic Humpback Whale Catalogue (see Item 3.1.5). The work would be undertaken by Carlson and colleagues with a budget of £15,000 GBP in 2016/17, as agreed during SC/66b. It was suggested that future funding be more strategically framed in terms of the specific scientific questions that this work can help to address and which geographic regions are highest priority for photo-identification matching for this sub-committee. An intersessional e-mail group was convened under Zerbini and Olson to facilitate this (Annex V).

The sub-committee also **recommended** further intersessional discussion to clarify relationships between photo-identification data holders from initiatives such as *Happywhale.com* that provide opportunistic sightings data and existing catalogues, and the role that they might play within the context of the IWC's use of photo-identification data generally. An intersessional e-mail group was convened under Bell to facilitate this (Annex V).

The sub-committee **recommended** the organisation of a one-day workshop to bring together researchers from South America to discuss standardisation and integration of photo-identification catalogues for blue and humpback whales (see discussion in Item 5.3.1). The meeting would be held just before the Latin American Marine Mammal (SOLAMAC) meeting in November 2016 to ensure maximum attendance and cost-effectiveness. The organisation would be undertaken by Zerbini, Olson and colleagues with a budget of £4,600 GBP in 2016/17, as agreed during SC/66b.

10.1.2 Arabian Sea humpback whales

Recognising the Endangered status of the Arabian Sea humpback whale population and **reiterating** serious concern about its status and threats, the sub-committee **recommended** continued support of the Arabian Sea Whale Network, exploratory surveys, molecular genetics for the Arabian Sea population, undertaken by Minton, Willson and colleagues, as detailed below.

The sub-committee recognised the importance for the Arabian Sea Whale Network of developing a regional online data archiving platform based on the open source Wildbook/Flukebook platform, to facilitate data archiving, analyses and sharing. The development will be undertaken by Minton and colleagues, with a budget allocation for development of £10,000 GBP in 2016/17.

The sub-committee also supported continued work to: (i) confirm the taxonomic subspecies/species status of the Arabian Sea humpback whale population; and (ii) to explore the genetic variability of the population in detail by studying individual age, relatedness, family trees and social structure, including inbreeding assessment. The work would be carried out by Rosenbaum and colleagues, with a budget allocation of £7,500 GBP in 2016/17.

In 2014, the sub-committee recommended that Sutaria and colleagues conduct a series of exploratory surveys to be undertaken off the coast of Gujarat, India, to determine seasonal patterns in spatial and temporal habitat use of humpback whales and gather current information through interviews of marine users and opportunistic vessel based surveys. New information arising from this work has been presented to SC/66a (Sutaria *et al*., 2016) and SC/66b (SC/66b/SH34). To date the study has identified the Saurashtra and Kachchh coasts of northern Gujarat as likely habitat for the Arabian Sea humpback whale, and has begun documenting regional strandings, with blue and Bryde's reported and blues sighted off the coast between November and April. The survey work has been conducted very frugally to date, and there is now a significant under-spend on 2014-16 allocated funds of £19,694 GBP. During SC/66b the sub-committee **commended** this work and efforts to conduct more indepth analysis of stranded whale carcasses and collect genetic samples both from strandings and in the field. They **recommended** the continuance of this work and particularly urged the collection of genetic samples where possible as the population identity and structuring of many of these species is unknown. The sub-committee therefore **recommended** that these surveys continue in 2016-18, with a broader focus to also collect opportunistic sightings, acoustic and genetic data on blue whales (see Items 4.1 and 5.1) and obtain training in biopsy sampling. The work can be carried out by Sutaria and colleagues, using the allocated budget of £19,694 GBP that was not spent on this project during 2014-16. This work is also relevant to Item 10.2.

The sub-committee **recommended** the continuance of the intersessional Arabian Sea Working Group convened under Baldwin (see Annex V).

10.2 Blue whales

10.2.1 Antarctic blue whales

Work on the Antarctic Blue Whale Catalogue is ongoing. During the upcoming year photographs contributed from various sources will be examined, including those submitted from South African, Japanese, French, German, Dutch and American colleagues, as well as from naturalists working in the Antarctic region. The addition of approximately 45 individuals is expected.

An intersessional email group formed under Brownell and Kato in SC/66a is still in progress in order to match the accession numbers of baleen plates from whales caught during the 1946/47 Antarctic season and currently stored at the Smithsonian with the Japanese whaling logs. Details are given in Appendix 4 of IWC (2016). Terms of reference are given in Annex V.

At SC/66a, the sub-committee **recommended** a review of available photo-identification data, and other data from the post CPIII IDCR/SOWER surveys, to determine whether the data are of any use for informing on Antarctic blue whale trend or abundance (IWC, 2016). This intersessional work has been convened under Kelly. Kelly was unable to attend and provided an informal report to the sub-committee, advising that there is potential for regional model-based abundance estimates for Antarctic blue whales, particularly in areas close to the sea ice boundary in Area III and Area IV. The sub-committee **welcomed** these analyses and noted the importance of maximising these data opportunities given the difficulties of the data collection. Work on this item will continue intersessionally and will be funded under an existing allocation to Kelly of £5,000 GBP (see Annex V).

10.2.2 Pygmy blue whales

Preparation for Southern Hemisphere pygmy blue whale assessments is now underway. The sub-committee **recommended** a number of intersessional initiatives in support of this, as follows.

