SECTION 3 – SCIENTIFIC COMMITTEE

3.1

REPORT OF THE NINETEENTH MEETING OF THE NAMMCO SCIENTIFIC COMMITTEE

EXECUTIVE SUMMARY

The 19th meeting of Scientific Committee (SC) was held in Tasiilaq, East Greenland, 19 – 22 April 2012. The SC had reports from two NAMMCO SC Working Groups (WG): the NAMMCO JCNB JWG on Narwhal and Beluga in the North Atlantic (Annex 1) and the WG on Survey Planning (Annex 2). It had also the Report from the Age Estimation Workshop, Tampa, Florida (Annex 3) and the Summary of the Report from the Age Estimation Workshop, Beaufort, North Carolina (Annex 4). Additionally there were reports from the ICES/NAFO WG on Harp and Hooded Seals and from several other meetings and workshops.

THE ROLE OF MARINE MAMMALS IN THE MARINE ECOSYSTEM

Last year the SC reiterated its determination to the project on modelling of marine mammals in the ecosystem, and urges that financing bodies be identified and applications submitted. The SC was informed that applications had been submitted to NORA and the EU 7FP. Reviews from NORA were very positive, but no funding has been obtained.

An ongoing Norwegian project (EPIGRAPH) uses satellite tags, diet studies and estimates of fish resources to evaluate the ecological role of harbour seals in Porsangerfjord, North Norway.

A joint Norwegian-Russian Ecosystem Survey had been used to examine habitat use and prey associations of white-beaked dolphins in late summer. Dolphins used the southern Atlantic water and the Polar Front area farther north, with a general overlap with most prey species, and positively association with blue whiting in the southern habitat. The Polar Front may offer predictable prey aggregations that are more beneficial for foraging than non-front patches with higher densities.

The Icelandic minke whale programme is coming up for review in IWC, with deadline in the winter 2012/13. This marks the end of the programme and the results will be available for examination by the NAMMCO SC at its next meeting.

BY-CATCH OF MARINE MAMMALS

Catch and by-catch data from 2006-2008 from a monitored segment of the Norwegian fleet of coastal gillnetters targeting monkfish and cod were used to estimate by-catch rates of harbour porpoises in Norway. Landings statistics were used to extrapolate to the entire fishery, estimating a total annual by-catch of 6,900 porpoises by the two fisheries. According to the criteria advised by ASCOBANS, that by-catches should not exceed 1.7% of the best population estimate, a population in excess of 400,000 is required to sustain the annual by-catch. One third of the Norwegian coast is bordering the North Sea where the abundance of porpoises is estimated at approximately 1/3 million. The abundance in the North Sea, however, is not necessarily related to the majority of the Norwegian by-catch, and the abundance along the Norwegian coast is unknown.

Considering the large number of by-caught harbour porpoises in Norway, the **SC recommends** that the sustainability is assessed by the WG on Harbour Porpoises, including a validation of the by-catch estimate itself. The SC also noted the potentially high by-catch of grey, and especially harbour seals, in Norway, and referred this to the WG on Harbour and Grey Seals.

The by-catch numbers of harbour porpoises, grey seals, and harbour seals could also be high in Iceland, based on preliminary information presented to the NAMMCO-ICES workshop in 2010. Reporting is often of unidentified seals, making it difficult to estimate by-catch for species. The **SC recommends** that total by-catch estimates be attempted, and that assessments of sustainability proceed through the relevant WGs.

By-catch of marine mammals around the Faroese is likely of a smaller magnitude due to the absence of gillnets in coastal waters, and by-catch in Greenland is generally reported as direct catch, although the SC is still missing estimates of the extent to which by-catch is reported as direct catch. Irrespectively of sustainability, the SC also recommends that by-catch be reduced as much as possible.

SEALS AND WALRUSES

Harp Seal

White Sea / Barents Sea

A Russian survey in March 2010 estimated 163,032 (95% C.I. 97,682 – 228,382) pups. The ICES WGHARP discussed several hypotheses to explain the reduced pup production since 2004. Given lack of evidence for a significant adult mortality event, the most parsimonious explanation is a decline in fecundity. A modified population model with time-varying fecundity estimated 1,364,700 (95% C.I. 1,230,384 – 1,498,916) animals in 2011, with the sustainable catch for the White Sea/Barents Sea being 15,827 *1+*animals (or an equivalent number of pups, where one *1+* seal is balanced by 2 pups).

Greenland Sea

The WGHARP considered the stock data rich, and used population modelling to estimate abundance and catch options. This indicated a substantial abundance increase from the 1970s to 649,570 (95% CI: 379,031 – 920,101) animals in 2011, with the sustainable catch for the Greenland Sea being 16,737 *1+* animals, or an equivalent number of pups.

Given that the most recent estimate of total population size is the largest observed to date, ICES suggests that the harvest level can be set to ensure an 80% probability that the population does not decline by more than 30% over a 10 year period. This estimates a catch level of 25,000 *1+* animals, or an equivalent number of pups. Any allowable catch should be contingent on an adequate monitoring scheme to detect adverse impacts before it is too late for them to be reversed, particularly if the Total Allowable Catch (TAC) is set at a level where a decline is expected.

An aerial survey to assess harp seal pup production was conducted by Norway in the Greenland Sea in 2012.

