Annex Q

Ad hoc Working Group on Abundance Estimates, Status and International Cruises

Members: Zerbini, Butterworth (co-Convenors), Allison, Baba, Baker, Bell, Bickham, Bravington, Brockington, Brownell, Burkhardt, Castro, Cipriano, Clapham, Collins, Cooke, Cubaynes, De la Mare, de Moor, Diallo, Doherty, Donovan, Double, Enmynkau, Filatova, Fortuna, Fretwell, Frey, Fruet, Funahashi, Galletti Vernazzani, Genov, Givens, Gunnlaugsson, Hakamada, Herr, Hielscher, Hubbell, Iñíguez, Isoda, Ivashchenko, Jackson, Kim, Kitakado, Konan, Konishi, Lang, Lauriano, Lundquist, Mallette, Matsuoka, McKinlay, Miyashita, Mizroch, Morishita, Morita, Moronuki, Murase, New, Øien, Olson, Palka, Panigada, Park, Pastene, Punt, Redfern, Reeves, Rendell, Robbins, Rodriguez-Fonseca, Rose, Rosenbaum, Simmonds, Slooten, Slugina, Tamura, Víkingsson, Wade, Walløe, Walters, Yasunaga, Yoshida, Zharikov.

1. INTRODUCTORY ITEMS

1.1 Opening remarks
Zerbini welcomed participants.

1.2 Election of Chair
Zerbini was elected as Chair.

1.3 Appointment of Rapporteurs
Herr, McKinlay and Olson acted as rapporteurs.

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

1.5 Documents available
SC/67a/ASI01-10; SC/67a/AWMP08-09; SC/67a/CMP01, SC/67a/CMP06; SC/67a/NH05; SC/67a/NH07; SC/67a/NH09-11; SC/67a/RMP03-04; SC/67a/SM18, SC/67a/SM21; Hansen *et al.* (2016); Calambokidis *et al.* (2017); Durban *et al.* (2017); Baker *et al.* (2017); Dares *et al.* (2017); Bravington *et al.* (2016); Vacquié-Garcia *et al.* (2017); Sutaria and Marsh (2011); Weller *et al.* (2016); Pike *et al.* (2009); Pike *et al.* (2002); Pike *et al.* (2010); Hammond *et al.* (2016); Hamner *et al.* (In press); Paudel *et al.* (2015); Pike *et al.* (Unpublished); Minton *et al.* (2013); Rone *et al.* (2016); Durban *et al.* (2015); Paxton *et al.* (2007); Matsuoka and Hakamada (2014).

2. TERMS OF REFERENCE AND APPROACH

Following previous discussions within the IWC Scientific Committee (IWC, 2017, p.94), the Working Group on Abundance Estimates, Status and International Cruises was established to formally review and agree on the status of the abundance estimates submitted to the Scientific Committee across all of the Committee's sub-committees and working groups. The Working Group will also be responsible for assisting the Committee and the Secretariat in developing a biennial document to inform the Commission on the abundance and status of whale stocks. Finally, this Group will also consider survey design and data analysis related to abundance estimates of IWC-related projects. The **agreed** Terms of Reference of this new Working Group are provided in Appendix 2.

Allison provided a background on the current Tables of Accepted Abundance Estimates and explained that the aims of these tables are: (i) to collate information in a consistent way on abundance estimates accepted by the Scientific Committee for various purposes; and (ii) to provide a simplified table of abundance estimates suitable as a broad overview for the Commission and the public. She detailed the changes made to the format of the tables since their inception in 2014 (IWC, 2014) and suggested that a grand, single table be developed. A single table would be easier to maintain and less prone to error when updating, as data would not need to be entered or changed in multiple places. Details of the items included in the table and the codes used are given in Appendix 3. The Working Group **agreed** that, when reviewing estimates of abundance (see Item 3), it would allocate these estimates to one of the following categories:

- **Category 1:** acceptable for use in in-depth assessments or for providing management advice;
- **Category 2:** underestimate - suitable for 'conservative' management but not reflective of total abundance;
- **Category 3:** while not acceptable for use in (1) or (2), adequate to provide a general indication of abundance; and
- **Category P:** provisional estimates.

The Working Group noted that the Table of Accepted Abundance Estimates (hereafter referred to as the 'IWC Abundance Table') contains estimates not yet agreed by the Scientific Committee. It was **agreed** that a process to conduct the reviews of these estimates will be developed by an intersessional email group (see Item 8).

3. EVALUATIONS OF ABUNDANCE ESTIMATES AND UPDATES OF THE IWC ABUNDANCE TABLE

3.1 Evaluation of new abundance estimates
3.1.1 Large whales
The Working Group noted that the AWMP workshop (SC/67a/Rep06) had extensively discussed abundance estimates of common minke, humpback and fin whales in West and East Greenland and recommended that the estimates presented in Table 1 (reproduced from SC/67a/Rep06) were appropriate for use in the *Strike Limit Algorithm* (*SLA*) development and implementation. In reviewing these estimates, the Working Group **agreed** that they were of high quality and the best available for the three whale species in West and East Greenland. The Working Group **endorsed** these estimates for inclusion in the IWC Abundance Table under Category 1.

3.1.1.1 NORTH ATLANTIC MINKE WHALES
SC/67a/NH05 presented an aerial survey using cue counting methods to estimate minke whale abundance, which had been conducted in coastal Icelandic waters in July 2016. This was the most recent estimate from a series of surveys conducted in 1987, 1995, 2001, 2007 and 2009 using nearly

Table 1

Summary of new agreed abundance estimates (see text) for common minke, fin and humpback whales in West and East Greenland. Detection depth was assumed to be up to 2m apart from for fin whales for which estimates were not corrected for availability bias. Availability bias takes time in view into account. For the MRDS for humpback whales, a combined mean group size was used. Key: LT=line transect; SC=strip census; ESW=effective search width; *N*=number of sightings; E+W indicates that sightings from East and West Greenland were pooled to estimate the detection function.

			Perception bias					
Method	ESW (m)	*N*	Model	Value	Availability bias	Abundance	CV	95% CL
Common minke whale – East 2015								
LT	450	23 E+W	MRDS 2015	0.97 (0.04)	0.20 (0.26)	2,681	0.45	1,153; 6,235
Common minke whale – West 2015								
SC	300	12	Chapman	0.94 (0.06)	0.18 (0.32)	5,241	0.49	2,114; 12,992
Common minke whale – West 2007								
SC	240	18	Chapman	0.98 (0.02)	0.18 (0.32)	9,853	0.43	4,433; 21,900
Fin whale – West 2015								
LT	700	75 E+W	MRDS 2015	0.99 (0.001)	-	465	0.35	233; 929
Humpback whale – East 2015								
LT	1,200	76 E+W	MRDS 2015	0.98 (0.02)	0.42 (0.14)	4,288	0.38	2,097; 8,770
Humpback whale – West 2015								
LT	1,200	76 E+W	MRDS 2015	0.98 (0.02)	0.42 (0.14)	1,008	0.38	493; 2,062

identical survey design and methodology. These surveys were generally associated with the wider ship-based North Atlantic Sighting Surveys (NASS) carried out in surrounding waters. The aerial NASS survey in 2015 was unsuccessful due to adverse weather conditions. The 2016 survey used a Twin-Otter aircraft for the first time and employed a full double platform configuration on both sides of the aircraft. However, the bubble windows on the Twin-Otter were smaller and less convenient than those from the Partenavia aircraft used in earlier work. A newly developed electronic device, the Geometer, was used to record declination angles and times of cetacean groups detected directly to a database. Prolonged periods of poor weather resulted in a realised coverage of only 53% of the planned effort, with no effort in the northernmost block. Minke whale sighting rates were similar to those in 2007 and 2009, but lower than in surveys prior to that. Duplicate sightings were identified using an algorithm based on similarity in observer measurements of declination angle, sighting time, group size and species identity. Cue counting methods, using a cueing rate of 53 surfacings per hour (as in earlier estimates), and corrected for visible cues missed by observers, estimated the abundance at 13,497 (CV=0.50, 95% CI=3,312-55,007). An alternative approach, using line transect methodology with corrections for visible groups missed by observers and for animals not in view during passage of the aircraft based on tagging in Greenland, resulted in an estimate of 11,428 (CV=0.48, 95% CI=3,727-35,046). This estimate is likely negatively biased due to the inclusion and identical handling of the submerged animals, and did not appreciably reduce the CV. The results, although not totally comparable to earlier estimates due to the total lack of effort in one block, confirm that minke whale density has declined substantially in the area since 2001. The authors suggested that this decline may be the result of a re-distribution of the population due to ecological changes observed in the area.

In discussion, several problems associated with the 2016 survey were identified, including incomplete survey coverage leading to non-random sampling in some areas, and the potential for estimation bias. Most issues seemed related to poor weather conditions that occurred during the survey, with incomplete sampling towards the edge of the survey area and insufficient coverage in several strata being of particular concern. The use of model-based abundance estimation approaches to correct for poor coverage was discussed; however, it was generally recognised that such patterns of 'missingness' would likely render the data unsuitable because they would require a model to extrapolate beyond the range of existing data, rather than the more acceptable approach of interpolating between areas with sufficient surveys. Documented annual changes in the distribution of minke whales in the survey area might also make spatial modelling approaches difficult. In addition, the reliability of applying the same 'cue' counting rate used in previous surveys would be questionable if environmental changes result in changes in behaviour or group sizes.

It was suggested that if estimates were to be adopted for use in future *Catch Limit Algorithm* (*CLA*) *Implementation Review* trials, then incomplete coverage need not necessarily be an issue because those effects could be explored in simulations. However, it was noted that it was unlikely that future *CLA Implementation* trials would commence before 2022, providing ample time for more reliable estimates to be computed from new surveys. It was also noted that Generalized Linear Model (GLM) approaches could be used to account for missing coverage if survey data were post-stratified, potentially also resulting in estimates of minimum abundance for use in future *CLA*s. However, the use of such methods was likely to provide estimates with large variances. In conclusion, it was **agreed** that the estimates were of insufficient quality to allow their adoption for use in the *CLA*. The Working Group **recommended** that the authors consider post-stratification, possibly using GLM methods to take account of information from past surveys, in an attempt to obtain a minimum estimate of abundance.

SC/67a/RMP03 presented preliminary abundance estimates of common minke whales in the Northeast Atlantic area based on the progress made during the first three years of the mosaic survey cycle over 2014-19. The areas covered so far are the Svalbard area, the Norwegian Sea and the Jan Mayen area. The analyses have been conducted using the same methodology as for the most recent completed survey cycle over 2008-13. The resulting estimates indicate that large distributional shifts of minke whale abundance are occurring in this region. The drop in abundance in the Jan Mayen area, which was observed in the 2008-13 survey cycle to fall to 40% of the abundances recorded in the two earlier survey cycles, seems to have reversed recently. In 2016, the abundance in the CM Management Area (Jan Mayen) was more than twice the estimates from the 1996-

2001 and 2002-07 cycles, and five times that of 2010. The minke whale abundance attributed to the Norwegian Sea has seen a decrease during the recent survey cycles. In the Svalbard area (*ES*) the minke whale abundance in 2014 had decreased to 45% of the abundance level observed in 2008.

In discussion, the Working Group noted that the last complete survey-cycle for abundance estimation had been provided in 2008, and that the current work was an update of progress on work since that time. As such, no new abundance estimates were presented for consideration. However, results from the present work highlighted large shifts in the distribution of minke whales in the North Atlantic, suggesting that six-year survey cycles may eventually prove problematic for obtaining precise abundance estimates, if changes in distribution occur at smaller time-scales. While the need to finalise the current survey cycle was recognised, the Working Group considered there may be merit in investigating whether different patterns in the allocation of effort through time might better account for distributional shifts when estimating abundance. For instance, if the whole area is currently surveyed in six-year cycles, it is possible that that doubling survey coverage with half the intensity every three years (or similar) might better account for range shifts.

In conclusion, the Working Group acknowledged the progress report and **recommended** that the authors consider a simulation study to assess what benefit might be derived from a temporal reallocation of effort to account for potential changes in species distributions.

3.1.1.2 NORTH ATLANTIC HUMPBACK WHALES

Víkingsson provided a short overview of abundance estimates of humpback whales in the Central North Atlantic derived from the North Atlantic Sightings Surveys (NASS) during 1987-2007 (Paxton *et al.*, 2009; Pike *et al.*, Unpublished; Pike *et al.*, 2002; 2009; 2010). These estimates are relevant for a forthcoming assessment of North Atlantic humpback whales as well as for ecosystem modelling. The estimates were derived from conventional line-transect methods, and in addition spatial modelling was applied to the 1995 and 2001 survey data. None of the estimates were corrected for availability bias and only the 2007 estimate was corrected for perception bias. The estimates indicate a rapid increase in the abundance of humpback whales in Icelandic waters during this period, with the first estimate (1987) at less than 2,000 whales, while the more recent uncorrected estimates (1995-2007) were in the range of 11,000-14,000 animals. The clumped distribution of humpback whales is reflected by the high CVs for most estimates. The authors considered the most recent analysis to provide best estimates from each survey.

There was insufficient time to review all the estimates during the meeting. An intersessional correspondence group was established under Palka to perform this review. A report from this group will be presented at the Scientific Committee meeting next year (see Item 8).