(1) Work to continue on the Southern Hemisphere Blue Whale Catalogue. Work to be conducted by Galletti and associated researchers with a budget allocation of £17,521 GBP for 2016/17 and £15,501 GBP for 2017/18, starting with the migration of the server for this catalogue to the IWC Secretariat.
(2) The sub-committee highlighted the urgent need to collect photo-identification data from other areas along the Chilean coast north of Chiloé, particularly including areas of blue whale aggregations such as Isla Chañaral, as well as to reconcile photo-identification catalogues among all survey areas. They **recommended** that this work be done and **agreed** that a one-day workshop held just before a regional marine mammal science conference, to encourage and assist reconciliation of regional photo-identification catalogues, would be a helpful way to achieve this (see Item 10.1.1 and Annex V). A budget allocation of £4,600 GBP is required for this project in 2016/17. The project will be convened under Zerbini.
(3) The sub-committee **recommended** the deployment of hydrophones to conduct passive acoustic monitoring in deep water habitat off the northwest coast of Madagascar, to document the presence and seasonality of pygmy blue whales that have recently been documented in that area (see Item 5.3.3). A budget allocation of £11,200 GBP was requested for Cerchio to conduct this project in 2016/17. The sub-committee also **encouraged** the collection of biopsy samples during this project if possible, since very few biopsy samples exist from blue whales with the 'Madagascar' song type.
(4) The sub-committee **recommended** the development of a permanent blue whale song reference library, for use by the research community via a web-based portal (see Item 5.1). The work will be organised by Širović and will include development of a metadata standard for data submission and data use agreements. This library will facilitate research on blue whale acoustics, as well as have potential to provide information on geographic occurrence, habitat use, and impact of noise by offering 'baseline' song types. This web portal will be hosted on IWC servers with a budgetary cost of £4,000 GBP in 2016/17.
(5) The sub-committee **recommended** an analysis of blue whale catches (pelagic fleets and land stations), using the 2016 IWC catch databases to delimit population structure, boundaries and regions of possible overlap across the Southern Hemisphere and northern Indian Ocean (see Item 5.1). This work will be conducted by Branch and will provide a historical catch time series for each blue whale population and/or subspecies, with a budget of £9,277 GBP to be disbursed in 2017/18.
(6) The sub-committee **recommended** photo-identification catalogues within New Zealand be reconciled within the Southern Hemisphere blue whale catalogue in order to enable mark recapture analysis of pygmy blue whale abundance around New Zealand (Item 5.3.4).
(7) The sub-committee **encouraged** Brownell and de Vos to continue developing a regional stranding database off Sri Lanka, recognising the great value of this work for obtaining information on the population identity, health and distribution of poorly known northern Indian Ocean blue whales.
(8) The sub-committee also strongly **encouraged** initial work conducted by Olson, information gathering and collecting photos obtained from organisations in the northern Indian Ocean region that hold photo-identifications of blue whales.
(9) The sub-committee requested that Branch contact Pastene regarding availability of the original catch data of blue whales taken off Chile in the 1960s. These data need to be checked against the IWC database.

The sub-committee received a scientific proposal with funding implications to conduct blue whale habitat modelling using MMO sightings data from seismic surveys around New Zealand and Australia. The sub-committee recognised the importance of new information on pygmy blue whale distribution and foraging hotspots in a region where their distribution is poorly known. However, they also noted the many challenges of working with such data, as discussed above. This proposal was reviewed as discussed in Item 10. No funding was allocated.

10.3 Fin whales

At SC/66a, the sub-committee recommended a review of available photo-identification data, and other data from the post CPIII IDCR/SOWER surveys, to determine whether the data are of any use for informing on fin whale trend or abundance (IWC, 2016). This intersessional work has been convened under Kelly. Kelly was unable to attend and provided an informal report to this meeting, suggesting that a CPIII abundance estimate may be possible but may not capture the complete summer fin whale distribution in the Southern Hemisphere since they are regularly sighted north of 60°S. The sub-committee **welcomed** these analyses and noted the importance of maximising these data opportunities given the difficulties of the data collection. Kelly will

Table 2

Summary of the work plan for the Southern Hemisphere sub-committee, 2016-17.