Northwest Atlantic

NAMMCO **Request R-2.1.11** had been forwarded to WGHARP, to examine how a projected increase in the total population of Northwest Atlantic harp seals might affect the proportion of animals summering in Greenland.

There are no abundance data for West Greenland, but catch statistics is strongly correlated with population size until 2000, suggesting that an increasing number of the seals migrated to West Greenland as the population increased. The relationship fails after 2000 when catches dropped, despite a continued increase in population.

Fairly precise predictions of catch numbers in Greenland can only be calculated for the years up to 2000. New estimates of abundance need to be developed with seals being surveyed in West Greenland at various times a year for a number of years. Alternatively, a proxy of relative seal abundance might be found by selecting catch data from settlements where changes in hunting effort are likely to have been relatively small. However, it would still be uncertain whether the distribution of the seals in years to come could be predicted.

An aerial survey to assess harp seal pup production was conducted in the Northwest Atlantic in March 2012.

Hooded seal

Greenland Sea

Population modelling at WGHARP indicates a decline in abundance from the late 1940s and up to the early 1980s, and gave point estimates of the 2011 abundance between 85,000 and 106,000 animals. This is well below the limit of 173,000 (30% of the maximum estimate of 575,000) animals, where WGHARP recommends that catches shall not occur. Therefore, no catches of hooded seals should be taken from the Greenland Sea, except for local catches in East Greenland.

The aerial survey for harp seal pups in 2012 was successful in obtaining data also on the pup production of hooded seals.

Other species

Experience from the first season with mandatory reporting from the protective hunt of grey seals at aquaculture farms in the Faroes demonstrates that the reporting system needs further adjustments.

An aerial survey in Iceland for harbour seal estimated 11,000 (95% CI 8,000-16,000) animals in 2011, which is similar to estimates from 2003 and 2006.

Extensive oil exploration, development and production are currently taking place in the Pechora Sea, where a joint Russian-Norwegian survey estimated 3,906 (95% CI, 3,571-4,285) walruses in 2011. No females with calves were found during the survey implying that the population that uses the Pechora Sea during summer has a larger distributional area. Risks associated with these activities to walruses and their food base should be assessed, and the delineations of the population clarified.

The **SC recommends** that a small WG update the advice for West Greenland walrus before the next SC meeting.

CETACEANS

Narwhal

West Greenland / Canada

The SC agreed on the metapopulation structure for narwhals in Baffin Bay, Hudson Bay, and adjacent waters as a useful approach for identifying summer aggregations as management units in narwhals. The model includes seasonal movements with relationships between stocks and hunting localities (Figure 2), and satellite tracking of whales that return to summering grounds the following year suggest inter-annual site fidelity, with summer aggregations to some extent being demographically-independent sub-populations with minimal or no exchange of animals.

Narwhals in Canada constitute five separate stocks with some limited exchange between three of the stocks. Coastal summer aggregations in Greenland constitute two stocks in addition to two fall-winter aggregations supplied by narwhals from several summering stocks. Several of the narwhal stocks are mixing on the wintering areas in Baffin Bay-Davis Strait, but mating most likely occur after the initiation of migration towards summering areas.

The **SC recommends** that a small WG fully explore the allocation of harvest to summer aggregations before next JWG meeting.

There has been an overall increase in West Greenland narwhal catches during the 20th century which is especially pronounced after 1950. However since 1993 a significant decline in overall catches has been observed; most pronounced in Uummannaq and Disko Bay, with no decline detected in Qaanaaq and Upernavik. Catches in East Greenland seem to have peaked during 1999-2006, with a declined thereafter. No new data was presented on the struck and lost rates in Canada or Greenland.

Aerial surveys conducted in the North Water in May resulted in fully corrected abundance estimates of 10,677 (95% CI: 6,120-18,620) narwhals in 2009 and 4,775 (95% CI: 2,417-9,430) in 2010.

Age estimation by racemization estimated biological parameters of narwhals, including a maximal lifespan expectancy of ~100 years of age. These data are useful for estimating exponential growth, and a full assessment, with estimates of abundance and population growth, can, for example, be provided from a catch history, a single abundance estimate, and a single sample of the age structure.