Estimates of abundance of humpback whales from aerial surveys in east and west Greenland in 2015 were provided in Hansen *et al.* (2016), presented in Table 1. The Working Group **endorsed** estimates of 4,288 (CV=0.38, 95% CI=2097-8770) for East Greenland in 2015 and 1,008 (CV=0.38, 95% CI=493-2,062) for West Greenland in 2015 for inclusion in the IWC Abundance Table under Category 1.

3.1.1.3 NORTH ATLANTIC FIN WHALES

Estimates of fin whale abundance in east and west Greenland in 2015 were presented in Hansen *et al.* (2016), summarised in Table 1. The Working Group **endorsed** the estimate of 465 (CV=0.35, 95% CI=233-929) for West Greenland in 2015 for inclusion in the IWC Abundance Table under Category 1.

3.1.1.4 NORTH ATLANTIC (SVALBARD) BOWHEAD WHALES

Vacquié-Garcia *et al.* (2017) provided the first partial survey estimates for the Svalbard/Spitsbergen stock of bowhead whales and narwhals in an ice-covered area north of Svalbard. The Svalbard archipelago is an Arctic hot spot which has experienced large changes in ice-related statistics like the coverage and extent of ice, its thickness and its multi-year character. Water and air temperatures have also increased, and modelling indicates the possibility of an ice-free Arctic at the end of this century. The main objective of this study was to try to provide baseline abundance estimates for three ice-associated cetacean species: the bowhead whale (critically endangered according to IUCN Red List), the narwhal and the white whale (near threatened). This was addressed by conducting helicopter and ship line transect surveys in the Marginal Ice Zone (MIZ), that is the transition zone between open ocean and sea ice, north of the Svalbard archipelago in August 2015. The helicopter ran parallel transects perpendicular to the ice edge and approximately 100 n.miles (185km) into the sea ice, while the ships ran zig-zag transects along the ice-edge in open water. The total primary survey search effort was 599km for the ship and 7,830km for the helicopter. No cetaceans were recorded on the ship transects, while 15 bowhead sightings (of 27 individuals) and 11 narwhal sightings (of 58 individuals) were made during the helicopter survey. No white whales or other cetaceans were observed. Bowheads occurred mostly near the ice-edge in medium ice concentrations and narwhals at higher latitudes with heavier ice concentrations. This resulted in abundance estimates uncorrected for availability bias of 69 for bowhead whales and 268 for narwhals. After correction for availability bias using external correction factors derived from similar Greenlandic surveys, abundance for bowhead whales was estimated at 343 (CV=0.49, 95% CI=136-862) animals. The local marine mammal sightings database gives some additional information on other species in adjacent open waters during the survey period in August 2015. In the open waters north of Svalbard towards the MIZ, a considerable number of baleen whales was recorded, especially fin and blue whales, indicating that the retreat of ice may also extend the possible feeding areas of the seasonally migrating baleen whales.

While the Working Group recognised several limitations with the survey and resulting abundance estimates for bowhead whales (e.g. partial coverage, high CVs), it also understood the importance of the survey work given that it relates to a population once thought to be extinct. Consequently, the Working Group **endorsed** the abundance estimate of 343 (CV=0.49, 95% CI=136-862) bowhead whales for the Svalbard/Spitsbergen stock in 2015 for inclusion in the IWC Abundance Table as Category 3.

3.1.1.5 BERING-CHUKCHI-BEAUFORT SEAS BOWHEAD WHALE

SC/67a/AWMP08 reported on a unique opportunity to estimate the abundance of Bering-Chukchi-Beaufort Seas (B-C-B) bowhead whales that arose in late August 2016. During a set of five line-transect survey flights for marine mammals that were conducted by the Aerial Surveys of Arctic Marine Mammals (ASAMM) project, the survey crew found unprecedented numbers of bowhead whales in the western Beaufort Sea. Although not explicitly designed to estimate absolute population abundance, the ASAMM survey protocols and design, data collected and encounter rates enabled abundance estimation of bowhead whales within the survey region that encompassed the continental shelf (0-200m) during a short four-day sampling period with 2,198km of on-transect effort. The plane diverted from the transects to circle sighted groups and determine group size. Total abundance was estimated with a Horvitz-Thompson type estimator using the results from a single-observer multiple covariates distance sampling analysis. It was not possible to estimate *g*(0), so a published value was used. The best estimate of abundance, which included data from circling and allowed for a variable strip width was 15,575 whales (CV=0.5). However, data from past surveys, satellite tags, opportunistic encounters and traditional knowledge all indicate that the bowhead whales in the survey region during these four days likely constitute only a portion of the overall B-C-B bowhead whale population.

The Working Group noted several limitations with the abundance estimates presented, including negative bias, an assumed *g*(0) that resulted in a relatively large correction factor (>5) for trackline detection bias adjustment, and no estimate of uncertainty for this adjustment. Comments were made that if the current estimate was to be used for *SLA* trials the CV of the abundance estimate itself could be considered too high, since it was outside the plausible range of uncertainties previously tested. The authors acknowledged these limitations, particularly the lack of an estimate of uncertainty for *g*(0), but indicated their view that overall CVs of this magnitude were not unprecedented for use in *SLA* calculations (e.g. minke whale abundance estimate CVs of around 0.5 have been used). It was further suggested that it might be possible to conduct sensitivity tests using a range of CV values for *g*(0). In considering this proposition, the Working Group noted that detectability varies with school size and that several very large school sizes were detected during the survey. Since the assumed *g*(0) value was derived from the literature, it would be important for its applicability to be carefully considered in the light of the distribution of school sizes observed in the original and in the present study. It was noted that an exact understanding of the design and methodological issues was hindered by the use of non-standard terminology for line transect sighting surveys, though these nomenclature issues did not ultimately limit an understanding of the final estimates. Some members of the Working Group considered that the lack of a CV for *g*(0) was unlikely to be the most important limitation, citing negative biases as potentially more important due to a possible interaction between *g*(0), availability and the method for estimating group size for which the circling nature of closing mode gives whales more time to come to the surface.

The Working Group referred the estimates provided in SC/67a/AWMP08 to the Standing Working Group (SWG) on Aboriginal Whaling Management Procedures (AWMP) for consideration as to whether they could be used as estimates of minimum abundance for use in *SLA*s (Annex E, item 5.3.1). The Working Group noted that as a result of additional work kindly undertaken by the authors and reported to the SWG on AWMP, the authors had decided to withdraw the estimate as the CV of the revised estimate was too high to be useful for management purposes.

SC/67a/AWMP09 presented new photo-identification data that were collected from a 2011 aerial survey of B-C-B Seas bowhead whales. These images were scored for photo quality and whale identifiability, and then matched to existing images from 1985, 1986, 2003, 2004, and 2005. Other inter-year comparisons between this set of years were also conducted to generate a complete matching matrix for the 6 years. These data were used to estimate bowhead survival rate and population abundance using Huggins models embedded in a Robust Design capture-recapture analysis. BIC was used to select covariates, and to rank, compare and average models. The estimated survival rate was 0.996 with an approximate lower confidence bound 0.976, which is consistent with previous estimates and with research showing that bowhead lifetimes can be very long. The estimated 2011 abundance was 18,797 (CV=0.214, 95% CI=12,403-28,486). Although much less precise than the 2011 ice-based abundance estimate (16,820 with CV=0.052, 95% CI=15,176-18,643) of Givens *et al.* (2016), this 2011 photo-identification estimate adds to the evidence that the stock is abundant, having increased from previous years, and unlikely to be harmed by limited subsistence hunting.

In considering these estimates, the Working Group sought clarification about how the markings on whales were used to re-identify individuals in subsequent years. The author provided an explanation of how multiple photographs of the same individual, and multiple zones on individuals, are used to re-identify whales across years. Importantly, the degree of 'markedness' and photo quality are treated in an integrated fashion; if marks on one zone are visible in one photo, but marks in another zone are visible in another photo, then it is the integration of this information that is important in determining a positive match to a known individual. It was noted by the author that if an individual is highly marked but the photo quality is poor, this may still prove adequate for identification since a high degree of marking can be sufficient for future recognition. The Working Group discussed the estimation method, which was a Robust Design model with a Jolly-Seber primary model and Huggins secondary model based on three primary periods. It was noted that only a single secondary occasion was available in the third primary period, necessitating the creation of a 'dummy' period. The Working Group queried how the dummy period could be accommodated in the Robust Design, and was advised that while data were obviously missing for that period, so too are the parameters in the estimation; the algebra shows how that part drops out of the likelihood. The Working Group noted that SC/67a/AWMP09 gives two alternate abundance estimates and, pending further work, it was not immediately clear which estimate should be adopted. The author indicated that further work to estimate p^*, the proportion of the bowhead whale population that is marked, is currently underway and a final abundance estimate would be presented in the future.

In light of this discussion, and recognising that new abundance estimates are not required for the current meeting, the Working Group supported the methodological approaches presented and **recommended** that further work be undertaken by the authors to finalise the estimate for consideration at a future meeting.

3.1.1.6 OKHOTSK SEA BOWHEAD WHALE

SC/67a/NH10 applied an open-population mark-recapture model to genetic samples from bowhead whales in the western Okhotsk Sea. The best-fitting model based on the AIC criterion resulted in an estimate of abundance that was declining, dropping to 218 (CV=0.22) individuals in 2016. However, an open population model with constant population size of 258 (CV=0.20) was not definitely rejected ($p \approx 0.03$, one sided). A more detailed summary and a discussion of this document is presented in Annex G, item 9.3.8.

The Working Group considered this to be an important population estimate given the low population size and paucity of information about the region. In discussion, it was noted that the estimate of survival seemed low for bowhead whales. The paper noted that hunting by killer whales was frequently observed, and the author speculated that earlier ice melting might increase the exposure to killer whale predation. The possibility of emigration would not explain the combination of apparent high mortality and population decline, which were estimated independently of one another. The recruitment rate was not well estimated (0.07 with an SE of 0.05) and even zero recruitment was consistent with the data. The author indicated that in future work it be might be possible to incorporate qualitative information on whale sizes, potentially informing the recruitment-mortality-emigration question by allowing some assessment of the distribution and relative contribution of smaller whales (sub-adults) to the estimates. The Working Group concluded that while the evidence for the decline was not conclusive, there was clearly a high priority for resuming the monitoring this stock. In addition, the Working Group **endorsed** the abundance estimate of 218 individuals (CV=0.22) in 2016 as appropriate to be included in the IWC Abundance Table as Category 3.

3.1.1.7 NORTH PACIFIC GRAY WHALES

SC/67a/NH11 presented an updated population assessment of gray whales off Sakhalin and Kamchatka, using a population model that allows for multiple feeding and breeding areas. The model is fit to photo-identification data collected off Sakhalin during 1995-2015 (Burdin and Sychencko, 2015), tracking of whales from Sakhalin to the eastern North Pacific (Mate *et al.*, 2015), photo-identification matches of gray whales between the Sakhalin and Mexico catalogues (Urbán R. *et al.*, 2013) and reported photo-id results from Kamchatka collected during 2014 (Yakovlev *et al.*, 2013). The results show that the Sakhalin and Kamchatka feeding populations have been increasing at 2-5% per year over the 10 to 20 years prior to 2015. The number of non-calf whales in 2016 is estimated to be 320-410, of which 130-170 are predominantly Sakhalin-feeding whales and 180-220 are whales that feed at least occasionally off Sakhalin. If some of the whales breed in the western North Pacific, the size of that subset of the population is estimated to be at most 50 animals.

Being essentially a modelled mark-recapture estimate, the method provides a time series of abundance estimates with covariances, and is dependent on stock structure assumptions because it estimates a population rather than a snapshot of the whales in a given area at a given moment. It was proposed that for the purpose of the IWC Abundance Table, it would be reasonable, given a stock structure hypothesis, to select one abundance estimate from near the start of the series and one from near the end, because the covariance between the two ends is negligible.

SC/67a/NH11 outlined various aspects of the latest application of the analysis method. However, it does not describe the method employed fully. The Working Group **recommended** that Cooke provide a consolidated paper that fully specifies the method to the next year meeting of the Scientific Committee, including full details of the likelihood function and how posterior samples are generated. This will involve combining aspects of SC/67a/NH11, Cooke *et al.* (2016) and SC/A16/GW02. The analysis is based on software developed by Cooke rather than conventional methods for analysing photo-identification data such as the program MARK.

The Working Group **endorsed** the estimates of abundance for 1995 and 2015 for the two cases: (i) a Sakhalin feeding population (whose members do not necessarily feed exclusively of Sakhalin); and (ii) a combined Sakhalin and Kamchatka feeding population (see Table 2) for inclusion in the IWC Abundance Table under Category 3, noting that these estimates arise from a population model that integrates several sources of data, including photo-id matches between the Sakhalin and Mexico catalogues as well as photo-id data from Kamchatka and Sakhalin Island and satellite-based tracking data.

Table 2

Estimates of abundance for gray whales (1+ population) in Sakhalin and Sakhalin and Kamchatka from SC/67a/NH11.

	Sakhalin		Sakhalin and Kamchatka	
Year	Estimate	SE	Estimate	SE
1995	74	5	129	10
2015	191	8	282	14

Table 3

Abundance estimates for the PCFG (Pacific Coast Feeding Group of western gray whales) based on mark-recapture analysis from SC/A17/GW5.