Item	Intersessional 2016/17	2017 Annual Meeting (SC/67a)
Southern Hemisphere humpback whales (Item 3/10.1.1)		
Complete assessment of breeding stock D (Item 3.2)	Estimate minimum abundance of humpback BSD (west Australia). Evaluate genetic data, assumptions and analytical approaches for humpback breeding stock mixing. Re-analysis of BSD sightings data. Revise population assessments from SH line-transect and mark-recapture surveys and develop a metaprior on r_{max}.	Reports to Annual meeting, conclude assessment. Final assessment runs may be conducted here.
Ongoing work	Modelling analyses for future assessments of SH humpback populations.	Report and decide next steps
	Antarctic Humpback Whale Catalogue and email group to discuss alignment of Catalogue work with future SH priorities.	Progress report
	Build and clarify relationships between opportunistic data holders and photo-identi-fication catalogues focused on Southern Ocean whales.	
	Humpback whale and blue whale photo-identification standardisation and integration workshop to be held before SOLAMAC, November 2016.	Workshop report
Northern Indian Ocean humpback whales (Item 4/10.1)		
	Construct Arabian Sea Whale Network data archiving platform.	Report
	Exploratory surveys and investigation of strandings along the coast of India.	Report
	Continue tasks identified by the Arabian Sea working group.	Report
Southern Hemisphere blue whales (Item 5/10.2)		
Antarctic blue whales (Item 5.2)	Antarctic Blue Whale Catalogue – continue matching. Matching of baleen plate accession numbers with Japanese whaling logs.	
	Review photo-identification and other data available from CPIII IDRC/SOWER for suitability for trend and abundance analyses.	Report
Pygmy-type blue whales (Item 5.3)	Southern Hemisphere Blue Whale Catalogue – migrate catalogue to IWC server, match within Australia and Chile, match between regions.	Report
	Analysis of blue whale catches in all regions (pelagic fleets and land stations) to delimit population, boundaries, regions.	Interim report
Southeast Pacific blue whales (Item 5.3.1)	Blue whale photo-identification standardisation and integration workshop at SOLEMAC, November 2016 (combined with humpback workshop listed above). Assess availability of Chilean blue whale catch data. Collection and reconciliation of Chilean photo-identification data.	Workshop report
Southwest Indian Ocean blue whales (Item 5.3.3)	Deploy hydrophones off NW Madagascar.	Report
New Zealand blue whales (Item 5.3.4)	Reconciliation of photo-identification catalogues within New Zealand within the Southern Hemisphere Blue Whale Catalogue.	
Northern Indian Ocean blue whales (Item 5.3.5)	Continue developing a regional stranding database off Sri Lanka. Collection of information and photo-identification data from Northern Indian Ocean region.	
Southern Hemisphere fin whales (Item 6/10.3)		
	Estimate regional fin whale abundance from CPIII and post-CPIII IDCR/SOWER surveys.	Report
	Compile available fin whale sightings, catch and associated data from the western Antarctic Peninsula and Scotia Arc.	Report
	Develop funding proposal for study of fin whales in Antarctic Peninsula and Scotia Arc.	
	Summarise available data on Southern Hemisphere fin whale stock structure.	Report
IWC-SORP (Item 2/10.4)		
	Analysis of data from previous IWC-SORP voyages.	Report
	Antarctic Circumnavigation Expedition (ACE) voyage.	Cruise report
	RV Tango voyage (early 2017).	Cruse report
	Almirante Maximiano voyage (early 2017).	Cruise report
	Baleen whale and krill research voyages in Western Antarctic Peninsula.	
	Retrieval and redeployment of passive acoustic recorders.	
	IWC-SORP Acoustic Trends Project Steering Group meeting (October 2016).	Report

continue to work on this item intersessionally (see Annex V). The sub-committee **recommended** that Kelly estimate abundance of fin whales from the full CPIII set of surveys from IDCR/SOWER, and subsequent surveys. This work will be funded under the existing budget allocation to Kelly, as detailed in Item 10.2.1.

The sub-committee **recommended** that in light of multiple smaller surveys being conducted in various places around the Antarctic, the results of these surveys should be compiled and presented to the Scientific Committee next year. It was **agreed** to form two intersessional e-mail groups (see Annex V for members of Terms of Reference) to: (1) summarise available fin whale information available from the Antarctic Peninsula region and adjacent Scotia Arc, and develop a proposal for a dedicated fin whale study in this region (convened by Herr); and (2) to examine Southern Hemisphere fin whale stock structure, convened by Jackson.

10.4 IWC-SORP

During SC/66b sub-committee strongly **recommended** the continuation of this program and its five constituent research projects. The 2015/16 expenditure against this budget was £6,090 GBP (SC/66b/SH09). There are no further budgetary implications.

Project activities planned for 2016/17

Progress all projects and fieldwork outlined in Annexes 1-5, SC/66b/SH10 including but not limited to:

Table 3

Summary of the work plan for the Southern Hemisphere sub-committee, 2017-18.

Item	Intersessional 2017/18	2018 Annual Meeting (SC/67b)
Southern Hemisphere humpback whales (Item 3/10.1.1)		
Ongoing work	Modelling analyses for future assessments of SH humpback populations.	Report, conclusions and next steps
	Build and clarify relationships between opportunistic data holders and photo-identification catalogues focused on Southern Ocean whales.	
Northern Indian Ocean humpback whales (Item 4/10.1)		
	Continue development of Arabian Sea Whale Network data archive.	Report
	Arabian Sea Whale Network genetic study: (i) confirm taxonomic status of Arabian Sea humpback whale population; and (ii) explore genetic variability.	Report
	Exploratory surveys and investigation of strandings along the coast of India.	Report
	Continue tasks identified by the Arabian Sea working group.	Report
Southern Hemisphere blue whales (Item 5/10.2)		
Antarctic blue whales (Item 5.2)	Antarctic Blue Whale Catalogue – continue matching.	Report
	Begin analysis of Antarctic blue whale baleen plates.	
Pygmy-type blue whales (Item 5.3)	Southern Hemisphere Blue Whale Catalogue – matching.	Report
	Analysis of blue whale catches in all regions (pelagic fleets and land stations) to delimit population, boundaries, regions.	Interim report
Southeast Pacific blue whales (Item 5.3.1)	Assess availability of Chilean blue whale catch data.	Catch update
	Collect and reconcile Chilean photo-identification data.	
Southwest Indian Ocean blue whales (Item 5.3.3)	Acoustic study off NW Madagascar.	Report
New Zealand blue whales (Item 5.3.4)	Continue reconciliation of NZ photo-identification catalogues within the Southern Hemisphere Blue Whale Catalogue.	Report
Northern Indian Ocean blue whales (Item 5.3.5)	Continue developing a regional stranding database off Sri Lanka.	
	Collection of information and photo-identification data from Northern Indian Ocean region.	
Southern Hemisphere fin whales (Item 6/10.3)		
	Consider data availability and gaps for Southern Hemisphere fin whale assessment.	Report
	Plan survey of fin whales in Antarctic Peninsula and Scotia Arc.	
IWC-SORP (Item 2/10.4)		
	Analysis of data from previous IWC-SORP voyages.	Report
	RV Tango voyage (early 2018).	Cruse report
	Almirante Maximiano voyage (early 2018).	Cruise report
	Baleen whale and krill research voyages in Western Antarctic Peninsula.	Report
	Retrieval and redeployment of passive acoustic recorders.	Report