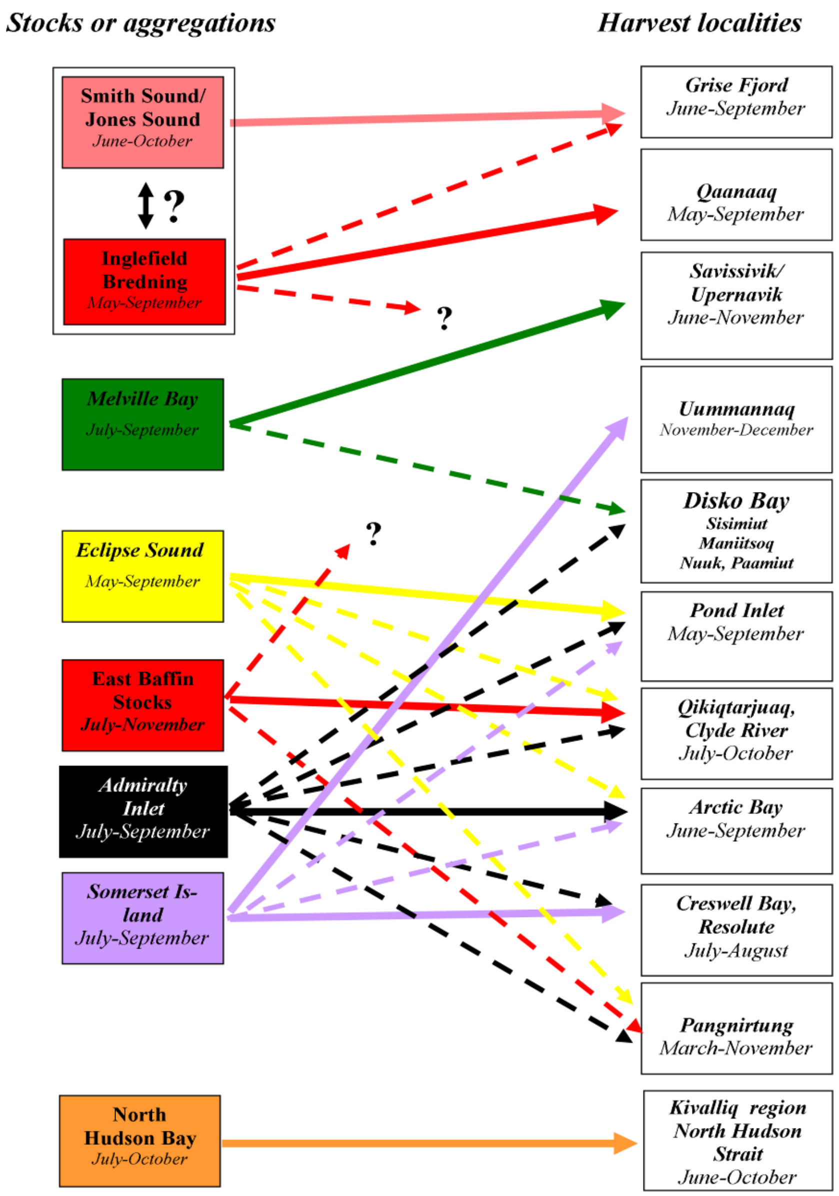

Figure 1. Diagram relating summer stocks and aggregations to hunt locations. Solid lines are verified by tagging studies, dashed lines are based on geography and inference from other sources.

The assessments of West Greenland narwhals was updated with age-structured data, recent abundance estimates, and catches. Several scenarios of stock delineations and harvest allocations were explored, and the SC agreed that the current quotas (Table 1) are sustainable. A new and updated advice is expected from the next JWG meeting, based on the allocation method to be developed at the proposed intercessional meeting. No advice on management was developed for any of the Canadian stocks.

Area	**Current quotas**
Inglefield Bredning	85
Melville Bay	81
Uummannaq	85
Disko Bay	59
Total	310

Table 1. Current quotas in West Greenland.

East Greenland

Satellite tracking shows that narwhals in East Greenland have a yearly migration where they leave the fjords and move off the coast in winter. Whales from the Scoresby Sound area seem to belong to a stock separate from other narwhal aggregations in East Greenland, and the SC agreed that narwhals in Scoresby Sound (Ittoqqortormiit) and Kangerlussuaq-Sermilik (Tasiilaq) should be treated as two separate stocks.

Age-structure data from Ittoqqortormiit was applied to assessments of both East Greenland areas, and the harvest was found to select for older animals. It was estimated that narwhals in the Ittoqqortormiit area have increased slightly, while narwhals in the Tasiilaq/Kangerlussuaq area might be stable. The current growth rate in the absence of harvest was estimated between 1.2% (95% CI:0–3.5) and 3.7% (95% CI:1.6–5.9), depending upon model and area.

Narwhal	**Ittoqqortormiit**	**Kangerlussuaq**
Probability of increase	**Total removals**	**Total removals**
95 %	17	0
90 %	35	1
85 %	45	6
80 %	50	9
75 %	60	13
70 %	70	18

Table 2. The probability that total annual removals from 2012 to 2016 will ensure an increase in the two exploited stocks of narwhal in East Greenland.

The probability that total annual removals from 2012 to 2016 will ensure an increasing stock for the two stocks in East Greenland was estimated (Table 2).

In discussions on management advice it was noted that there is little information on the predicted response of marine mammal populations to changing arctic conditions including changes in sea ice, climate and prey species as well as increased human development activity as seismic, shipping, and drilling. The **SC recommends** holding an international symposium on the effect of seismic and other development activities on arctic marine mammals with a focus on beluga and narwhal.

Beluga

The Somerset Island stock supplies the belugas overwintering in the North Water and off West Greenland, where the majority of the removals take place. Although there are not enough data to quantify the influx of belugas from Cumberland Sound to West Greenland, it is unlikely that these animals contribute significantly to the exploited winter aggregation in Greenland.

Catches of beluga in West Greenland declined during 1979-2011 from about 1,300 in the early 1980s to levels below 300 whales per year after 2004. There are no research plans for quantification of struck and lost rates in belugas.

Aerial surveys conducted in the North Water in May resulted in fully corrected abundance estimates of 2,008 (95% CI 1,050-3,850) beluga in 2009 and 2,482 (95% CI 1,439-4,282) in 2010.