Year	Estimate [PCFG]	CV
1995		
1996		
1997		
1998	126	0.087
1999	145	0.101
2000	146	0.098
2001	178	0.076
2002	197	0.069
2003	207	0.084
2004	216	0.077
2005	215	0.125
2006	197	0.108
2007	192	0.136
2008	210	0.089
2009	208	0.101
2010	200	0.095
2011	205	0.078
2012	217	0.052
2013	235	0.059
2014	238	0.080
2015	243	0.078

Calambokidis *et al.* (2017) provided updated abundance estimates of gray whales for the Pacific Coastal Feeding Group (PCFG) range as defined by the IWC. Photo-identification data collected from 1996 through 2015 were used in open population models to estimate survival and a time series of abundance estimates. The most recent estimate for 2015 was 243 whales (SE=18.9). Abundance had been relatively stable since the early 2000s but increased in the 2013-15 period.

The Working Group noted that this document provided an update from existing estimates previously reviewed and accepted by the Scientific Committee. It was **agreed** that the updated time series of abundance estimates for PCFG gray whales (Table 3) be accepted for use in the assessments of North Pacific gray whales and for inclusion in the IWC Abundance Table under Category 1.

Durban *et al.* (2017) provided results from two years of new counts and abundance estimates for gray whales migrating southbound off the central California coast between December and February 2014/15 and 2015/16. These counts were made from a shore-based watch station at Granite Canyon, California, and represent a continuation of the NOAA gray whale abundance time-series that began in

1967 (Laake *et al.*, 2012). Counting methods and analytical techniques for the 2014/15 and 2015/16 estimates followed those previously reviewed by the Scientific Committee and described in Durban *et al.* (2015) for four previous abundance estimates between 2006/07 and 2011/12. The 2014/15 estimate was 28,790 (95% HDPI=23,620-39,210) and the 2015/16 estimate was 26,960 (95% HDPI=24,420-29,830). There was consistency between the model predictions and observed counts for both years. However, daily and total abundance in 2014/15 were subject to considerable uncertainty, as shown by the large error bars associated with each of the daily estimates (illustrated in Fig. 1 of Durban *et al.* (2017)) and the relatively large coefficient of variation (CV=posterior standard deviation/posterior median; CV_{2015}=0.13). This is likely explained in part by the results of model fitting, as significant departures from the Normal migration model (probability of Normal model <0.25) were estimated in 18/90 days in 2014/15 compared to only 9/90 days in 2015/16. These departures, and the uncertainty associated with estimating an independent migration curve, constrained the estimation of a precise migration curve. In contrast the CV_{2016}=0.05 was consistent with previous estimates using this counting approach and model (CV=0.04-0.06 for four previous estimates since 2006/07), and this estimate was therefore more useful for interpretation in the context of the abundance time series. Differences in the CVs from the two years demonstrated the value of completing two counts and abundance estimates in back-to-back years, which provided a measure of redundancy.

Being updates to previous estimates using previously agreed methods, the Working Group **agreed** that the gray whale abundance estimates from shore-based counts off California in 2014/15 (*N*=28,790, 95% HDPI=23,620-39,210) and 2015/16 (*N*=26,960, 95% HDPI=24,420-29,830) are suitable for use in *SLA* and as part of the conditioning process for range-wide modelling, and are classified as Category 2 in the IWC Abundance Table. However, potential methodological issues were raised in discussion, including apparent oscillatory behaviour between the spline and standard model, and a tendency for the spline model to be consistently estimated to lie below the Normal model in 2014/15. The Working Group **encouraged** the authors to investigate these issues and report their findings to the Scientific Committee in the future.

3.1.1.8 NORTH PACIFIC SEI WHALES

No paper was presented under this agenda item.

3.1.1.9 NORTH PACIFIC BRYDE'S WHALES

SC/67a/RMP04 provided western North Pacific Bryde's whale abundance estimates by sub-areas and additional variance estimates for use in *Implementation Trials* for this species. This paper had been submitted in response to a recommendation from the first intersessional Bryde's whale Workshop (SC/67a/Rep07) that a new document be provided to the Scientific Committee meeting in May 2017. This document had been recommended to include more details on the survey collection modes and data used, analytical methods (e.g. how were the CVs calculated, model averaging, use of alternative covariates) and results reported. It had also been recommended that the paper include the additional analyses that need to be undertaken before the estimates can be agreed such as: (a) including sightings that were identified as 'Bryde's like' and 'unidentified large baleen whales'; and (b) attempting to estimate *g*(0). Abundances by sub-area were estimated incorporating the new boundaries agreed at the workshop. Abundance estimates are based on 2013-15 IWC-POWER surveys and 2008, 2012 and 2014 JARPNII surveys. In this paper, details on the survey collection modes and data used, analytical methods and reported results are presented in accordance with the review Workshop's recommendations. Plots for pre-determined tracklines, the survey order in each survey year, primary and secondary sightings of the Bryde's whales, and tracklines actually surveyed are provided. Abundance estimates and their variance were estimated using Horvitz-Thompson like estimators. Detection functions are fitted using school size, Beaufort scale and year as candidate covariates. Covariates were selected by AIC for POWER and JARPNII data, respectively. Akaike weights were used to obtain weighted averages of abundance estimates, with higher weights assigned to those estimates with lower AIC scores. Sensitivity analysis was performed to assess the effects of including undetermined large baleen whales and Bryde's-like whales in estimates. Additional CVs were estimated using abundance estimates by sub-area in three periods (1988-96, 1998-2002 and 2008-15) using four models. These four models (with/without adjustment by areal coverage and with/without exponential growth) are used to estimate additional CVs and their standard deviations. Abundance estimates are 8,219 (CV=0.179) for the IWC-POWER data and 18,080 (CV=0.272) for JARPNII, both using the best estimated detection function. These estimates were used to estimate abundance by sub-areas. Weighted averages using Akaike weights and abundance estimates including species codes other than Bryde's whales were not substantially different from the abundance using the best model for IWC-POWER and JARPNII. The abundance estimates were 15,422 (CV=0.289), 6,716 (CV=0.216) and 4,161 (CV=0.264) in sub-areas 1W, 1E and 2 respectively, based on the recent surveys. The total abundance estimate was 26,299 (CV=0.185, 95% CI=18,374-37,643). Additional variance was estimated as 0.335 with SD=0.161 for the best model.

The Working Group thanked the authors for following up on the workshop recommendations, and **agreed** to accept the total abundance estimate of 26,299 (CV=0.185; 95% CI=18374-37643) and the additional variance estimate of 0.335 (SD 0.161) for inclusion in the IWC Abundance Table under Category 1, noting that the estimate assumes that *g*(0)=1. The Working Group **reiterated** the recommendation from SC/67a/Rep07 that an investigation be undertaken to ascertain if *g*(0) can be estimated, and that results of this investigation be reported to the Working Group next year.

3.1.1.10 SOUTHERN HEMISPHERE RIGHT WHALES

SC/67a/CMP01 estimated the relative abundance of southern right whales by conducting an aerial survey of individuals in a 620km coastal strip in the Península Valdés (PV) area, Argentina. Perfect detectability of animals was assumed due to the shallow depth of the survey area (<20m) and the fact that flights were conducted during Beaufort Sea State 0-3 conditions only. The purpose of the survey was to estimate temporal trends in relative abundance for the study region. Surveys were carried out using high-wing single-engine aircrafts, with a total effort of 65 flights from 1999 to 2016. Mother-calf pairs, solitary individuals and breeding groups were counted. Data were analysed using a generalised linear model with log-link and assumed negative-binomial distribution. Predictor variables included year and a quadratic term in month, with the latter was tested against an alternate within-season term, reflecting a quadratic effect in Julian day. Response variables were total number of whales; number of calves; number of solitary individuals and number of mating groups. AIC was used for all model selections. The selected model for total number of whales estimated a rate of increase of 0.60% p.a. and 2.30% p.a., for calves while solitary individuals and mating groups had negative rates of increase. The annual rate of increase declined from 2007 to 2016, both for total number of whales and calves. The declining trend in the rate of increase, the increase in mortality rate, and the relocation of adults to deeper waters to the Northern Golfo San Matias is thought to provide evidence of a density dependence process and an indication that whales are is reaching carrying capacity for the PV region.

In discussion, the authors were asked why standard distance sampling methods were not employed for these surveys. In response, the authors explained that detection functions had been estimated in the past, but surveys are only conducted in good flying conditions and over shallow depths, so that the survey was essentially a time- and area-specific census. It appeared there may have been some expansion of the population into deeper waters, and that this may have been increasing over time. The author suggested that carrying capacity may have been reached in the PV area, and this apparent expansion might account for the estimated decreasing rates of population increase. It was not possible to know if rates of increase were decreasing at a local scale, or simply due to an expansion of their usual range. The Working Group **recommended** that surveys to monitor relative abundance continue within the PV study area.

3.1.2 Small cetaceans

3.1.2.1 SMALL CETACEANS IN RIVERS, ESTUARIES AND RESTRICTED COASTAL HABITATS IN ASIA

There was insufficient time to discuss papers relevant to this agenda item. The Working Group **agreed** that documents relevant to the work of the Scientific Committee or those containing estimates that could be incorporated in the IWC abundance table would be reviewed intersessionally by an email correspondence group under Palka (see Item 8, below).

3.1.2.2 OTHER SMALL CETACEANS

Baker *et al.* (2017) presented results from the continued genetic monitoring of the Māui dolphin subspecies in 2015-16, following methods published previously which had been applied to surveys conducted in 2010-11 and from 2001-07. A total of 25 small-boat surveys dedicated to the collection of biopsy samples had been conducted in the known current range of Māui dolphins during a three-week period in the austral summers of 2015 and 2016. Māui dolphins are highly aggregated in distribution, with an extreme occurring in 2015, and are very attracted to boats, making them good candidates for biopsy sampling. A total of 92 biopsy samples were collected from individual dolphins older than one year of age. DNA profiles were completed for each sample, including genotyping of up to 25 microsatellite loci, genetic sex identification and mitochondrial DNA (mtDNA) control region sequencing. Based on matching of the microsatellite genotyping, 17 individuals were sampled in both 2015 and 2016, providing a minimum census of 51 individuals (19 males, 32 females) alive at some point during the two-year study, of which two were identified genetically as Hector's dolphins. For the Māui dolphins, a two-sample, closed-population model was used to estimate an abundance of 63 individuals of age 1+ (CV=11%) for the 2015-16 surveys. This estimate is comparable to, but slightly larger than the previous estimate of N=55 (CV=15%) based on the genotype surveys in 2010-11. In addition to the conventional genotype capture-recapture analysis, the study took advantage of the microsatellite genotypes to estimate the effective population size using linkage disequilibrium (Do *et al.*, 2014; Waples and Do, 2008). Using the combined sample of 49 Māui dolphins from 2015-16, the linkage disequilibrium method estimated an effective population size of N_e=34 (95%, CI=24-51). Retrospective matching of DNA profiles for all samples collected from 2001 to 2016 resulted in a total count of 115 individual Māui dolphins, 102 of which were sampled live, 13 sampled beached (dead) and one sampled alive and dead two years later. Three individuals (two females; one male) were sampled in both 2001 and 2016, confirming a minimum survival of 15 years.

The Working Group asked for clarification on how the estimates of effective size (N_e) should be interpreted. It was noted that the method used effectively calculates the number of parents contributing to the current population (N_b). This estimate can be converted into a 'true' N_e estimate if life history parameters of the species are known (Waples *et al.*, 2014). The estimate of effective size was based on the linkage disequilibrium method (Waples and Do, 2008). A benefit of using this approach is that, unlike genetic mark-recapture, samples from two distinct time periods are not required. The Working Group commented that the last two estimates of census size (i.e. from the genetic mark-recapture approach) are similar, and both are markedly more precise than the earlier estimate of abundance (2001-07) reported in Baker *et al.* (2013). The author clarified that the 2001-07 estimate was based on an open population model, while the last two estimates were based on a closed population model given that they encompassed two sequential years. There were also differences in survey effort between the first period and the last two periods. It was noted that the survival rates estimated using the genetic mark-recapture data are low, which is consistent with a declining population. Additional surveys would be needed, however, to obtain a robust estimate of the trend in abundance from the mark-recapture genetic data.

In discussion, the Working Group **agreed** that while other estimates of abundance estimates using similar methods were mentioned on the paper, only the one computed for 2015-16 (N=63, CV=0.11), for which the methods were explicitly presented in the report, were **endorsed** for inclusion in the IWC Abundance Table under Category 1. Suggestions were made that earlier estimates obtained using similar techniques should also be approved. However, the Working Group **agreed** that for consistency of the review process, the methods used to compute estimates must be available when abundance estimates are reviewed and **encouraged** submission of these estimates for discussion at the Scientific Committee.

Hamner *et al.* (In press) described a similar estimate of abundance (N) using genotype capture-recapture and effective population size (N_e) using Linkage Disequilibrium methods for a local population of Hector's dolphins, the sister subspecies of the Māui dolphins. This population was chosen, in part, because of the availability of estimates of abundance using different methodologies, e.g. vessel and aerial line transect (Dawson *et al.*, 2004; Mackenzie and Clement, 2014). Cloudy Bay was surveyed by small vessels during August 2011 and again in 2012, with the primary objective of collecting genetic samples and photographs for individual identification. A total of 263 samples had been collected for genetic identification and 856 photographs for individual identification. The assumption of geographic closure in Cloudy Bay was supported by the lack of genetic differentiation between the two survey years and the absence of any genetically detectable migrants. Using a two-sample closed population recapture analysis based on genotype identifications, the authors estimated the abundance of individuals age 1^+ (N_{1+}) to be 269 (CV=0.12). This was similar to, but more precise than, *N*=230 (CV=0.30) from the more traditional analysis using contemporaneously collected photo-identifications. The N_e of the parental generation was 191 (95% CI=23-362), and the resulting N_e/N_{1+} of 0.71 was in reasonable agreement with species of similar life history characteristics (Waples *et al.*, 2014).