(1) Ongoing analysis of data resulting from the IWC-SORP voyages conducted during the period 2015-16 (e.g. SC/66b/SH05, SC/66b/SH10, SC/66b/SH15, SC/66b/EM05, Bell, 2015; Best *et al.*, 2013; Brownell Jr *et al.*, 2015; Double *et al.*, 2015; Findlay *et al.*, 2014; Galletti Vernazzani *et al.*, 2015; Geelhoed *et al.*, 2015; Reyes Reyes *et al.*, 2014; Reyes Reyes *et al.*, 2015).

(2) Preparation for and conduct of the Antarctic Circum-navigation Expedition (ACE) voyage, December 2016-March 2017 (SC/66b/SH07).

(3) Preparation for and conduct of the 4th voyage of the Argentinean coast guard vessel, *RV Tango*, in early 2017 (Annex 1, SC/66b/SH10).

(4) Preparation for and conduct of a voyage on the Brazilian navy vessel, *Almirante Maximiano*, in early 2017 (Annex 2, SC/66b/SH10).

(5) Conduct of baleen whale and krill research using multiple vessel platforms, including United States polar vessels and ships of opportunity around the west Antarctic Peninsula (Annex 3, SC/66b/SH10).

(6) Retrieval and redeployment of passive acoustic recorders within the Southern Ocean Hydrophone Network (Annex 5, SC/66b/SH10) off east Antarctica and the west coast of South Africa.

(7) A meeting of the IWC-SORP Acoustic Trends Project Steering Group (ATWG) will be held in Brest, France in October 2016 in order to synthesise recent data collection and analysis efforts, collaborate on a paper detailing these, and explore pathways to greater international collaboration and funding opportunities to make this happen.

11. ADOPTION OF THE REPORT

The report was adopted on 16 June 2016 at 08:49am. The Chair and Co-Chair thanked the rapporteurs for all their hard work. The sub-committee thanked Jackson and Bell for their excellent work chairing the meeting.

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Appendix 1

AGENDA

1. Introductory items
   - 1.1 Convenor's opening remarks
   - 1.2 Election of Chair
   - 1.3 Appointment of rapporteurs
   - 1.4 Adoption of agenda
   - 1.5 Review of documents
2. Southern Ocean Research Partnership (SORP)
3. Southern Hemisphere humpback whales
   - 3.1 Review new information
     - 3.1.1 Breeding stock A
     - 3.1.2 Breeding stock E1
     - 3.1.3 Breeding stocks E2/E3/F
     - 3.1.4 Breeding stock G
     - 3.1.5 Feeding grounds
   - 3.2 Results of intersessional email groups
   - 3.3 Future directions for Southern Hemisphere humpback assessments
   - 3.4 Conclusions and recommendations
4. Arabian Sea humpback population
   - 4.1 Review new information
   - 4.2 Progress toward development of a Conservation Management Plan and other conservation initiatives
5. Assessment of Southern Hemisphere blue whales
   - 5.1 Southern Hemisphere population structure
   - 5.2 Antarctic blue whales
     - 5.2.1 Review new information
   - 5.3 Pygmy-type blue whales
     - 5.3.1 Southeast Pacific blue whales
       - 5.3.1.1 Review new information
       - 5.3.1.2 Progress on population assessment
     - 5.3.2 Australian-Indonesian blue whales
     - 5.3.3 Southwest Indian Ocean blue whales
     - 5.3.4 New Zealand blue whales
     - 5.3.5 Northern Indian Ocean blue whales
   - 5.4 Conclusions and future directions
6. Southern Hemisphere fin whales
7. Review of Southern Hemisphere abundance estimates
8. Genetic databases arising from Southern Hemisphere assessment work
9. Other
10. Work plan and budget considerations
    - 10.1 Humpback whales
    - 10.2 Blue whales
    - 10.3 Fin whales
    - 10.4 IWC-SORP
11. Adoption of the Report

Appendix 2

PROPOSED WORK TO FILL KEY DATA GAPS AND LIKELY IMPACT OF PROPOSED WORK ON POPULATION ASSESSMENT OUTCOMES

Within each set of breeding stocks, rows are ordered in terms of priority for future assessments where possible.