The assessments of West Greenland beluga was updated with age-structured data, recent abundance estimates, and catches. Results from different scenarios provided annual growth rate estimates from 3.2% to 5%, in the absence of harvest. The depletion ratio for 2012 was estimated to 44% (95% CI: 16%–88%), with a yearly replacement of 510 (95% CI:170–780) individuals. The SC agreed that the revised assessment confirmed that the current removals based on the 2009 advice are sustainable. Based on a 70% probability of population increase, it is concluded that a total annual removal of 310 belugas in West Greenland is sustainable (excluding Qaanaaq). A new updated advice is expected at the next meeting based on a new abundance estimates from the spring survey in 2012, and the SC noted that new abundance estimates for assessments should be available at least every 10th year.

No specific advice was given on the North Water (Qaanaaq), since the current removals remain at a low level relative to the population size. No advice was given for the harvest in Canada.

Relating to **Request-3.4.13**, the SC reiterated the recommendations for seasonal closures:

- Northern area (Uummannaq, Upernavik and Qaanaaq): June through August.
- Central area (Disko Bay): June through October.
- Southern area (south of Disko Bay to 65°N): May through October.

- The area south of 65°N, closed for hunting.

The purpose of these is to allow for the possibility of reestablishment of local aggregations of belugas in Greenland.

Age-determination workshops

Recognizing that there are a number of problems with age determination for beluga and narwhal, three age determination workshops were organised. The first in Tampa (FL, USA) examined the state of the art of general ageing techniques; the second in Beaufort (NC, USA) focussed on age estimation of belugas using teeth; and the third in Copenhagen focussed on the use of tusks for age estimation in narwhals.

There are several aging methods which are or may be applicable to narwhal and belugas, including potential new methods which, depending on the type of tissue required for analysis, may be applicable both to living and dead animals. Tooth GLG are only useable in belugas, and the Aspartic Acid Racemization is very promising in narwhals. A further method that is accurate and can be used for calibration is that of bomb radiocarbon, ^{14}C. However, this requires animals that were born after the fallout commenced, *i.e.*, post-1958.

The SC agreed that an annual deposition rate of tooth GLG was to be the accepted standard in belugas, and it recommends that Aspartic Acid Racemization is applied to belugas, to included known history/age animals in the analyses in order to calibrate the technique and provide an alternative ageing method. Relating to beluga age estimation from teeth, there should be standardisation of readings among laboratories with inter-laboratory calibrations.

Pilot whale

Relating to **Request-3.8.6** the SC agreed that it was unlikely that a full assessment could be attempted in the near future. Regarding a short term advice, the SC noted that both the AWMPc procedure (which has been used for preliminary advice for baleen whales in West Greenland by NAMMCO and the IWC), as well as the PBR approach, could be used for an inverse advice calculation of the minimum abundance required to sustain the average take by the Faroese.

With the average annual catch by the Faroese since 1997 being 678, and the CV of the latest abundance estimate being 0.27, the AWMPc procedure estimates that an abundance estimate around 50,000 pilot whales and a similar precision is required to sustain the catch. In comparison, the PBR approach calculates an abundance estimate around 80,000 whales. These calculations reflect precautionary estimates of the minimum abundance estimates required to sustain the Faroese hunt. However, the geographical range of the stock(s) that supply the Faroese hunt is unknown, and it is unresolved how the calculated estimates compare with the accepted estimate of 128,000 (95% CI: 75,700-217,000) pilot whales from the Icelandic and Faroe Islands area of T-NASS.

The average annual catch of long-finned pilot whales in West Greenland during 1993-2007 was 126 whales, and an aerial survey estimated 7,440 (95% CI 3,014-18,367) animals in 2007. Applying a PBR approach, it is suggested that a sustainable harvest level of pilot whales taken from this abundance would be around 50 whales per year. An estimate based on the AWMPc procedure, suggests that an annual take 70 whale is sustainable. However, the survey did not cover the entire range of pilot whales in West Greenland and the summer aggregation cannot be considered an isolated stock. Instead, it is likely connected to pilot whales along Labrador and at Newfoundland, and the occurrence and abundance in West Greenland is probably influenced by the sea temperature regimes in the area (Fullard *et al*. 2000), although the extent of this is not known.

Other species

The rerunning of fin whale trials with 60% tuning of the RMP remains to be completed, and a testing of stock structure hypotheses for Central North Atlantic fin whales will be submitted by Iceland to the 64th meeting of IWC SC. Despite the allocation of quotas for 2011 and 2012, there was no catch of fin whales in Iceland in 2011 and, as yet, no decision on catches for 2012.

The SC noted that humpback whales are present in previously unsurveyed areas off East Greenland, in agreement with information provided by observers on seismic surveys.

For minke whales the MC recommended in 2010 the calculation of catch limits based on running the RMP on the Central North Atlantic medium area, with catch cascade allocation of catches to small areas. No progress on this has been made, partially because the quota set for Iceland coastal area alone has not been fully utilised. Catches in 2011 were 58 minke whales, well below the sustainable catch levels of 229 animals recommended by the NAMMCO SC.

The average annual catch of white-beaked dolphins in West Greenland during 1993-2007 was 30 dolphins. An aerial survey estimated 11,801 (95% CI: 7,562-18,416) animals in 2007. Applying a PBR approach suggests that the sustainable harvest level of white-beaked dolphins taken from this abundance would be around 125 whales per year.

The **SC recommends** that assessments of harbour porpoise be attempted for all areas by the WG on Harbor Porpoise. This will require at least two meetings. The first meeting could provide a full assessment for West Greenland, and initiate the process for Norway, including a review of the method used for obtaining total by-catch estimates. The second meeting should focus on by-catch in Norway and Iceland, attempt to finalize assessments for Norway, Iceland and the Faroes, and could, if feasible, evaluate methods for reducing by-catch.