Baker noted that the capture-recapture estimates of abundance from both sources of identity (i.e., genotype and photo-identification) were larger than the previous vessel-based line transects (Dawson *et al.*, 2004) but considerably smaller than recent aerial line-transect surveys (Mackenzie and Clement, 2014) in the same region.

In discussion, a query was raised whether assumptions of random biopsy sampling and population closure were met. The author responded that there was no evidence of bias in individuals sampled and the field teams took care to avoid replicate sampling within a season. The lack of genetic differentiation between the two survey years was consistent with a closed population, supporting that assumption. In conclusion, the estimate of 269 individuals (CV=0.12) for the period 2011-12 was **endorsed** for inclusion in the IWC Abundance Table under Category 1.

Hammond *et al.* (2016) provided design-based estimates of cetacean abundance in European waters in summer 2016 from the SCANS-III survey. The independent project, ObSERVE, conducted surveys in Irish waters during the period 2015-17, providing coverage for the waters to the south and west of Ireland in the SCANS-III study area. These estimates will be reviewed next year.

3.2 Update of the IWC Abundance Table

An updated table including the abundance estimates discussed above and **agreed** for inclusion in the IWC Abundance Table during the meeting is presented in Appendix 4.

4. CONSIDERATION OF APPROACHES TO SPECIFY THE STATUS OF STOCKS

The Scientific Committee has been asked to provide the Commission with a summary of advice on the status of stocks on a broad level (e.g. ocean basin or region). RMP and AWMP *Implementation Simulation Trials* are designed to provide robust management advice but not 'status' in the traditional sense expected by the Commission (i.e. what is the present 'stock' level compared to the unexploited level and what are the likely future trends). Rather they provide considerable output for a wide range of plausible scenarios that would need to be integrated and summarised to provide measures of status. The results of a set of *Implementation Simulation Trials* should be summarised by the following three statistics to provide information on status:

- current depletion (number of animals aged 1+ and older relative to 1+ carrying capacity);
- current 1+ abundance; and
- 1+ abundance in 2050 if all future RMP and AWMP catches (but not projected bycatches) are assumed to be zero.

Results should be provided for two values for the MSY rate (1% in terms of harvesting of the total (1+) component of the population and 4% in terms of harvesting of the mature component) unless the base-case trials are based on a higher value for the lowest plausible value for MSY rate or if MSY rate has been estimated and there is an agreed value. In addition, results should be summarised across simulations and trials (medians over simulations and averages across base-case trials).

Each base-case trial may have a different number of breeding stocks. Results should be reported by area, specifically for the Ocean Basin (i.e. 'Region') and by 'Medium Area' rather than by the sub-areas on which the population models underlying the trials are based to avoid having a very large number of summary statistics. However, there needs to be flexibility in reporting. For example, the Committee may also wish to present results for individual biological stocks about which it believes the Commission needs to be informed and hence that the default of reporting results by area only provides a misleading impression. The choice of the stocks for which results are be reported needs to be decided during *Implementations* and *Implementation Reviews*. The sub-committee **recommends** that the Guidelines for Conducting *Implementations* and *Implementation Reviews* be updated to reflect this, and that the control programs used for *Implementation Simulation Trials* be modified to report the three measures of status listed above. In addition, the results for all stocks should be calculated and made available to the Commission, but not included in the primary presentation.

5. RESEARCH PROGRAMS – DESIGN AND PLANNING OF ABUNDANCE SURVEYS

5.1 IWC-POWER cruises

Donovan introduced the report of the planning meeting for the IWC-POWER cruise for 2017 (SC/67a/Rep02), held in Tokyo from 15-17 September 2016. Donovan thanked Japan for hosting the meeting and the warm welcome. The planning meeting finalised details for the forthcoming IWC-POWER cruise to be held from 3 July-25 September 2017, including transit from and to Japan using the research vessel *Yushin-Maru No. 2*, kindly provided by Japan. It was confirmed, after the planning meeting, that the ship had received international clearance. Sailing with international status will provide considerable benefits with regard to permits and port entries for refuelling, and acoustic components like deployment of sonobuoys. This will be the eighth cruise under the successful international IWC-POWER programme. Together, the cruises to be conducted in 2017, 2018 and 2019 will cover the Bering Sea (Fig. 1). These plans have been endorsed by the Scientific Committee at SC/66b in 2016. The 2017 cruise will cover the easternmost stratum in the Bering Sea (Fig. 1), i.e. the US coast. This will give more time for obtaining the relevant permits for covering Russian waters in the westernmost stratum of the survey area. The 2017 cruise objectives (and also those of the 2018 and 2019 cruises) will be broadly the same as in previous years, with the important addition of an acoustic component, as endorsed by the Scientific Committee, where this component will be conducted in cooperation with the US. The cruise will focus on the collection of line transect data to estimate abundance as well as collection of acoustic, biopsy and photo-identification data. This will make a valuable contribution to the work of the Scientific Committee on the management and conservation of populations of large whales in the North Pacific.

A number of tasks to be completed prior to the cruise were identified including application for permits, final choice of researchers (Koji Matsuoka of Japan has been nominated as Cruise Leader), updating of Guidelines for Researchers, obtaining necessary equipment including biopsy darts and improved equipment for angle and distance experiments, as well as technical details and logistics concerning the

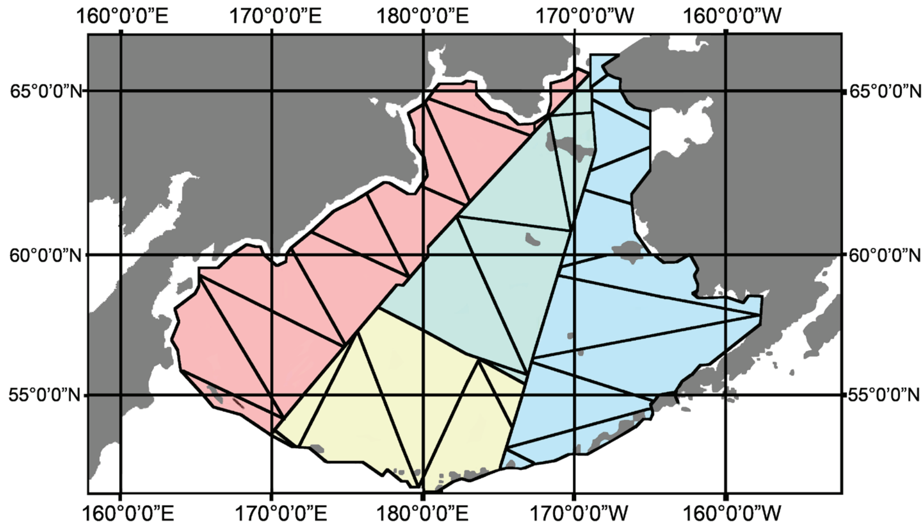

Fig. 1. Survey strata and proposed tracklines for POWER-cruises planned for the period 2017-19. The central block is divided into two strata for logistical reasons (trackline design). In 2017, the eastern (blue) block will be covered.

implementation of the acoustic component. Appropriate deadlines and responsible persons were identified. It was noted that a two-year budget had already been agreed upon, including the budget for the survey in 2018.

On behalf of the Working Group Donovan thanked the Government of Japan for the long-term provision of the vessel, and the Government of the USA for providing acoustic equipment. Russian colleagues were thanked for attending the planning meeting.

The Working Group **endorsed** the 2017 POWER cruise and recommended a detailed planning meeting for the 2018 cruise. Furthermore, the Working Group recommended that the USA and Russia facilitate the proposed research by providing respective permits for their national waters. The Working Group looked forward to receiving a report from the survey and **encouraged** this to be brought to the next Scientific Committee meeting.

It was noted that in the intersessional period funds for the development of the IWC integrated relational data base DESS, which links the various types of data that are collected and archived within the IWC (sighting, effort, and weather line transect related data; photographs; biopsies; processed genetic data; and processed passive acoustic data) had been made available. The next step to undertake is the development of a tender for the development of this database. The Working Group **encouraged** that this work be undertaken.

SC/67a/ASI09 reported the results of the 7th annual IWC-POWER cruise, conducted between 2 July to 30 August 2016 in the central North Pacific (with the dedicated research area located between 20°N-30°N and 135°W-160°W). The survey was conducted aboard the Japanese R/V *Yushin-Maru No.3*. Researchers from Japan, the US and the Republic of Korea participated in the survey, which was implemented using methods based on the guidelines of the Scientific Committee. Sighting coverage was 97.2% of the planned track-line. A total of 2,237.5 n.miles was surveyed under the Passing with abeam closing (NSP) and the Independent Observer passing (IO) modes. Additionally, 626.2 and 580.1 n.miles were surveyed during transit to and from the research area respectively. The following sightings were made: blue whale (1 school/1 individual), sei whale (1/1), Bryde's whale (28/32), sperm whale (32/125), Cuvier's beaked whale (2/5), Mesoplodon spp. (2/3), Ziphiidae (7/11), short finned pilot whale (2/31), pygmy killer whale (1/16), Risso's dolphin (2/19), bottlenose dolphin (1/37), common dolphin (8/217), striped dolphin (5/378) and spotted dolphin (1/133). Bryde's and sperm whales were the most frequently sighted large whale species. The Estimated Angle and Distance Training Exercises and Experiments were completed with improvements following Scientific Committee suggestions. Photo-identification data for 12 Bryde's whales and 2 sperm whales were collected. A total of 23 biopsy (skin and blubber) samples was collected from 1 blue, 1 sei, 16 Bryde's and 5 sperm whales using the Larsen biopsy rifle/darts system. In the case of Bryde's whale, 3 samples were collected from sub-area 1 (west of 180°E) and 13 samples from sub-area 2 (east of 180°E). A total of 153 marine debris objects were observed.

In discussion, an enquiry was made whether the numbers of sightings had been expected to be as low as encountered. In response, it was pointed out that the main objective of the cruise had been to investigate the easterly and southerly distribution of Bryde's whales, which could be addressed despite low sighting numbers.

On behalf of the Working Group, Kato thanked the Cruise Leader, researchers, Captain and crew, and the Steering Committee for completing the 6th cruise of the IWC-POWER programme. The Government of the USA had granted permission for the vessel to survey in their waters, without which this survey would not have been possible. The Government of Japan generously provided the vessel and crew. The Government of Republic Korea provided a researcher. Furthermore, the IWC Secretariat was thanked for providing support. The Working Group recognised the value of the data contributed by this and the other POWER cruises, collected in accordance with survey methods agreed by the Committee, covering many regions not surveyed in recent decades, and addressing an important information gap for several large whale species. The Working Group encouraged the future provision of abundance estimates arising from these data.

5.2 IWC-Southern Ocean Research Partnership (IWC-SORP)

No new information from the IWC-Southern Ocean Research Partnership programme on abundance estimates or survey plans for estimating abundance required consideration during this meeting. The Working Group **looks forward** to receiving information from future IWC-SORP projects in the future.

5.3 National Programs

SC/67a/ASI01 proposed a cetacean sighting survey conducted by COMHAFAT in coastal waters of western North Africa in the winter of 2018. The study area is set in the coastal waters of Guinea to Liberia, except for shallow waters less than 20m (for safe sailing). Zigzag track lines with around 1,100 n.miles total length are placed in the area. A 15-day survey period is planned for the 2018 winter season (in January and/or February of 2018). The survey is started off Conakry, Guinea and finished off Palmas Cape in Liberia. The research vessel, *General Lansana Conte* of Guinea (198 tons), will be engaged. Researchers from COMHAFAT member states will conduct the survey. Scientists from non-member states may attend if COMHAFAT and vessel capacity allow this. Cetacean searching will be conducted using line transect methodology, under good weather conditions (Beaufort wind scale of 3 or less and greater than 2 n.miles in visibility). Researchers will search the sea surface for cetaceans from the vessel following the pre-determined track lines at around 10 knots. The normal closing mode survey will be carried out, in which closure is conducted for all cetacean species encountered on the track lines.

In discussion, an explanation was given that the planned tracklines did not include the coastal waters beyond the 20m isobath due to limitations of time available for the survey, and furthermore that the survey will be a multispecies survey targeting small and large cetaceans.

The Working Group **welcomed** this multispecies survey in these waters since there have been few previous surveys of this area. It **endorsed** the proposal and **encouraged** future presentation of abundance estimates from this survey. It was noted that no IWC oversight was needed for this survey.

SC/67a/ASI02 presented a plan for a systematic vessel based dedicated sighting survey in the eastern Okhotsk Sea (the eastern part of the sub-area 12NE for common minke whales as defined for the RMP *Implementation*) by Russia in 2017. The research vessel *Vladimir Safonov* is a stern trawl type research vessel with a barrel for observation. The objective of the survey is to obtain information on distribution and abundance of large whales using normal closing mode. The period of the survey will be from 4 August to 7 September (35 days), and the vessel will cover the research area from 51°N-57°N and west of the Kamchatka Peninsula to 152°E. The research area will consist of a single block. During transit to the research area, the vessel will conduct a sighting survey in passing mode to enhance research capability of the crew and researchers. The distance and angle estimation training and experiments will be conducted during this survey. Photo-identification of cetaceans such as northern right whales, gray whales and humpback whales will be also be attempted. When peeled skin is found after breaching, the vessel will try to collect a DNA sample using a landing net.