Breeding stock	Assessment element	Impact on assessment outcomes	Work **recommended**
A	Trend: normal prior on population growth was not strongly updated by available survey data: estimate had very broad variance.	High: actual growth rate may have been similar to growth rate prior shape, or could be very different.	Aerial/ship based surveys over multiple years. This work is in progress and new estimates of abundance from ship and aerial surveys will be available shortly.
	Catch: catches missing from pre-1900 whaling and 20th century whaling from northeastern Brazilian land station Costinha, 1910 and 1929-46.	Medium: under-reported catch causes negative bias in estimated *K*.	Review pre-modern and modern whaling catches. This work has been ongoing and is nearly completed.
B1/B2/C1	Population structure: identity of BSB2 requires re-evaluation. Population structure within BSB unknown. Identity of animals off WSA region may be different at different times of year and include both B1 and C1. BSB2 may be an area of B/C mixing. Therefore allocation of catches from coastal stations is uncertain, as is abundance and trend for both populations.	High	Extensive photo-identification/genotype matching between both populations using existing datasets. Structured data collection on large scale and matching temporal periods required to measure this over management-relevant timescale. Range-wide ship based surveys conducting satellite tagging, photo-identification and skin biopsy, principally off Angola and Namibia, further offshore and to the north and south of Gabon. Power analysis useful to specify ideal scale of survey. Also possible that C1 whales feed in B2, so coordination with photo-identification/genotype sequencing from whales in C1 necessary (see below).
B1	Abundance and trend: this has to date been inferred from mark-recapture data and has a very wide CV. Additionally, surveys to date have been limited to Gabon but the BS range spans Angola to Guinea and numerous whales are also further offshore of Gabon than surveys have covered.	High	Add more sites from across breeding ground range- scoping required to determine best locations. Recommend power analysis to assess scale of data collection (e.g. Carroll *et al.*, 2015) for the population and determine most efficient approach for repeat surveys, e.g. mark recapture or line transect. Survey selected sites in the Gulf of Guinea including Gabon. Explore breeding ground distribution ground and connectivity between Senegal and the Gulf of Guinea.
C1 and C3	Catch allocation: genotypic recaptures indicate that whales from C1 and C3 may have been feeding in BSB2 region and therefore catches from there may apply to BSC1 and C3 whales.	High	Explore degrees of stock mixing between BSB and BSC to refine catch allocation hypotheses for future stock structure assessments.
C1/C2/C3/ C4	Population structure: limits of breeding stocks uncertain. Northern C1 (C1N) has not been surveyed, may contain C2/C3 whales.	Medium	Ship based surveys to collect photo-identifications/genetic samples from northern BSC1 and satellite tracking to identify connections. Some satellite tagging in C1, C2, C3 and C4 has since been conducted and movement analysis is in progress/completed. A number of the priority areas for SH humpback work were outlined at the Comprehensive Assessment Workshop (see IWC, 2011) and while some key gaps have been filled, many remain un- or under-surveyed.
Western Indian Ocean substock range C1N to C4	Regional abundances not available (but these are probably not core breeding areas).	Low	Interrelationship of C1N and C1 south (C1S) unknown but C1N is not a core breeding area. BSC2 is not genetically differentiated from C3 and migratory route can include C3 area (Ersts *et al.*, 2011; Fossette *et al.*, 2014; Rosenbaum *et al.*, 2009) so limited evidence that this is a distinct population. Satellite tracks link C3 and C4. Regular boat based surveys useful to collect photo-identification/genotypes. Some photo-identification data are already available (Ersts *et al.*, 2011).
D	Abundance: available data from aerial surveys are non-standard and difficult to convert to absolute abundance.	Very high	Potentially very difficult to achieve due to distribution and behaviour of migrating whales. IWC report from Kelly to consider in detail where future abundance surveys should take place.
E1	Catch: allocation of BSE1 whales, given population mixing with BSD and BSO on feeding grounds.	Low: assessment model allowed high latitude catches from BSD and BSO to be allocated to BSE1.	Population modelling, mixed stock analysis
Oceania	Abundance: of breeding sub-stocks BSE3 (Tonga) and BSF2 (French Polynesia) required to conduct multi-stock assessment of this region.	High	Photo-identification and mark-recapture surveys, see Carroll *et al*. (2015) for Tonga recommend-ations.
	Trend: no data available for Oceania, BSE3 or BSF2, though there is a recent trend estimate available for New Caledonia with a very high rate of 15% which is not biologically possible for an isolated population, suggesting a recent influx of whales from BSE1.	Medium/high	Surveys, see Carroll *et al*. (2015). BSF2 is not covered but equally important as geography-ically/genetically distinct

Cont.

Breeding stock	Assessment element	Impact on assessment outcomes	Work **recommended**
G	Abundance: no single representative number for the entire breeding area	High: previous assessment was conducted using data from one region	Regional catalogue holders to compare photo-identifications - this may be sufficient but otherwise see above.
	Population structure: significant mtDNA population structuring within BSG, and significant differentiation between Antarctic Peninsula and Magellan Strait feeding grounds. Population structuring may have analogies with BSB.	High: enables multi-stock assessment allowing for sub-structure within BSG	Existing genetic and photo-identification collections to be compiled and compared between regions along the breeding and feeding range of this species. Potentially also some strategic sample collection from understudied areas within the breeding/feeding range.
	Trend: no trend data available.	Medium/high	Regular surveys but very challenging. Surveys of the breeding ground logistically difficult to achieve because of the vast multi-country breeding area involved. Would have to be an initiative with a scope similar to that of SPLASH to get to this question with photo-identification and microsatellite genotypes.
Feeding ground	Feeding/breeding ground connections: do contemporary migration links reflect historical catch allocation in the Antarctic? Investigation of breeding/feeding ground linkages will assist catch allocation in future assessments.	Medium	Review all satellite tracking data for information on contemporary migratory links between breeding and feeding grounds. Conduct mixed stock and population structure analysis on genetic samples from breeding and feeding grounds to inform catch allocations.

Table 2

Additional population modelling which can assist future population assessments.