A genetic mark-recapture estimate of bowhead whales in West Greenland revealed a 2009 abundance of 1410 (95% CI: 783-2038) animals, which confirm the increase observed in previous aerial surveys. A new estimate based on aerial surveys and genetic mark-recapture will be available later in 2012.

A bowhead whale male tagged in Disko Bay in May 2010 moved into the Northwest Passage where it spend a couple weeks in September 2010 in close proximity of a bowhead whale tagged in Alaska in spring the same year. Both returned to their normal seasonal range, but the excursions suggest that bowhead whales from the Pacific and the Atlantic occasionally may be connected in years with little sea ice in the Northwest Passage.

Based on an increase in sightings, the **SC recommends** monitoring of trends and abundance of the Spitsbergen population of bowhead whales. Norway will continue passive acoustic monitoring with two extra devices in the northern Fram strait and north of Svalbard.

SURVEY PLANNING

The most optimal year for a large scale coordinated survey is 2015. The survey plans for the different countries are generally similar to those of the last T-NASS survey, with some exceptions described in the main report.

The state of the art in aerial survey for cetaceans was reviewed. Aerial surveys were used for all types and sizes of cetaceans, except deep divers such as sperm and beaked whales. It was emphasized that a double-platform configuration was essential to quantify perception bias for all species. It was recognized that additional and more detailed data on dive profiles of target species were required from all areas to facilitate the application of corrections for availability bias. The **SC recommends** that efforts be made to obtain these data in Iceland, Greenland, and Canada.

A review of the implementation of the double-platform mode in shipboard surveys was conducted. Biases in distance data introduce bias in abundance estimates, and the SC considered that the measurement of distance by precision instruments represent a considerable progress that should be pursued.

Two Technical Working Groups, one for aerial and one for shipboard surveys, were established to seek a wide cooperation on the joint development of protocols, techniques and equipment. Initial reports were received by the SC, which recommends that member countries relate to the recommendations, with reports being considered in detail at the next meeting of the WG on Survey Planning.

Based on the WG report and with reference to Council's decision that a new large-scale T-NASS survey of cetaceans in the North Atlantic is desirable within the near future, the SC discussed how best to approach such a large scale survey effort.

Based on experience from past surveys agreement was reached on the following specifications for a proper survey that could inform and improve management decisions:

- The survey should to the extent possible cover the potential range of the target species to provide robust abundance estimates useful for management

- The following species were identified as being targets: long-finned pilot whales, humpback whales, fin whales, sei whales and minke whales
- The survey should include all previously surveyed areas and it should be designed so that shifts in occurrence can be detected and that previously unsurveyed areas are covered if they are considered potentially important for abundance estimation
- Fully corrected abundance estimates should be developed for all the areas and this will include double-platform design of survey vessels and aircrafts
- It should early in the planning stage be attempted to include Canada and Russia and neighboring countries in surveying parts of the Atlantic to ensure that all important areas are covered intensively
- The survey should be planned for 2015 to ensure sufficient time for preparations and because other areas of the Atlantic likely will be covered by surveys conducted by the US and by EU. Seasonal timing will be agreed upon at a later meeting.

The geographical extent of the survey is shown in Figure 1. In addition to areas covered in the past the following new areas were considered critically important to include in a TNASS-15 survey:

- The East Greenland shelf from Kap Farvel to about 80^{o}N where significant numbers have been detected by platforms of opportunity in recent years.
- The offshore areas between the Labrador coast and the shelf areas of West Greenland that has not been surveyed in the past
- The areas between Iceland and Jan Mayen should be surveyed in case it is not included in the Norwegian mosaic surveys, which is important for minke whales
- Areas south of the Irminger Sea and generally south of 55^{o}N where sei whales and pilot whales occur
- Areas north of 70^{o}N in West Greenland where recent catches of minke whales have been taken
- Areas between east Iceland and Norway depending on the Norwegian mosaic survey effort
- Areas in the northeast Barents Sea, Pechora Sea where Russian surveys have indicated increased presence of cetaceans.

Proper coverage of all areas of importance will ensure that unbiased estimates are obtained. The use of double-platforms will further reduce the bias of the estimates. Both approaches are critical for achieving a survey that will be of long-term value for the management of whales in this area. Such a large-scale survey will also be able to detect major shifts in abundance caused by ongoing climatic perturbations in the North Atlantic. Finally the survey will provide critically important information of several of non-target species and provide abundance estimates for some of those.

An example of how the results of this planned survey will be fundamental to the interpretation of observed changes in abundance is the minke whales around Iceland. A significant decline in abundance in coastal areas of Iceland was detected in the T-

NASS-07 survey compared with previous surveys. However, critical areas north of Iceland and the East Greenland coast were not included in the survey effort in T-NASS-07. It is therefore impossible to say if the decline represents a catastrophic drop in population abundance or if it constitutes a shift in occurrence, perhaps in response to oceanographic changes. In the survey planned for 2015 all areas will be covered and major shifts in abundance should be detectable.