In discussion, the proponents of the survey explained that no biopsy samples would be taken due to safety constraints on board. The researchers expect to encounter minke, killer, northern right and gray whales in the study area.

The Working Group **welcomed** and **endorsed** the plan to survey the eastern Okhotsk Sea, noting that Miyashita had been appointed to provide IWC oversight.

SC/67a/ASI04 presented the research plan for the NEWREP-A dedicated sighting survey in the 2017/18 austral summer season. The main objective of the survey is the systematic collection of sighting data aimed to produce abundance estimates of Antarctic minke whale and other large whale species. The survey plan follows the IWC's 'Requirements and Guidelines for Conducting Surveys and Analysing Data within the Revised Management Scheme (RMS)'. The survey is planned to be conducted in the eastern part of Antarctic Area V (165°E-170°W), which includes the Ross Sea, and the western part of Area VI (170°W-145°W). Whale sightings will be conducted under Normal Passing (NSP) and Independent Observer (IO) modes. The duration of the survey including transit is planned to be 130 days and the number of days dedicated to research in Antarctic waters to be 80 days. The survey will be conducted using two research vessels, *Yushin-Maru No. 2* (*YS2*) and an undetermined vessel with similar platforms. Both vessels will be equipped with a top barrel (TOP), an independent observer platform (IOP) and an upper bridge platform (UBP). For the sighting survey under IO mode, two researchers are required on board each vessel. SC/67a/ASI04 provides details of the stratification of the research area, trackline design, sighting effort and mode, distance and angle experiment and data entry system. Krill and oceanographic surveys and feasibility studies on biopsy sampling and telemetry for Antarctic minke whales will be also conducted (see details in the appendices of ASI04). After validation, sighting and associated data will be submitted to the IWC Secretariat. A cruise report will be prepared immediately after the survey is completed, and will be presented to the 2018 Scientific Committee meeting.

In discussion, the question was asked why Antarctic minke whales, not other large whale species, would be targeted in a feasibility study for telemetry with trials for attaching tags from the bow of the large vessel. The proponents explained that Antarctic minke whales are the focal species of the NEWREP-A research program and that the expert panel evaluation had requested these trials. Furthermore, it was explained that employment of zodiacs for tagging was not feasible under the survey conditions far-offshore and would not be considered due to safety requirements. The timing of the survey was discussed, following a suggestion that conducting the survey earlier in the year could potentially provide more sightings. Clarification was provided that the time period proposed had been selected for reasons of consistency and comparability with previous surveys.

The Working Group **welcomed** the proposed NEWREP-A multi-disciplinary survey involving a dedicated cetacean sighting survey, krill survey and oceanographic sampling survey, in addition to conducting biopsy and tagging experiments.

The Working Group **endorsed** the cetacean abundance estimation component of this proposal and the appointment of Matsuoka to provide IWC oversight.

SC/67a/ASI06 presented the research plan for the NEWREP-NP dedicated sighting survey in the North Pacific in 2018. The main objective of the survey is the systematic collection of sighting data to produce abundance estimates of common minke whales. The survey plan follows the IWC's 'Requirements and Guidelines for Conducting Surveys and Analysing Data within the Revised Management Scheme (RMS) (IWC, 2012)'. The survey will be conducted using the research vessel *Yushin-Maru No. 2* between 11 May and 25 June 2017. The vessel is equipped with a top barrel (TOP), an independent observer platform (IOP) and an upper bridge platform (UBP). SC/67a/ASI06 provides details of the stratification of the research area, trackline design, sighting effort and mode, distance and angle experiment, and the data entry system. The research area comes between 41°N and 46°N and 136°E and146°E (a part of sub-areas 10E and 11). Given the objective of whale abundance estimation, distance and angle estimation experiments will be conducted. Biopsy and photo-id experiments on large whales will be also conducted. After validation, sighting and associated data will be submitted to the IWC Secretariat. A cruise report will be prepared immediately after the survey is completed, and will be presented to the 2018 Scientific Committee meeting.

The Working Group **welcomed** the proposed NEWREP-NP multi-disciplinary survey involving a dedicated cetacean sighting survey, in addition to conducting biopsy sampling and photo-identification.

The Working Group **endorsed** the cetacean abundance estimation component of this proposal and the appointment of Matsuoka to provide IWC oversight.

SC/67a/ASI08 provided a plan for a systematic vessel-based dedicated sighting survey in the North Pacific during 2017 by Japan. It was noted that this survey is not conducted under NEWREP-NP. The main objective of this cruise was to examine distribution and estimate abundance of common minke whales for management and conservation purposes. The survey was being conducted using the research vessels *Yushin-Maru* and *Yushin-Maru No. 3* from 28 April to 27 May 2017 in the area north of 35°N, south of 43°N and between 140 and 146°E (a part of sub-areas 7CS and 7CN for the RMP *Implementation* for minke whales). Cruise tracks were designed systematically and the start point of the track lines were chosen randomly. Given the objective of whale abundance estimation, distance and angle estimation experiments will be conducted. Biopsy skin samples of blue, fin, sei, Bryde's, humpback and North Pacific right whales will be collected. Photo-identification experiments on blue, North Pacific right and humpback whales will also be conducted. Data related to abundance estimates will be stored at the Institute of Cetacean Research (ICR) and submitted to the IWC Secretariat based on the Scientific Committee Guidelines (IWC, 2012). The report of the sighting survey will be submitted to the 2018 Scientific Committee meeting.

The Working Group **endorsed** the cetacean abundance estimation component of this proposal and the appointment of Matsuoka to provide IWC oversight.

SC/67a/ASI10 provided a plan for a dedicated sighting survey for common minke whale conducted by Korea using the research vessel *Tamgu 3* in the Yellow Sea of Korea in spring, 2018. This survey will complement surveys conducted in Korean waters during previous years. Another two strata further offshore to the west are planned to be covered in 2018. The first objective of this survey is to obtain information on the distribution and abundance of common minke whales for stock assessment purposes. The second objective is to collect general information on the distribution of other cetaceans in the area. Transect lines totalling 741.6 n miles in length and using closing mode will be searched with both binoculars and the naked eye. Other research activities such as biopsy sampling or photo identification will be conducted during the survey.

The Working Group **endorsed** the cetacean abundance estimation component of this proposal and the appointment of Park to provide IWC oversight.

Three cruise reports of national research programs were available (SC/67a/ASI03, SC/67a/ASI05, SC/67a/ASI07). It was **agreed** that these documents would not be discussed because they contained no new abundance estimates and their contents did not contribute to improving the design of future surveys. Summaries of these documents are presented in Appendix 5.

National research programs were **encouraged** to provide estimates of abundance in future cruise reports for review by the Working Group.

6. METHODOLOGICAL MATTERS

6.1 Model-based abundance estimates and amendments to the RMP Guidelines

6.1.1 Review of intersessional work and pre-meeting

Bravington reported on the pre-meeting on model-based abundance estimation (Appendix 6). Abundance estimates from line-transect surveys can nowadays be derived statistically using spatial models, as well as the more familiar Horvitz-Thompson (HT) approaches. Spatial models have potential advantages in reducing bias resulting from patchy coverage, and in providing more reliable estimates of variance. In recent years, the Committee has recognised the need to develop its expertise in evaluating spatial-model-based abundance estimates, which are fairly complex, and also in deciding whether an estimate based on the simpler HT formulae can safely be used in cases when the strict assumptions underpinning HT do not apply (e.g. design reflects uneven coverage). To further this process, a workshop was held on 7-8 May, run by David Miller (CREEM) and Mark Bravington (CSIRO). The workshop explored some issues around the current state of spatial modelling for cetacean abundance estimation, and introduced software (ltdesigntester) for exploring the reliability of HT-based abundance estimates of specific surveys, either post hoc or in the design phase. Bravington provided an overview of preliminary workshop conclusions and highlighted potentially controversial points. Details may be found in Appendix 6.

The Committee has for some time been considering the need to amend the RMP guidelines (IWC, 2012) to incorporate abundance estimates produced using methods (e.g. spatial models, mark-recapture models) not yet considered by the Guidelines. One of the tasks of the pre-meeting was to consider such amendments, but time constraints meant that these amendments could not be discussed in detail. The Working Group **agreed** that an intersessional e-mail group under Zerbini (Item 8) would be tasked to propose amendments for discussion at next year's meeting.

6.2 Review of new survey techniques/equipment

SC/67a/NH09 reported on a new, innovative method to potentially study large whales using Very High Resolution (VHR) satellite imagery. Results from the first study using the WorldView-3 satellite for whales were presented. This satellite has a maximum spatial resolution of 31cm and is the highest resolution satellite presently in orbit. In order to investigate the possibility of identifying, counting and differentiating between mysticete species, satellite images from four different locations were acquired to target the breeding or feeding grounds of four candidate species: fin (*Balaenoptera physalus*), humpback (*Megaptera novaeangliae*), southern right (*Eubalaena australis*) and gray whales (*Eschrichtius robustus*). Visual and spectral analysis of each species and their surrounding environment were conducted. All species were successfully manually detected; this included the first observations from satellite for fin and gray whales. The visual analysis highlighted morphological differences between some of the targeted species with some species more discernible than others, such as the gray and fin whales, which were more confidently identified due to their calm behaviour and light body colouration. The white head callosities of southern right whales were observed on some individuals. Non-whale features such as boats and planes were also observed and clearly distinct from the surveyed whale species. These results show the potential

Table 4

Work plan.

Item	Intersessional 2017/18	2018 Annual Meeting (SC/67b)
2, 5 and 6	(1) Develop a process to facilitate the review of abundance estimates in a timely fashion prior or during the annual meetings. (2) Identify minimum requirements for presentation and review of abundance estimates for inclusion in the IWC consolidated table. (3) Develop processes to validate non-standard software, non-standard methods and how to consider estimates computed from population models. (4) Consider how to evaluate abundance estimates already included in the IWC consolidated table, but not yet reviewed by the SC. (5) Amend the RMP Guidelines, particularly in regard to methods so far not included in the guidelines (e.g. spatial modelling and mark-recapture).	Review report from the intersessional e-mail group.
3	Review estimates of abundance of North Atlantic humpback whales and Asian coastal and river dolphins.	Review report from the intersessional email group.
4	Incorporate the estimates agreed at this meeting, upload them to the IWC website and continue to update the IWC Abundance Table intersessionally (Allison).	Review intersessional progress.
5.1	2017 IWC-POWER cruise in the Bering Sea. Planning Meeting for the 2018 IWC-POWER cruise.	Review cruise report, report from the planning meeting and new abundance estimates from IWC-POWER cruises.

of using satellite imagery to study baleen whales. The next objective is to trial the automation or semi-automation of whale detection, because manually counting whales from satellite images is very time-consuming. Furthermore, it is intended to address the question of how deep below the sea surface whales are likely to be detected.

The influence of sea state on detection of whales by satellite imagery was discussed. Earlier studies trying to detect blue whales were not successful, mainly due to sea state issues. Despite the higher resolution of the WorldView-3 satellite, detections in sea states higher than 3 on the Beaufort scale are still problematic. Future applications of this technique were also discussed. Given an automated detection processes, the technique could be used to analyse occupancy or relative abundance of cetaceans, particularly for remote, inaccessible habitats with calm seas. It was suggested that areas of priority for investigation so could be identified by the IWC. The potential difficulty in species identification was discussed. Currently the method has been used only in areas of known species occurrence, with limited chances for species misidentification. Exploratory studies in areas of unknown species occurrence may be difficult. However, it was noted that at this stage, the study mainly represented a proof of concept. It was suggested that for further proof of concept analyses of other areas may be supported by existing acoustic or satellite tag data. The potential application to small cetaceans was also discussed. Since the method had not been able to detect any calves of large whales, which are larger in size than many small cetaceans, it was concluded that it was unlikely that small cetaceans could be detected. Moreover, it was noted that it is unlikely that the spatial resolution of the satellite would be further increased in the near future, because the current resolution satisfies commercial needs.

Until automated detection is available, crowd funding and citizen science projects were suggested for cost-efficient evaluation of satellite images. Furthermore, application of high-resolution satellite imagery for ship strike assessments was raised as potentially valuable.

Bravington *et al.* (2016) described a new method for computing abundance estimates and other population parameters integrating mark-recapture methods and relatedness of individuals inferred from genetics. This method is currently referred to as Close-Kin Mark-Recapture (CKMR). A summary of this paper and discussion by the Scientific Committee is provided in Annex I, item 6.2.1.

7. OTHER

7.1 IWC-IDCR/SOWER cruise data analysis and special volume

Donovan reported that the editorial work on the SOWER volume of the *Journal of Cetacean Research and Management* is expected to be completed in October, during a three-day meeting that will follow the POWER Cruise Planning Meeting.