Population modelling	Impact on assessment outcomes	Achievability	Priority
Power analysis of sampling sizes/effort required to obtain abundance and trend indices of reasonable resolution on each breeding ground.	High	High	5
Investigate disaggregated models (either age- or stage- or sex-structured); note sex is known for ~44% of catches.	Medium. Not possible for all stocks. Not likely to change recovery outcomes appreciably.	High	3
Construct a circumpolar population dynamics model that integrates data from all Southern Hemisphere breeding stocks.	High	Low	5
Integrate mixed stock proportions into the multi-stock population models, as this provides information on the relative abundance of multiple populations sharing a common feeding ground in multi-stock assessments. Mixing proportions would be fitted onto the model-predicted abundances for the year/average of years over which the genetic samples were taken, and used to inform the likelihood.	Medium- depends on region and quality of source samples	High	3
Alternative population assessment models, including exploring alternative maximum sustainable yield (MSYL) values for humpback whales, developing population models that explicitly incorporate environmental variability, and explore alternatives to the standard density-dependent logistic model.	Medium high	High	4
Examine the impact of pre-1900 humpback whale catches on population assessment results.	Impact on population assessment outcomes may be substantial (Smith *et al.*, 2006) and current abundance is not large, e.g. Tonga (BSE3) and Central America (BSG).	High	5

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Appendix 3

BLUE WHALE SONG TYPES BY REGION

A. Širović and K. Findlay

Blue whale song types by region, based on McDonald *et al.* (2006) and expanded with new information available since then. 'Type locality' is first/most complete published reference of the given song type, also after McDonald *et al.* (2006).

Song type	Region	Type locality (reference)
2A	Southeast Pacific (SEP1)	Isla Guafo, Chile (Cummings and Thompson, 1971)
2B	Southeast Pacific (SEP2)	Eastern Tropical Pacific (Stafford *et al.*, 1999)
3	Southwest Pacific (SWP)	New Zealand (Kibblewhite *et al.*, 1967)
6	Antarctic Blue Whale (ANT)	Antarctica (Širović *et al.*, 2004)
7	North Indian Ocean (NI)	Sri Lanka (Alling *et al.*, 1991)
8	Southeast Indian (SEI)	Fremantle (McCauley *et al.*, 2000)
9A	Southwest Indian (SWI1)	Madagascar Plateau (Ljungblad *et al.*, 1998)
9B	Southwest Indian (SWI2)	Diego Garcia (McDonald *et al.*, 2006)
10	South Atlantic (SA)	South Georgia/Islas Georgias del Sur (Pangerc, 2010)
11	Western Tropical Pacific (WTP)	Solomon Sea (Frank and Ferris, 2011)

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Appendix 4

SUMMARY OF GENETIC DATASETS RELEVANT FOR ASSESSING PYGMY-TYPE BLUE WHALE POPULATION STRUCTURE IN THE SOUTHERN HEMISPHERE

A.R. Lang, C.R.M. Attard, C.S. Baker, L.M. Möller, H.C. Rosenbaum, A.L. Sremba, D. Steel, L.G. Torres, and J.P. Torres-Florez

Table 1

Measures of genetic diversity within regions across different studies. Here, *n* refers to the number of individuals analysed.

	mtDNA				Microsatellites				
Stratum	*n*	No. of haplotypes	Haplotype diversity	No. of bps	*n*	Mean no. alleles	Mean Ho.	No. of loci	Reference
Indian Ocean:	36	12	0.765	347-414	36	6	0.680	7	LeDuc *et al.* (2007)
SE IO: Australia [combined Perth Canyon and Bonney Upwelling]	89[§]	14	0.680	414	109	6.00	0.602	20	Attard *et al.* (2012b; 2015)
Perth Canyon	67	14	0.683	394	47	6.70	0.659	10	Attard *et al.* (2010)
Bonney Upwelling	32	9	0.758	394	25	5.80	0.590	10	Attard *et al.* (2010)
SWP: TB, New Zealand	9	3	-	410	-	-	-	11-15	Sremba *et al.* (2015b)*
Other, New Zealand	14	4	-	410	-	-	-	11-15	Sremba *et al.* (2015b)*
SEP:	28	10	0.852	347-414	28	7	0.723	7	LeDuc *et al.* (2007)
CG, Chile	48	12	0.895	421	52	7.857	0.695	7	Torres-Florez *et al.* (2014)
C-N OFF, Chile	19	9	0.906	410	19	6.286	0.721	7	Torres-Florez *et al.* (2014)
ETP: sETP	25	7	0.773	410	25	6.286	0.742	7	Torres-Florez *et al.* (2014)
Antarctic: Areas I-VI	47	26	0.969	347-414	46	10.42	0.752	7	LeDuc *et al.* (2007)
	78	36	0.968	410	78	11.714	0.751	7	Torres-Florez *et al.* (2014)
	183	52	0.968	410	163	-	-	16	Enriquez-Paredes *et al.* (unpubl.)
	140	46	0.968	414	142	11.65	0.758	20	Attard *et al.* (2012b; 2015; 2016)
South Georgia (bones)	18	16	0.98	194	-	-	-	-	Sremba *et al.* (2015a)

Table 2

Measures of genetic differentiation between areas in the Southern Hemisphere. 'NS' is used to indicate a p-value reported only as being non-significant.