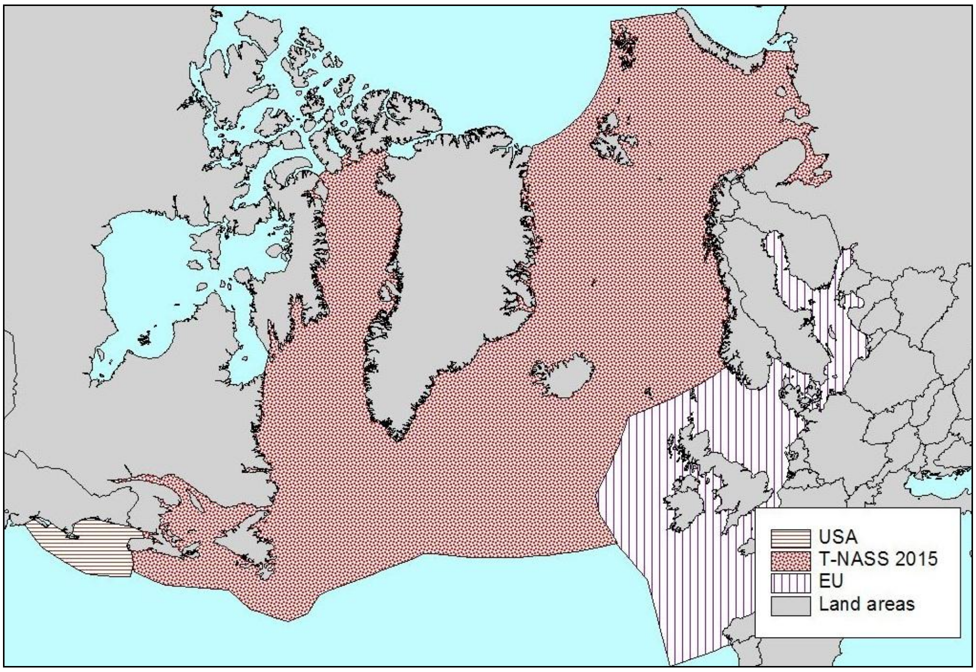

Figure 1. Extension of the proposed T-NASS 2015 and associated surveys.

Based on experience from past surveys the SC has estimated the costs for a large scale to be in the magnitude of 50mill NOK. In comparison the total cost of the T-NASS-07 survey was 30mill NOK, when corrected for inflation to 2012. Partial funding of the survey could cause gaps in coverage that will leave areas without data that cannot be included in the abundance estimates and will also reduce the options for detecting shift in abundance between areas and will hamper the assessment of whale stocks.

Aside from already planned national survey activities there are also plans for surveys of cetaceans funded by oil companies in areas where oil exploration is planned and there are also expected participations from Russia, Canada and other countries. However, the expenses for a large scale TNASS-15 cannot solely be covered by current national budgets or by NAMMCO funding. It is unlikely that funding for such an effort can be secured from scientific funding agencies and SC seeks the advice from the Council on if it is desired that SC continues its planning of a large scale TNASS-15 and on possible avenues for ensuring proper funding of the survey.

MAIN REPORT

1. CHAIRMAN'S WELCOME AND OPENING REMARKS

The Scientific Committee (SC) Chair Witting opened the 19th meeting of the NAMMCO SC. He welcomed all the NAMMCO participants (Section 5.4) to the Hotel Ammassalik in Tasiilaq as well as the observer from Japan and the Russian Federation.

2. ADOPTION OF AGENDA

The Draft Agenda (Appendix 1) was adopted with minor amendments.

3. APPOINTMENT OF RAPPORTEUR

Acquarone (Scientific Secretary) was appointed Rapporteur with the help of the Secretariat and meeting participants as needed.

4. REVIEW OF AVAILABLE DOCUMENTS AND REPORTS

The documents available to the meeting are listed in Appendix 2.

4.1 National Progress Reports

National Progress Reports for 2011 from the Faroes, Iceland and Norway were received by the Committee. In addition the SC was pleased to receive progress reports from Canada, the Russian Federation and Japan. No report from Greenland was submitted by the time of the meeting.

4.2 Working Group Reports

Reports from four NAMMCO WG meetings / workshops were available at the meeting:

- NAMMCO-JCNB Joint WG on Narwhal and Beluga (Annex 1),
- WG on Survey Planning (Annex 2),
- Age-estimation Workshops (Annexes 3 and 4).

4.3 Other reports and documents

Several other reports and documents were presented to the meeting and were examined under the relevant agenda items.

5. COOPERATION WITH OTHER ORGANISATIONS

Observer reports from meetings of other organisations were available for consideration and are summarized below.

5.1 IWC

The 63rd meeting of the SC of the International Whaling Commission was held in Tromsø, Norway, 30 May -11 June 2011 and Acquarone and Lockyer attended as observers for the NAMMCO SC.

Lars Walløe presented a summary of the 17th meeting of the NAMMCO Scientific Committee and Tore Haug presented the work of the joint NAMMCO/ICES Workshop on observation schemes for by-catch of mammals and birds (WKOSBOMB) which met at the ICES HQ in Copenhagen, Denmark, 28 June-1 July 2010.

NAMMCO informed of progress in the modelling exercise initiated by the NAMMCO Scientific Committee under the Marine Mammal and Fisheries Interactions Working Group. An expression of continued interest from the IWC Environmental Modelling sub-committee was recorded which will be followed by an invitation to report on progress on occasion of the next meeting of the IWC Scientific Committee.