8. WORK PLAN

Based upon the experience gained at this meeting, the Working Group noted that a process needed to be developed to facilitate the review of: (a) new abundance estimates in a timely fashion prior or during the annual meeting; and (b) existing estimates that had not yet been endorsed by the Committee. This process should include identifying minimum requirements for the presentation and review of abundance estimates for inclusion in the IWC consolidated table. The Working Group also noted that this process should consider how to validate non-standard software, non-standard methods, and how to address issues related to estimates computed from population models. The Working Group **agreed** that an email correspondence group under Zerbini would be tasked to develop this process intersessionally.

The **agreed** work plan is provided in Table 3.

9. ADOPTION OF THE REPORT

The report was adopted on 17 May 2017 at 22:07. The Chair thanked the rapporteurs, Herr, McKinlay and Olson, for their wonderful job recording the discussions during the Working Group sessions and for the timely completion of the report. The Chair also thanked the following members of the Scientific Committee who reviewed documents on behalf of the Working Group during the meeting: Givens, Palka, Punt and Wade.

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Appendix 1

AGENDA

1. Introductory items
   1.1 Opening remarks
   1.2 Election of the Chair
   1.3 Appointment of rapporteurs
   1.4 Adoption of the Agenda
   1.5 Documents available
2. Terms of reference and approach
3. Evaluations of abundance estimates and updates of the IWC consolidated table
   3.1 Evaluation of new abundance estimates
      3.1.1 Large whales
         3.1.1.1 North Atlantic minke whales
         3.1.1.2 North Atlantic humpback whales
         3.1.1.3 North Atlantic fin whales
         3.1.1.4 North Atlantic (Svalbard) bowhead whales
         3.1.1.5 Bering-Chukchi-Beaufort Seas bowhead whale
         3.1.1.6 Okhotsk Sea bowhead whale
         3.1.1.7 North Pacific gray whales
         3.1.1.8 North Pacific sei whales
         3.1.1.9 North Pacific Bryde's whales
         3.1.1.10 Southern Hemisphere right whales
      3.1.2 Small cetaceans
         3.1.2.1 Small cetaceans in rivers, estuaries and restricted coastal habitats in Asia
         3.1.2.2 Other small cetaceans
   3.2 Update of the IWC abundance table
4. Consideration of approaches to specify the status of stocks
5. Research programs – design and planning of abundance surveys
   5.1 IWC-POWER cruises
   5.2 IWC-Southern Ocean Research Partnership (IWC-SORP)
   5.3 National programs
6. Methodological matters
   6.1 Model-based abundance estimates and amendments to the RMP Guidelines
      6.1.1 Review of intersessional work and pre-meeting
   6.2 Review of new survey techniques/equipment
7. Other
   7.1 IWC-IDCR/SOWER cruise data analysis and special volume
8. Work plan

Appendix 2

TERMS OF REFERENCE OF THE *AD HOC* WORKING GROUP ON ABUNDANCE ESTIMATES, STATUS AND INTERNATIONAL CRUISES

The following are the Terms of Reference for the new *ad hoc* Working Group on Abundance Estimates, Status and International Cruises.

(1) Review of new abundance estimates on behalf of other sub-committees/working groups.
(2) Development of a biennial document compiling agreed abundance estimates including a basin wide summary.
(3) Development of a summary of information on the status of stocks (based on completed assessments or *Implementations*).
(4) Consideration of the design and analyses of IWC research projects related to abundance estimation including relevant IWC-SORP projects, IWC-POWER cruises and progress on IWC-SOWER related work.

Appendix 3

TABLES OF 'ACCEPTED' ABUNDANCE ESTIMATES

The aim of the tables of 'Accepted' Abundance Estimates is: (i) to collate information in a consistent way on abundance estimates accepted by the Scientific Committee for various purposes; and (ii) to provide a simplified table of abundance estimates suitable as a broad overview for the Commission and the public. See IWC (2014) for further details on the objectives.

(1) Accepted abundance estimates for Scientific Committee. The aim is to provide information consistently in a single table to represent an initial summary of the Committee's current set of 'accepted' abundance estimates. Work will be required to examine the comments and commonalities in order make the tables more consistent.
(2) Broad overview estimates for the Commission and general public.

IWC (2014) envisaged the broad overview estimates as a separate table. They are included here in the same table as (1) above but shown as being either on, or recommended for inclusion on, the IWC website. The advantage of using a single table is that it is easier to maintain and less prone to error when updating as data would not need to be entered or changed in multiple places. Different subsets can be used for different purposes.

Estimates for disjoint areas are summed if they were from the same year or years close together in time. These combined estimates are highlighted in grey. Approximate 95% confidence intervals for summed estimates are calculated from the CVs of the estimates and assuming a log-normal error distribution. In the interests of simplicity and a common approach, any additional variance estimate (available in only some cases) has been ignored for this purpose.

Only the most recent estimates for a species and ocean basin are given for the broad overview. Information on trend should be considered as an additional step to be pursued in the future, recognising the need for more consideration inter alia of information from modelling exercises.

The tables include notes about early values of the estimates which were later updated (or corrected) to explain from where different values have come and to ensure the most recent agreed values are used.

The key to the table columns is given below.

REFERENCE

International Whaling Commission. 2014. Report of the Scientific Committee. Annex Q. Report of the *ad hoc* group to develop a list of 'accepted' abundance estimates. *J. Cetacean Res. Manage. (Suppl.)* 15:416-17.

Heading	Contents
Area	If *Areas* are identified in an RMP context these should be used. If estimates pertaining to only a portion known range are agreed to be included (e.g. for AWMP) a comment should be included to show that this constitutes only part of the population. Otherwise use broad categories (e.g. Schedule *Management Areas*) and indicate whether coverage is total or partial.
Category	As described below. In each case if not clear add an asterisk to indicate that the estimate needs to be considered further. Use either: (1) acceptable for use in in-depth assessments or for providing management advice; (2) underestimate - suitable for AWMP usage or other 'conservative' management but not reflective of total abundance; (3) while not acceptable for use in (1) or (2), adequate to provide a general indication of abundance; (P) Provisional or Preliminary estimates (will be omitted from published tables); (X1) Category (1) estimates that have been superseded by newer estimates (will be omitted from published tables); or (ND) Not discussed. Used to show other estimates which have not been discussed by the Scientific Committee, but which may be discussed in future. They are shown 'Greyed out' and will be omitted from published tables.
Evaluation extent	Degree to which the estimate is considered originally by the sub-committee concerned. Use: (1) estimate was examined in detail by the sub-committee; (2) estimate was partially examined by the sub-committee but method is standard; (3) degree to which the estimate was considered by the sub-committee is unclear but method is standard; (4) estimate was partially considered by the sub-committee and a new method was used; or (5) degree to which the estimate was considered by the sub-committee is unclear and a new method was used.
RMP/AWMP status	Status in RMP trials. Use: 'I' agreed to be suitable for use in an actual *CLA* calculation to produce a catch limit; 'C' used in the RMP trial conditioning as an absolute estimate of abundance; 'C_{min}' used in the RMP trial conditioning a minimum estimate of abundance; 'CP' provisional estimate suitable for use in conditioning but further analysis needs to be considered before use in an actual *CLA* or *SLA* calculation; 'T' used in RMP/*SLA* trials but further analysis needs to be considered before use in an actual *CLA* or *SLA* calculation; 'S' agreed to be suitable for use with a *SLA* to produce strike limits; 'E' suitable for conditioning *Evaluation* and *Robustness Trials*, and for *Implementation Reviews*. 'R' Suitable for conditioning *Robustness Trials* or suitable for conditioning some *Evaluation* or *Robustness Trials*, or *Implementation Reviews* where the value is used as a minimum estimate of abundance.
Date stamp	The year to which estimate applies. This will normally be the year of the survey unless the estimate is based on multiple years or a population assessment model. (Note: Consideration needs to be given as to whether estimates from such models are acceptable for this table, in contrast to, for example, mark-recapture based estimates which do require model-processing.)
Range of years	The years concerned when the estimate applies to surveys over a number of years.
Method	LT: line transect (or distance-sampling): MR: mark-recapture; SM: spatial modelling; LT+SM: distance-sampling with spatial modelling; CC: Cue counting; PA: population assessment; PId: Photo-identification of individuals; SC: Strip census; GMR: Genetic mark recapture.
Correction (Corr)	Where applicable, indicate if the estimate is corrected for A: availability (corrects for the time the whales are available at the surface); P: perception bias (corrects for missed sightings); A+P: availability and perception bias; or adjustment for $g(0)<1$ applied. Note. Care should be taken regarding the interpretation of $g(0)$ because the distinction between availability and detection bias for ship-board surveys is somewhat arbitrary and dependent on the exact analysis method employed.
Estimate	Estimate of 1+ abundance unless otherwise indicated.
CV	CV of estimate from survey sampling error only.
CV (AV)	CV with Additional Variance component arising from annual distributional changes added.
95% CI	Approximate 95% confidence intervals (or equivalent) rounded to three significant figures of upper limit.
Areal coverage	Areal coverage as a percentage.
IWC reference	The reference to when and where the estimate was discussed in the Scientific Committee.
Original reference	The reference of the analysis presented originally.
Comments	Brief comments on survey and any difficulties encountered.
Program	Survey program/organiser.
On web?	Is estimate listed on the IWC website? Y: Yes. R: Recommended for inclusion. N: Not recommended for inclusion.

Appendix 4

TABLE OF AGREED ABUNDANCE ESTIMATES DURING THE 2017 SCIENTIFIC COMMITTEE MEETING

Area	Cat.	Eval. extent	RMP/AWMP status	Date stamp	Range of years	Method	Corr.	Estimate	CV	Approx. 95% CI	Original reference	Comments	Aerial coverage	Programme	On web?
North Atlantic common minke whales															
West Greenland	1	1	S	2015	2015	SC	A+P	5,241	0.49	2,114-12,992	Hansen *et al.* (2016); SC/67a/Rep06	-	-	-	R
West Greenland	1	1	S	2007	2007	SC	A+P	9,853	0.43	4,433-21,900	Hansen *et al.* (2016); SC/67a/Rep06	-	-	-	R
East Greenland	1	1	S	2015	2015	LT	A+P	2,681	0.45	1,153-6,235	Hansen *et al.* (2016); SC/67a/Rep06	-	-	-	R
Iceland	Not Ac	-	-	2016	2016	-	-		-	-	SC/67a/NH05	Coverage too poor. Could re-stratify to use as minimum estimate.	-	-	-
ES	P	-	-	-	2014-16	-	-	12,846	-	-	SC/67a/RMP03	Final estimate to be calculated on completion on full survey cycle.	-	-	-
EW	P	-	-	-	2014-16	-	-	16,537	-	-	SC/67a/RMP03	As above	-	-	-
CM	P	-	-	-	2014-16	-	-	57,472	-	-	SC/67a/RMP03	As above	-	-	-
North Atlantic fin whales															
West Greenland	1	1	S	2015	2015	LT	P	465	0.35	233-929	Hansen *et al.* (2016); IWC/67a/Rep06	-	-	-	R
North Atlantic humpback whales															
West Greenland	1	1	S	2015	2015	LT	A+P	1,008	0.38	493-2,062	Hansen *et al.* (2016); IWC/67a/Rep06	-	-	-	R
East Greenland	1	1	S	2015	2015	LT	A+P	4,288	0.38	2,097-8.770	Hansen *et al.* (2016); IWC/67a/Rep06	-	-	-	R
(Iceland)	-	-	-	-	-	-	-	-	-	-	-	Several estimates to be reviewed intersessionally.	-	-	-
North Atlantic bowhead whales															
Svalbard	3	1	-	2015	2015	LT	A	343	0.488	136-862	Vacquié-Garcia *et al.* (2017)	Partial coverage and high CV.	-	-	R
North Pacific bowhead whales															
Okhotsk Sea	3	1	-	2016	1995-2016	MR	A+P	218	0.22	142-348	SC/67a/NH10	(Require copy of time series	-	-	-
North Pacific gray whales															
Sakhalin Is.	3	4	-	1995	1995-2015	MR:PA	A+P	74	0.06	65-82	SC/67a/NH11	(Require copy of time series).	-	-	-
Sakhalin Is.	3	4	-	2015	1995-2015	MR:PA	A+P	191	0.04	175-208	SC/67a/NH11	(Require copy of time series).	-	-	-
Sakhalin and Kamchatka	3	4	-	1995	1995-2015	MR:PA	A+P	129	0.08	107-149	SC/67a/NH11	(Require copy of time series).	-	-	-
Sakhalin and Kamchatka	3	4	-	2015	1995-2015	MR:PA	A+P	282	0.05	255-312	SC/67a/NH11	(Require copy of time series).	-	-	-
N California-N Vancouver Is.	1	1	-	2015	-	P Id	-	243	0.08	-	Calambokidis *et al.* (2017)	SD=18.9; N_{min}=228.	-	-	-
California	2	1	-	-	2014/15	-	-	28,790	-	23,620-39,210	Durban *et al.* (2017)	Suitable for use in *SLA* and conditioning range-wide model. Some methodological issues.	-	-	-
California	2	1	-	-	2015/16	-	-	26,960	-	24,420-29,830	Durban *et al.* (2017)	As above	-	-	-

Cont.