Comparison	mtDNA F_{ST}	mtDNA p	mtDNA Φ_{ST}	mtDNA P	Microsatellites F_{ST}	Microsatellites p	Reference
Within Indian Ocean: Australia: Perth Canyon *vs* Bonney Upwelling	0.001	0.34	-	-	0.002	0.319	Attard *et al.* (2010)
Australia: Geographe Bay *vs* Perth Canyon and Bonney Upwelling	-0.011	0.604	-	-	-0.008	0.986	Attard *et al.* (2012a)
Within Eastern South Pacific: sETP v C-N OFF, Chile	0.021	NS	0.035	NS	0.005	NS	Torres-Florez *et al*. (2014)
sETP *vs* CG, Chile	0.029	NS	0.107	<0.05	0.004	NS	Torres-Florez *et al*. (2014)
C-N OFF, Chile *vs* CG, Chile	-0.025	NS	-0.009	NS	0.0013	NS	Torres-Florez *et al*. (2014)
Between SH regions (except Antarctic): NZ (all) *vs* SEP[1]	0.243	<0.001	0.338	<0.001	-	-	Sremba *et al.* (2015b)
NZ (all) *vs* SE IO	0.000	0.549	0.000	0.579	-	-	Sremba *et al.* (2015b)
SEP *vs* IO (combined)[2]	0.186	<0.0001	-	-	-	<0.001	LeDuc *et al.* (2007)
SH regions vs Antarctic: NZ *vs* Antarctica	0.198	<0.001	0.300	<0.001			Sremba *et al.* (2015b)
IO (combined)[2] *vs* Antarctica	0.122	<0.0001	-	-	-	<0.001	LeDuc *et al.* (2007)
SE IO (Perth Canyon and Bonney Upwelling) *vs* Antarctica	-	-	-	-	0.112	0.001	Attard *et al.* (2012b)
Geographe Bay, Australia *vs* Antarctica	0.169	<0.001	-	-	0.099	<0.001	Attard *et al.* (2012a)
SEP[3] *vs* Antarctica	0.081	<0.0001	-	-	-	<0.001	LeDuc *et al.* (2007)
sETP *vs* Antarctica	0.117	<0.05	0.157	<0.05	0.028	<0.05	Torres-Florez *et al*. (2014)
C-N OFF Chile *vs* Antarctica	0.058	<0.05	0.139	<0.05	0.024	<0.05	Torres-Florez *et al*. (2014)
CG, Chile *vs* Antarctic	0.066	<0.05	0.155	<0.05	0.025	<0.05	Torres-Florez *et al*. (2014)
Within Antarctic: between IWC Management Areas	0.032	<0.001	0.023	0.012	0.005	0.031	Sremba *et al.* (2012)

[1]Includes samples from the CG and C-N OFF, Chile and the sETP. [2]Includes samples from off the coast of Australia (SE IO), the Maldives (NIO), and the east coast of South Africa (SW IO). [3]Includes samples from Chile, Ecuador, and Peru.

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Appendix 5

BLUE WHALE CATCH DISTRIBUTIONS

Trevor Branch

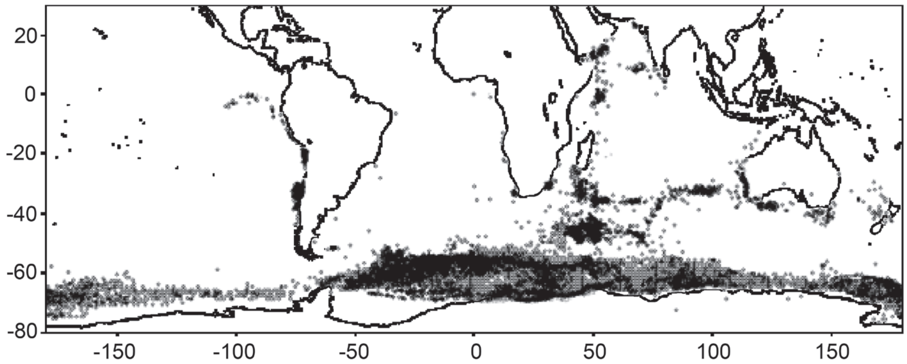

Fig. 1. All individually identifiable catch locations in the Southern Hemisphere and northern Indian Ocean (from the 2006 version of the IWC catch database, a couple of visible minor errors plotted here have since been corrected).