Arne Bjørge summarised the work on planning a proposed global review of monodontids (involving, at a minimum, IWC, NAMMCO and JCMB - the Canada-Greenland Joint Commission on Narwhal and Beluga). The United States, Russia and Norway have expressed interest in participating. Additional preparatory work is needed and a proposal is being developed for consideration by the IWC Scientific Committee for a workshop to be held in the autumn of 2013.

The IWC Scientific Committee noted that NAMMCO is convening three workshops addressing monodontid age estimation at the request of the Joint Scientific Working Group (JWG) of NAMMCO and the JCMB.

The IWC Scientific Committee examined a report by Bjørge *et al* which estimate a total annual by-catch of 6,900 harbour porpoises in Norway in the anglerfish and cod fisheries combined.

Lars Walløe was appointed as the IWC representative at the next NAMMCO SC meeting.

The NAMMCO SC appointed Iceland as observer for the NAMMCO SC to the IWC SC 64.

5.2 ASCOBANS

The 19th meeting of the ASCOBANS Advisory Committee was held in Galway, Ireland, March 20-22, 2012, and attended by the Scientific Secretary. On the programme NAMMCO was mentioned in relation to questions on the hunt of Risso’s dolphins in the Faroe Islands in 2009 and 2010. The ASCOBANS Secretariat had written to the Faroese authorities and had contacted NAMMCO as the competent international forum.

Also in the programme was that ASCOBANS had noted that there seemed to be sufficient indication of an overlap between the stock of pilot whales utilized in the Faroes and the animals occurring in the ASCOBANS area. They remarked that there were “no reliable data” on trends in abundance and that pilot whale population structure in the North East Atlantic remained unclear. According to ASCOBANS Resolution 3.3 a total anthropogenic removal of much less than 1.7 % as an "unacceptable interaction" would be applicable in this case, exacerbated by the fact that the available data did not allow a reliable estimation of total anthropogenic removal, which would have to take into account all threats to the population, not just the deliberate take.

Mario Acquarone explained that in the latest approved abundance estimate based on the 2007 surveys NAMMCO used conventional sampling methodology and questioned the doubts raised in the ASCOBANS documentation about the "reliability" of this population estimate. He underlined that the population estimates lay within a range of 70,000 to 200,000, and therefore the Faroese hunts which took on average 600 animals (between 0.4 and 0.8 per cent of the total) were considered sustainable and lay within ASCOBANS standards for acceptable anthropogenic removals. Acquarone pointed out that new survey work was planned for 2014 or 2015 in conjunction with the Russian Federation, Canada, the USA and the EU. ASCOBANS should positively welcome such studies. ASCOBANS recognised that it was neither competent nor in a position to set and police quotas, and that it would attempt at securing the cooperation of the Faroese through persuasion.

The Advisory Committee decided that:

- They would write to the Faroese authorities welcoming the detailed information regarding the small cetacean hunts
- That they would maintain dialogue with NAMMCO and
- That further research into species abundance, such as NAMMCO's T-NASS II and further CODA and SCANS surveys, should be encouraged and supported.

5.3 ICES AND NAFO

Haug reviewed the 2011 activities in ICES which have some relevance to the work in NAMMCO SC. This included work in the ICES Working Group on Marine Mammal Ecology (WGMME), the Working Group on By-catch of Protected Species, and the Joint ICES/NAFO Working Group on Harp and Hooded Seals (WGHARP). The ICES Annual Science Conference generally include sessions with marine mammals included as an integral part, occasionally also sessions entirely devoted to marine mammals.
Preparations for the upcoming T-NASS survey and the advantages of a synoptic survey coordinated with parallel initiatives such as SCANS/CODA survey were mentioned in the March 2012 meeting report of the WGMME.

5.4 JCNB

A meeting of the NAMMCO-JCNB JWG took place in February 2012 (SC/19/14). The JCNB is scheduled to hold a meeting later in 2012.

6. ROLE OF MARINE MAMMALS IN THE MARINE ECOSYSTEM

6.1 Update

Acquarone reported about funding applications (SC/19/O/07; O/09; O/10; O/11) developed in collaboration with Matís (Iceland) and submitted to NORA (North Atlantic Cooperation, www.nora.fo) and the EU 7th Framework Programme (7FP, http://cordis.europa.eu/fp7) for the "Modelling Exercise" project. Vikingsson underlined that the applications to NORA and to the 7FP differ fundamentally in magnitude and that the feedback received from NORA SC/19/O/08 has been very positive, hence the recent resubmission by 5 March 2012.

Haug and Zabavnikov reported that a high priority part of the planned Joint Norwegian-Russian Research Program on Harp Seal Ecology is to deploy satellite transmitters on harp seals in the White Sea. In all the years 2007-2011 it was planned to do this in a joint Russian-Norwegian effort just after the moulting period (in late May), or, alternatively, in late March – early April if ice conditions turns out to be unfavourable in early May. Unfortunately, the Federal Technical Committee (FTC) did not permit satellite tagging using non-Russian tags in Russian waters in all years. In 2012, however, permission to tag harp seals in the White Sea was given by the Russian Authorities, but now a lack of funding prevented tagging of seals. In 2013 the Russian colleagues in PINRO will renew their attempt at obtaining funding for and carrying out both aerial surveys and satellite tagging in the White Sea – if only one of the projects proves feasible, tagging will be given priority over the aerial surveys. During the tagging experiment, PINRO will provide the necessary logistics required for helicopter- or boat-based live catch of seals in April-May 2013. The Institute for Marine Research (IMR), Norway, will, as before, be responsible for the satellite tags, including providing all necessary technical details, as well as for providing experienced personnel and equipment for anaesthetizing seals and tag deployment. For proper planning and budgeting on both institutes, PINRO scientist must obtain the necessary permissions from Russian authorities before December 2012. The permission from Russian authorities is not dependent on the origin of the transmitters; both US and Russian transmitters can be used. The transmitters cannot collect georeferenced temperature and salinity data. After the 2013 tagging season future seal tagging will be decided upon following an evaluation of both the tagging methods and the obtained seal movement data set. Due to low pregnancy rates and decline in pup production it will be important to focus on harp seal ecology and demographics in the coming years.