Area	Cat.	Eval. extent	RMP/AWMP status	Date stamp	Range of years	Method	Corr.	Estimate	CV	Approx. 95% CI	Original reference				Comments
North Pacific Bryde's whales															
1W	1	1	I	2011	2008-15	LT	-	15,422	0.289	-	SC/67a/RMP04	*g*(0)=1. Could be updated if *g*(0) estimated in future. See SC/67a/RMP04 *re* additional variance.	78.4	POWER /JARPNII	-
1E	1	1	I	2011	2008-15	LT	-	6,716	0.216	-	SC/67a/RMP04	As above	92.4	POWER /JARPNII	-
2	1	1	I	2014	2008-15	LT	-	4,161	0.264	-	SC/67a/RMP04	As above	78.9	POWER /JARPNII	-
W N Pacific	-	-	-	-	2008-15	LT	-	26,299	0.185	18,000-38,000	-	Combined estimate ~ 26,000	-	-	R
Māui dolphin															
North Island, NZ	1	1	-	-	2015-6	MR	-	63	0.11	-	Baker *et al.* (2012)	Based on assumption of closure.	-	-	-
Hector's dolphin															
Cloudy Bay, NZ	1	1	-	-	2011-12	MR	-	269	0.12	-	Hamner *et al.* (in press)	Based on assumption of closure	-	-	-

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Appendix 5

SUMMARIES OF CRUISE REPORTS OF NATIONAL SURVEYS

SC/67a/ASI03 presented the cruise report of a dedicated cetacean survey conducted in the northern part of the Sea of Okhotsk (north of 57°N) in 2016 by Russia using the research vessel *Vladimir Safonov,* from 5 August to 10 September 2016. Of the two blocks surveyed in the research area, a western and an eastern block, the former had already been covered in a 2015 survey, and the latter (Shelikhov Gulf) had last been covered in 1992 by a Japanese survey. Because of bad weather conditions, the percentage of coverage on effort was 63% and 70% only in the western and eastern blocks, respectively. A total distance of 1,067 n.miles was covered in closing mode in the research area and 1,348 n.miles in passing mode during transit. The following species were sighted: common minke whale (19 school/21 individuals), like-minke whale (2/2), fin whale (5/6), humpback whale (3/3), killer whale (7/27), sperm whale (2/3), Dalli type Dall's porpoise (20/60), Truei type Dall's porpoise (1/5), Harbour porpoise (9/22), unidentified type Dall's porpoise (62/171), white whale (32/255), unidentified large cetacean (4/5) and unidentified small cetacean (1/3).

SC/67a/ASI05 reported on a systematic large-scale vessel-based sighting survey successfully conducted in 2016 by Japan, to examine the distribution and abundance of large whales in the western North Pacific. The research area was between 35°N and 43°N and 140°E and 150°E (sub-areas 7CN, 7CS, 7WR and 7E in the RMP *Implementation* for common minke whales). The survey was conducted between 29 July and 6 September 2016. The research vessels *Yushin-Maru* and *Yushin-Maru* No. 2 were engaged for this survey. A total of 2,791.8 n.miles was searched in the research area. Coverage of the planned cruise track lines was 94.6% for the 7CN and 7CS and 67.6% for the 7WR and 7E areas, respectively. In total, five large whale species including fin (4 schools/6 individuals), Bryde's (125/160), common minke (12/12), humpback (2/2) and sperm (103/393) whales were sighted during the cruise. Photo-identification images were collected from one humpback whale. Biopsy skin samples using a Larsen system were successfully collected from fin (1) and humpback (1) whales, respectively. These data have been submitted to the IWC Secretariat in a form based on the Scientific Committee guidelines. The IWC oversight report is provided as an attachment to the cruise report (SC/67a/ASI05).

SC/67a/ASI07 reported the results of the 2016/17 NEWREP-A dedicated whale sighting survey in Antarctic Area V (south of 60°S). Two dedicated sighting vessels were engaged and successfully conducted the survey for 33 days, from 13 December 2016 to 14 January 2017 in the western sector of Areas V (130°E-165°E), using two survey modes (Normal Passing mode (NSP) and Independent Observer mode (IO)), and based on IWC/IDCR-SOWER survey procedures. The total searching distance in the research area was 2,937.1 n.miles, including 1,542.0 n.miles covered in NSP and 1,395.1 n.miles in IO mode. The survey coverage was 77% in the northern stratum and 91% in the southern stratum. Five baleen whale species, blue (11 schools/13 individuals), fin (21/67), Antarctic minke (115/223), southern right (1/1) humpback (253/516) and at least three toothed whale species (sperm (30/30), southern bottlenose (4/8), killer (4/26)), were sighted in the research area. Estimated Angle and Distance Experiments were completed as in previous years. Routine photo-identification and biopsy sampling of large whales were also conducted, and a total of 20 individual photos (9 blue, 1 southern right and 10 humpback whales) were obtained. Furthermore a total of 10 individual biopsy samples were collected from 2 blue, 1 southern right and 7 humpback whales using the Larsen system. A total of eight marine debris items was observed. A feasibility study on biopsy sampling on Antarctic minke whales was conducted and 15 biopsy trials were performed. Location data from three of the satellite tags deployed on Antarctic minke whales were received. These data have already been submitted to the IWC Secretariat in terms of Scientific Committee guidelines. The IWC oversight report is attached to the report (SC/67a/ASI07).

Appendix 6

REPORT OF THE PRE-MEETING ON MODEL-BASED ABUNDANCE ESTIMATION (BLED, 7-8 MAY 2017)

Abundance estimates from line-transect surveys can be derived statistically using 'spatial models' (AKA 'density surface models', and several other names; see below), as well as the more familiar stratified (AKA 'Horvitz-Thompson-like', or HT; Borchers and Burnham, 2004) approaches. Spatial models have potential advantages in reducing bias resulting from patchy coverage, and in providing more reliable estimates of variance. The Scientific Committee has recognised the need to develop its expertise in evaluating spatial-model-based abundance estimates, which are fairly complex, and in deciding whether an estimate based on the simpler HT formulae can be used safely in cases when the strict assumptions underpinning HT do not apply (e.g. uneven coverage of the region).

To further this process, a pre-meeting was held on 7-8 May, (convened by David Miller, CREEM and Mark Bravington, CSIRO). The pre-meeting explored some issues related to the current state of spatial modelling for cetacean abundance estimation, and introduced software named 'ltdesigntester' for exploring the reliability of HT-based abundance estimates of specific surveys, either *post hoc* or in the design phase. This software, its accompanying report[1] are available at *http://converged.yt*. See both that report and the earlier paper by Hedley and Bravington (2014) for more detailed background to discussions.

SECTION A: INTRODUCTION

The IWC Scientific Committee (SC) often has to consider abundance estimates derived from line-transect surveys which have been analysed using 'design-based estimators', but where for various reasons it is not clear whether the resulting estimates and CVs are trustworthy for, say, RMP purposes.

[1]Miller, D.L., and Bravington, M.V. 2017. When can abundance surveys be analyses with 'design-based' methods? (unpublished). 30pp. [Available from the author, *http://converged.yt*].

The Scientific Committee has therefore in recent years (up to 2016) considered revising its formal Guidelines to take advantage of metholodogical developments, in particular the increased flexibility offered by 'model-based' abundance estimates, constructed statistically around smoothed estimates of animal density across space. As background for that revision, Hedley and Bravington (2014) describes the randomisation assumptions *required* by design-based *principles*; it also introduces some of the practical issues associated with model-based estimates, which are more flexible but also more complicated to implement. In section 11 of that document, the authors note that it may sometimes be possible to derive acceptable estimates and CVs using a design-based calculation - a 'Horvitz-Thompson-like' estimate - even when the underlying design-based assumptions are not strictly met, provided that (among other things) achieved coverage is sufficiently uniform. This has been common practice at the IWC and elsewhere, but generally on an *ad hoc* basis with no clear criteria for 'how bad is too bad?'. For such cases, Hedley and Bravington (2014) recommend instead that HT acceptability needs to be verified on a case-by-case basis, using diagnostics derived from model-based analysis.

Miller and Bravington (2017)[2] follow up on that suggestion. They start by again briefly reviewing the main differences between HT and model-based estimates, explains where problems can occur with the former, and through simulation demonstrates how those problems and whether they might be present may be checked for using model-based criteria. The idea is to consider a range of scenarios about underlying density gradients, then fit different spatial models (including a 'null model' that is HT-equivalent) to data simulated from the actual survey tracks and each density scenario, then check the consistency of point estimates and variance estimates across the different models. Software implementing these criteria/checks is available in the R package ltdesigntester, available from: *http://github.com/dill/ltdesigntester*.

SECTION B: SUMMARY OF DISCUSSIONS

1. General comments

- Spatial models *can* give a way to avoid the bias in abundance-estimation that may result from applying a 'standard' HT estimator when its assumptions are not met, e.g. if coverage is incomplete or uneven.
- Even when there is little bias in HT estimates as a result of good coverage, spatial models can perform much better in capturing true uncertainty (for example, systematic patterns in distribution are not classed as 'variance' by spatial models, but generally are by HT) and of giving more *stable* variance estimates. HT requires many transects per stratum for reliable variance-estimation; 20 has been suggested by experienced practitioners, but many surveys considered by the IWC have far fewer transects per stratum.
- Spatial models also provide a clean and simple way to obtain abundance estimates and variances for any desired subregion of a surveyed area. This can be very difficult for HT estimates.
- Spatial models avoid the unpleasantness of post-hoc (re) stratification, which is sometimes an operational necessity with HT, but which makes variance calculations, in particular, rather dubious.
- Spatial models can incorporate environmental covariates such as depth (as distinct from 'observational covariates' such as Beaufort state, and 'sighting-level covariates' such as group size) to explain distributions, as well as or instead of purely spatial (lat/long) 'explanatory covariates'. This can be very informative for management advice on certain issues and for ecological insights, although there are complications when used for abundance estimation *per se*; see below.
- Most applications of spatial modelling to cetacean abundance and distribution have used the family of statistical models known as GAMs, and in particular the implementation in the widely-used R package mgcv (Wood, 2006). There are other frameworks for spatial models which may also prove useful in future, but (in the view of the workshop leaders) GAMs and mgcv in particular so far have the best integration with other aspects of abundance estimation (e.g. detection functions – note that here this term is taken to encompass all aspects of detection probability, including strip widths, $g(0)$ and availability), the widest range of modelling options, the most extensibility and the most 'case law'. Practical discussions at the workshop were all based on the DSM toolbox for GAM-based spatial models (see e.g. Miller *et al.*, 2013) for reference, although there have been numerous extensions since then), although some of the general principles should also apply to other types of spatial models.
- Over the last 10 years, there have been extensive mathematical and computational developments in spatial modelling and related techniques, coupled with widespread practical experience in many fields well beyond whales and abundance estimation - this includes mission-critical applications in e.g. medical statistics and electricity-grid management. There is both a coherent underlying statistical theory for GAMs, and reliable computational engines through software such as mgcv. However, the power and flexibility of GAMs do come with terms and conditions. The underlying principles of statistical inference - the very reasons some credence can be given to abundance estimates, for example - are at the limit of their range with GAMs. The ease of fitting GAMs nowadays disguises the underlying complexity, and with models that are so fundamentally complex, *ad hoc* approaches to inference cannot be trusted to give reliable results (whereas *ad hoc* tweaks can sometimes be justified for simpler types of model, such as HT abundance estimates in 'good' surveys). For example, GAMs constitute a particular type of random-effect model, and bootstrapping is well-known to be statistically incompatible with random-effect models (there is an extensive literature starting with Laird and Louis, 1987). Developing new varieties of spatial model, and extending the types of inference e.g. to variable selection, are tasks for the GAM professionals only.
  - Not all spatial models are equal. Within mgcv, for example, there are different ways of representing spatial effects which, while likely to give similar results within the spatial range of 'good' survey data, may behave differently near the edges of the surveyed region and especially beyond. In addition there are also well-formulated spatial models outside what mgcv offers, such those used by Illian *et al.* (2012), which will have somewhat different properties, though there is as yet less practical experience with non-mgcv frameworks. Furthermore

[2]Miller, D.L., and Bravington, M.V. 2017. When can abundance surveys be analyses with 'design-based' methods? (unpublished). 30pp. [Available from the author, *http://converged.yt*].

there are yet other approaches to spatial modelling which, unlike mgcv and INLA, do not have a solid basis in statistical theory and computational practice. Unless and until the necessary theory and practical experience are developed, it would be rather difficult to evaluate abundance estimates from such models.

- There are limits to what a spatial model can fix. In particular, low numbers of encounters are problematic; spatial models have to estimate more parameters than HT (especially, the degree of spatial wiggliness [yes, that really is the correct term!]). Hence, in a setting where HT can be expected *a priori* to work reasonably but sightings are few, spatial models perhaps require more sightings for reliable performance. And although spatial models can alleviate some problems of patchy coverage, there are again limits: extrapolation comes with big risks, and it is not yet clear how far the current generation of spatial models 'do the right thing', i.e. of automatically reporting a very high CV when large extrapolations are involved.
- The DSM approach to abundance estimation is multi-stage. The first stage is to fit detection functions, $g(0)$, etc. using familiar tools; then the results are incorporated into the second stage of spatial modelling, and the uncertainty associated with the detection-function stage is propagated automatically. Some other approaches (e.g. INLABRU) fit detection functions simultaneously with *all* parts of the abundance-estimation model. The considerable appeal of multi-stage modelling is that detection-functions etc. require expertise and often experimentation to fit, and sometimes need case-specific flexibility which is difficult to build into an all-in-one model; it is desirable to be able to concentrate separately on this stage. The appeal of all-in-one is that, at least in principle, it can be more statistically efficient (because the number of sightings in different weather-conditions conveys some information about how the overall detection probability varies with weather, even in a spatial model). The workshop presenters suggested that the first approach is perhaps more valuable in practice.