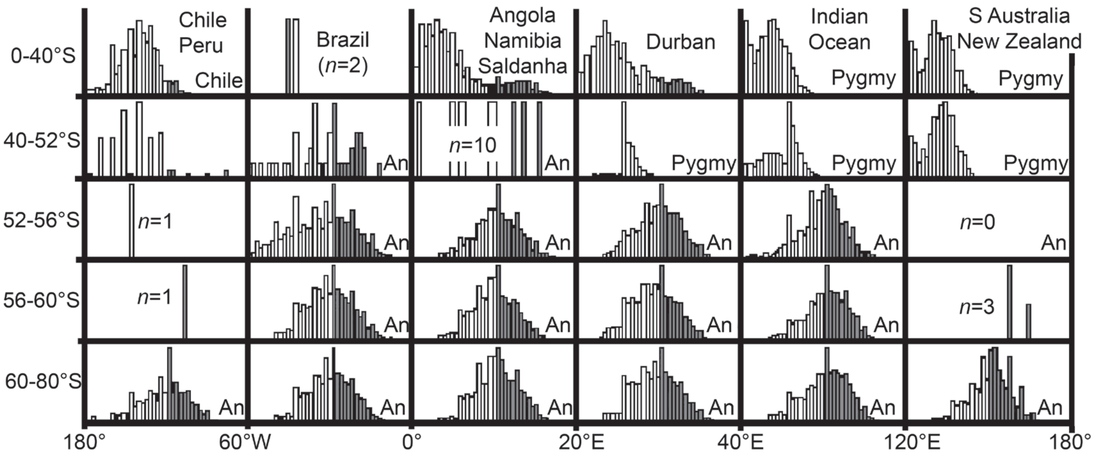

Fig. 2. All catches of blue whales in the Southern Hemisphere, including coastal and pelagic catches, and sexually immature and mature. The groupings by longitude and latitude are carefully chosen to divide the Southern Hemisphere into regions (of different sizes) with contrasting length frequencies. The large numbers of small blue whales in Angola, Namibia, and Saldanha are immature blue whales; sexually mature females were similar in size to those in the Antarctic regions. Where the three (possible) subspecies were clearly caught, these are indicated by An (Antarctic), Pygmy, or Chile. Shaded bars are longer than 80ft (maximum recorded length of pygmy blue whales). Rounding to 5ft intervals is visible in some regions, as is whale 'stretching' from 1937/38 when the minimum length of 70ft was introduced. From the 2006 version of the IWC catch database.

Appendix 6

REANALYSIS OF CHILOÉ ISLAND BLUE WHALE MARK RECAPTURE DATA 2006-11

Justin Cooke and Jen Jackson

1. INTRODUCTION AND DATA

The blue whale photo-identification data collected from Chiloé Island during 2006-11 (Galletti Vernazzani *et al.*, 2017) used for the assessment in SC/66b/SH27 is re-analysed here using a more flexible model with an emphasis on the resident/transient issue. The data contain a total of 291 left sides and 251 right sides. The left and right sides were not cross-matched. The data were organised into annual sighting histories by side (i.e. seen/not seen by year; resightings within a year are not counted). There were a total of 722 histories with an average number of 1.32 annual sightings per history.

2. MODEL DESCRIPTION

The generic individual state-space model used for gray (SC/66b/BRG25) or right whales (Cooke *et al.*, 2015) was used. This model was designed for more complex data sets involving, for example, mother-calf pairs, but can also be applied to simple data sets such as this one.

To examine the resident/transient issue, the notional population was divided into Residents and Transients. An individual cannot be assigned definitively to one transience class: the model estimates the probability that each individual is resident. The model cannot handle multiple aspects (e.g. left and right sides) when these are not cross-matched. Hence, left and right sides were treated as if they were different whales (e.g. like male and female); all resulting population estimates were halved. The model for the sampling/availability process allows for sampling probability to vary by Side (Left/Right), Year (2006-11) and Transience (Transient/Resident). The minimal model has Year and Side, because these are affected by sampling effort choices. Alternative models allowed sampling probability to vary by Transience (the idea being that Transient animals are by definition less available) and an optional Transient*Year interaction (in case the relative availability of transients and residents varies between years). Both a closed population model (no recruitment, 100% survival) and an open population model (recruitment and partial survival) were considered. Recruitment was by transience class, and an optional time trends by class. A common survival was estimated in the minimal model, with optional differential survival between class. Model selection was based on the AIC criterion.

3. RESULTS

The results of model selection are shown in Table 1. With both the open and closed models, introducing a resident/transient distinction improves the fit somewhat. Allowing the relative availability of transients and residents to vary by year (Year*Transience interaction) improved the fit substantially. Hence this sampling/availability model was selected. Temporal trends in recruitment and differential survival by transience class were also tried, but these increased the AIC (not shown in Table 1). With the selected sampling model, the open population model gives a slightly better fit than the closed model, but results are shown for both. The estimates of population size and parameters are shown for the open and closed models are shown in Table 2. For the open model, results are shown for the two end years (2006 and 2011) and for the mid-year (notionally 2008.5). For the open model, survival is not precisely estimated (point estimate 0.89, SE 0.05). The mid-year estimate from the open population model is about the same as that from the closed population model when dead animals are included in the former, as is usual for models of this kind. The best estimate of the living population in the mid-year from the open population model is **450** (CV 0.17). The resident proportion is estimated at 41-45% (SE was not calculated). The Left/Right ratio was estimated to be 51:49. This is close enough to the true population value of 50:50 (since every whale has a left and a right side), that the 'error' that results from not forcing this ratio to be 50:50 can be assumed to be negligible.

Table 1

Model selection.

Case	Sampling model	Pop. model	Log-like	Eff. df	AIC
A	Side+Year	Closed	-474.7	7.7	964.7
B	Side+Transience+Year	Closed	-470.0	9.1	958.2
C*	Side+Transience*Year	Closed	-460.6	12.5	946.2
D	Side+Year	Open	-471.0	9.4	960.7
E	Side+Transience+Year	Open	-468.7	10.3	958
F*	Side+Transience*Year	Open	-458.0	14.2	944.6

*Preferred models based AIC.

Table 2

Results.

Population model		Open		
Year	Closed	2006	2008.5	2011
Survival (with SE)	-	0.89 (0.05)	0.89 (0.05)	0.89 (0.05)
Recruitment (with SE)	-	0 46 (24)	46 (24)	46 (24)
Population (with CV)	-	-	-	-
Resident	235 (0.22)	214 (0.20)	196 (0.19)	182 (0.25)
Transient	343 (0.33)	257 (0.45)	254 (0.29)	252 (0.28)
Total live	578 (0.16)	471 (0.25)	450 (0.17)	434 (0.20)
Dead/gone	-	-	124 (0.64)	242 (0.51)
Total	578 (0.16)	471 (0.25)	575 (0.15)	676 (0.13)
Left proportion	0.51	0.50	0.51	0.51
Resident proportion	0.41	0.45	0.43	0.41

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