2. Abundance estimates from spatial models: general points

First addressed was the more straightforward case of single survey where group size variations are unimportant. More complex issues are covered in the next section. Although this section is fairly general, it overlaps somewhat with suggestions for specific diagnostics that need to be reported whenever a spatial abundance estimate is being put forward for endorsement by the Scientific Committee.

- Whale densities can be modelled using just spatial covariates, or environmental covariates, or both. For *abundance estimation* per se within the region of the survey, spatial alone should usually be reliable (i.e. purely spatial covariates are sufficient, even if not optimal). There is some theory to suggest that this may be true even if the ideal environmental covariates could be identified, which itself is a big ask. As to the alternatives, the following comments are offered.
  - If using *just* enviro covariates to explain density, then the abundance estimate is susceptible to bias unless exactly the right covariates have been used, and measured on the right scales. This risk cannot be checked reliably *post hoc* from the model.
  - It is appealing to consider including both environmental *and* spatial terms, in the hope that the latter will 'mop up' any modest remaining variations in density that are unexplained by the environmental terms. Unfortunately, this is not what tends to happen, at least with current models; the spatial terms and the environmental terms tend instead to fight for control of the model, and the outcome is not necessarily sensible (although overall predictions within the survey area are not necessarily bad). This is a topic of active research, and until it is resolved, it seems wisest to stay away from abundance estimates involving environmental covariates, at least for core management purposes.
  - If abundance estimates using environmental covariates are to be considered, it is particularly important to explore sensitivity to choosing different covariates, and/or combining them in different types of smoother.
- There are different flavours of spatial smoother available as GAMs (e.g. tensor product smooths, thin-plate splines, Duchon splines, 'shrinkage' versions of all those, Soap-film smooths where coastlines impinge, etc. Although there are reasons to prefer certain choices in some cases, the different methods generally give similar results when applied to reasonable line-transect datasets, at least within the broad extent of the survey. Consequently, there is in general no particular need to present estimates from different flavours of spatial model as 'sensitivity checks', provided the diagnostics are acceptable for the one model that is presented. Nor is there any need in general to present extensive simulation results to justify standard spatial modelling approaches; the underlying tools have been thoroughly investigated in settings which include outside abundance estimation.
  - The foregoing does not apply if substantial extrapolation is entailed. Desirable behaviour for a smoother should normally be to report rapidly-increasing CVs as the amount of extrapolation increases, in which case it should not matter much which smoother is used; however, not all current smoothers do this reliably (unmodified Thin-Plate Splines in particular; Wood, pers. comm.). Hence, if making substantial extrapolations, it is important to at least verify that different smoothers agree (or e.g. that the choice of a Soap 'boundary' in parts of the region without a hard boundary does not make much difference).
  - Large-scale extrapolation is of course undesirable. Bravington noted, however, that some degree of extrapolation is inevitable whenever spatial models are applied to line-transect data. From a statistical perspective, the 'survey region' is meaningless to the spatial model (unlike for a design-based HT estimate); it is simply the set of points where densities are to be predicted, and is in principle unrelated to where the data were collected, which is a very small subset of the prediction region close to the tracklines. All surveys have, for example, corners that would be 'outside the surveyed area' in certain reasonable definitions, e.g. the convex hull of the tracklines, or the 'x-y range' in a 45°-rotated coordinate system. This is not necessarily a problem - modern spatial models can cope with some limited extrapolation - but does indicate that there can be no hard-and-fast guideline for 'how much extrapolation is too much'; human judgement is required.
    - o Observation conditions along the track, as well as purely the presence of tracklines, are relevant in assessing extrapolation. If tracklines near the

edge of the region of interest tend to be in poor observation conditions, then the spatial model may effectively have no statistical information near that edge, and in practice faces the same issues as when it is asked to 'extrapolate'.

- o If there are concerns about extrapolation, then it is important to report not just the overall CV on abundance, but also separate CVs for the 'well-surveyed' and the near 'unsurveyed' areas. If the model is behaving well, the latter should be much higher.

- 'Spatial abundance estimation' entails not just a spatial model of school density, but also detection-function fitting and possibly school size modelling (see below). For a reliable overall CV, it is important to combine all sources of statistical uncertainty from the various steps ('variance propagation'). This is not necessarily simple with spatial models (e.g. the well-known three-part formula for HT variance does not apply). In the past software has not been available to do this properly (so developers had to write special-purpose code, as with SPLINTR when applied to Antarctic minkes), but new versions of DSM and other approaches like INLABRU will make this straightforward in future.
- Thanks to modern software like 'mgcv', spatial abundance estimates for straightforward cases are easily obtained, with not much more work than for an HT estimate. Nevertheless, spatial modelling is emphatically not a push-button process; there are many choices to make, implicitly or explicitly, and they can affect the result appreciably. It is essential that spatial-model-based abundance estimates be accompanied by a commentary explaining which particular choices were made, and why each choice is either clearly sensible in its own right or largely unimportant to the result. Hedley and Bravington (2014) covers numerous aspects, two simple examples being:
  - choice of coordinate system (lat/long needs adjustment to preserve distance in isotropic smooths; reparametrisation to offshore and alongshore distance to allow anisotropic smoothers; etc.); and
  - explaining why extrapolation is not a concern for the survey in question (since the 'prediction region' over which abundance is being estimated is also a choice of the analyst).

3. Diagnostics

The workshop suggested the following minimum set of diagnostics as required to assess adequacy of the output; this list should be reviewed as experience accumulates. Clearly, the points being made here require some understanding of spatial modelling issues; Hedley and Bravington (2014) gives more detail.

- Plotting the fitted density surfaces (and tracklines) for common sense consideration (regarding hotspots, edge effects, etc.)
  - There are different ways to plot density surfaces (colour-maps, contour plots, dot-plots), and people vary as regards which type they find easiest to interpret.
- Tabulate the observed and expected number of sightings grouped by potentially important covariates: e.g. observation covariates that are in detection function (or could be); environmental covariates; specific parts of the region (within/outside 20km of the coast). Expected numbers per grouping-level need to be reasonably large, say 10, for this to be useful, but it has helped diagnose spatial-model misfits in the past.
- Size of segments: there can be difficulties if these are set too big or too small. This requires common sense plus robustness checks; see Hedley and Bravington (2014) for the authors' opinions. There is the potential to develop DSM to handle fine-scale clustering (AKA local autocorrelation) automatically, which would alleviate this rather tedious problem; for one approach, see Skaug (2006).
- Response distribution for counts: the presenters suggested that it is usually safe to use Tweedie (constrained to ensure shape parameter exceeds 1.2) or NegBin, though a Quasi-Poisson might also work in some cases. As long as the results pass a diagnostic check (e.g. QQ plot), it is not necessary to explore other options; overall results should not be sensitive to the choice.
- There is a well-known suite of standard statistical diagnostics for GAMs, and especially for 'mgcv'. See Wood *op cit.* including for the acronyms used below. Specific issues for the low-expected-value count data found in line-transects surveys are:

deviance residuals are not useful.

  - RQR (randomised quantile residuals; results based on Dunn and Smyth (1996) are better, and should be plotted against observation-covariates or environmental covariates of interest. Having said that, the power of any residual-based diagnostic is limited with small-count data, and one presenter reported much better experiences from the observed/expected counts check above.
  - EDF (estimated degrees-of-freedom) checks on smooth terms are very important, and it is also important to report the estimated smoothing parameter itself (there can be some problems if it is very large, implying a completely smooth model).
  - Convergence failures *can* happen, but mgcv in particular is generally diligent in issuing warnings.
  - Concurvity checks if environmental covariates are used.

Overall, it was agreed that it would be useful to develop a worked example of 'good diagnostic practice' for a spatial model that does seem acceptable, and for one that does not (perhaps a version of the former with deliberately distorted data).

4. School size

Discussion was restricted to cases where schools are not too big; cases such as tropical dolphins with physically enormous schools of hundreds or thousands of animals always require special attention.

School size normally affects sighting probability, and obviously matters for abundance. Historically though, it has not played a large part in at least the DSM framework for spatial modelling. This may not matter much; if most sightings are single animals, with just a few schools seen; in that case simply replacing 'number of schools per segment' by 'number of animals seen per segment' may be good enough, even though not strictly correct because detection probabilities are affected. More generally, the implicit assumption of most DSMs has been that even if school size varies, it does so homogenously throughout the region of interest (i.e. it is not a case of big schools in one place and small schools in another), even though school density may vary substantially. If so, then it is valid to:

- first fit detection functions, presumably including school size as a covariate;
- then estimate the average true school size for the whole region (there are standard methods for that), and the average detection probability of a school for each survey segment depending on the observation conditions there; and
- then fit a DSM.

Variance propagation is still not straightforward unless observation conditions are constant, because bad weather can often affect overall detectability of big schools differently to small schools; in particular, the 3-term HT variance decomposition is not strictly valid. Nevertheless, correct variance-propagation is not much more complicated than for standard DSMs, and overall the homogenous-school-size approach to DSMs is reasonably simple.

For many species though, it is too simple. If school sizes vary through the region, then it somehow necessary to use more than one spatial model. There are two main options:

- one model (or set of models) for how true school size varies (mean, variance, etc.), and one for school density; and
- separate spatial models for each category of school size.

Neither is ideal; the former is difficult to set up correctly with off-the-shelf statistical models, and the latter will simply run out of data for some categories (as in this case each category fails to 'borrow strength' from what is seen at other categories). The workshop presenters reported encouraging results from a new approach that extends the separate-models idea to 'borrow strength' from all categories of school size, and stays within the GAM family where inference and variance-propagation are at least tractable.

When most school size estimates are biased, which is often the case in passing-mode surveys, then dealing with school size becomes even more problematic; it may no longer even be possible to fit detection functions as a first stage, because true school size is unknown. This is more-or-less the situation of Antarctic minke whales in SOWER. While such situations can be handled statistically - given ample data, good protocols and years of analytical effort, as with SOWER - it is unlikely that off-the-shelf spatial-models will ever be available for such cases.

School size in spatial models entails extra diagnostics; suggestions may be found in Hedley and Bravington (2014).

5. Time as well as space

DSMs make it straightforward to fit multiple surveys at once, e.g. from several years in the same regions. This is very useful for checking the consistency of possible environmental drivers of distribution, but also useful for purely spatial models. The density surface itself can be allowed to vary from year to year, while enforcing the same smoothing parameters (degree of wiggliness); this is helpful in estimation, and is usually biologically reasonable. The same applies to detection functions. It was noted that this leads to some covariance between estimates for different years; this does need to be taken into account when using the results for management decisions, but there is no major conceptual problem in doing so, and something similar is already required to deal with 'Additional Variance' (using IWC terminology).

Within-survey time effects are a different issue. GAMs do now allow space-time interactions to be fitted, i.e. 'moving maps', and this is potentially powerful in dealing e.g. with platform-of-opportunity sightings over long periods. Such models have occasionally been used, e.g. in fisheries, to describe seasonal movements. However, there are some pitfalls for abundance estimation, e.g. that existing models have no way to constrain the total number of animals to be constant through the survey, and that migration generally provides a hard problem for any survey. Reliability for abundance estimation *per se* thus has to be seen as untested for now, though with sufficient supporting evidence, e.g. through simulation, such estimates might be considered acceptable.

6. Acceptability of HT when assumptions are not met

HT estimators are simple, and can *sometimes* work reliably even if the underlying assumptions are not met: e.g. that the design was randomised and/or the coverage was not as planned (Hedley and Bravington, 2014). However, then the onus is on the analyst to show that it is necessary to move to a spatial model. The ltdesigntester software was developed to assist with this, without requiring the analyst to develop the entire spatial-modelling skill set.

Regardless of randomisation or otherwise, gradients in animal density need not imply bias in HT, unless coverage is uneven. Assessing the latter is not as simple as just looking at tracklines, because observation conditions also matter and may not be homogeneous across the region. This interacts with the type of model that is fitted; omitting weather from the detection function is particularly dangerous, since claims about pooling robustness (even if detection-on-the-trackline really is certain) do not apply when animal density varies substantially within a stratum. Even if weather is included in detection functions, very poor weather over a substantial part of the survey region can still lead to bias in HT estimates (since reliable stratification may not be possible) and especially to unreliable variance estimates.

Variance for HT estimates is not straightforward. There are several ways to calculate it, and the default in DISTANCE is probably not the best in most cases (Fewster *et al.*, 2009). There is a well-known problem that HT can interpret systematic trend in abundance as variance; although there are ingenious methods for tackling that (Fewster, 2011), they appear to be rather more complicated than just fitting a spatial model (at least in the view of the workshop presenters).

The ltdesigntester software (*http://github.com/dill/ltdesigntester*) which was demonstrated appears to be a useful tool for investigating HT reliability, and also how different flavours of spatial model can vary when applied to difficult situations (e.g. extrapolation). It was noted that there are some limitations of the way performance is summarised in the report; histograms for different models are not comparable between the different models fitted to the same data because the scale is not consistent, although they do reflect the model's ability to assess its own performance. Miller reported that the code is expected to migrate eventually into the existing software DSsim (*http://github.com/DistanceDevelopment/DSsim*) for simulation-based testing of survey designs, which is widely used by the line-transect-survey community.

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