Haug further informed about the ecological Norwegian EPIGRAPH project, which includes a study on the ecological role of harbour seals in the Porsangerfjord, Finnmark, and North Norway. In September-October 2009 and 2010, 6 harbour seals each year were equipped with GPS phone tags. Harbour seal scat samples were collected in autumn 2009 and 2010, and are in course of analysis. Data from the seal tags, diet studies and estimates of fish resources carried out in the project will be used to evaluate the ecological role of harbour seals in the area. Preliminary results from the analysis of individual movements showed that harbour seals habitat usage in the Porsangerfjord is limited to a restricted area, the inner part of the fjord, with very few registered trips to the outer areas. Preliminary analysis of the scat contents showed the presence of otoliths of a large number of fish species, particularly from the families *Gadidae*, *Cottidae* and *Stichaeidae*, but also with representatives from *Pleuronectidae*, *Cyclopteridae* and *Zoarcidae*.

Haug also reported that Norwegian scientists have used data from the Norwegian-Russian Joint Ecosystem Survey to examine habitat use and prey associations of white-beaked dolphins in late summer. Data was available for one period with low (2003-2006) and one with high (2007-2009) capelin abundance, and these periods were examined separately in order to assess the importance of this key species. Since associations may be scale dependent, associations between dolphins, prey and habitat (temperature, fronts, depth and slope) were analysed at two spatial scales: 1) at habitat scale, by analysing spatial associations between averaged distributions across years in a Principal Component Analysis, and 2) at mesoscale, by analysing spatial associations within 50 km grid cells in a Generalised Additive Model. Dolphins used two different habitats; the southern warm Atlantic water, and the Polar Front area farther north. The habitat scale suggested a general overlap with most prey species but did not reveal any specific associations, while at mesoscale, dolphins associated positively with blue whiting in the southern habitat. No clear prey associations could be identified in the frontal habitat, although capelin is likely of some importance as prey. The authors suggest that the Polar Front offers predictable prey aggregations that are more beneficial for the dolphins to forage on than the highest density prey patches, thus resulting in non-linear relationships between dolphin and prey densities.

6.2 Future work

Vikingsson reported that the minke whale programme is coming up for review in the IWC. The deadline for results in the IWC is the coming winter. This marks the end of the programme and the results will as well be available for examination by the NAMMCO SC at its next meeting.

7. BY-CATCH OF MARINE MAMMALS

7.1 Update

Haug reported from an estimation of by-catch of harbour porpoise in Norway (SC/19/O/02). Based on catch and by-catch data from 2006-2008 from a monitored segment of the fleet of coastal gillnetters targeting monkfish and cod, general additive models were used to model by-catch rates, where number of harbour porpoises entered as the response variable, and catch by the fisheries was entered as offset. Landings statistics of target species were used to extrapolate to entire fisheries. The two best models predicted the total number of porpoise by-catch to 20,719 and 20,989 porpoises, with CVs 36.05% and 27.33%, respectively. Thus, the models predict annual total by-catch of about 6,900 porpoises in the two fisheries. The minimum fishing depths ranged from 5-200 m for cod and 20-400 m for monkfish nets. In cod nets porpoise by-catch rate decreased rapidly with increasing depth from 5m to 50m and then levelled off. The by-catch rate decreased linearly with increasing depth throughout the depth range for monkfish nets. According to the criteria advised by ASCOBANS (by-catches should not exceed 1.7% of the best population estimate), a population in excess of 400,000 is required to sustain an annual by-catch of 6,900 porpoises. One third of the Norwegian coast is bordering the North Sea where the abundance of porpoises is estimated at approximately 1/3 million. The abundance in the North Sea, however, is not necessarily related to the majority of the Norwegian by-catch, and the abundance along the Norwegian coast is unknown.

This information had previously been requested in advance of the joint NAMMCO-ICES workshop held in July 2010 on by-catch monitoring, but has not been available to the SC before now. With NAMMCO being the international management authority of small cetaceans for Norway, it was noted that the information was received as a for-information paper from the June 2011 meeting the IWC SC.

Considering the large number of by-caught harbour porpoises in Norway, the **SC recommends** that the sustainability of the by-catch is assessed. Therefore the **SC recommends** that both the validation of the by-catch estimation procedure and the sustainability of the by-catch be assessed through the WG on Harbour Porpoises (*see point 9.11*). The SC also noted the potentially high by-catch of grey, and especially harbour seals, in Norway (NAMMCO 2011), and referred this work to the WG on Harbour and Grey Seals.

The by-catch numbers of harbour porpoises, grey seals, and harbour seals could also be high in Iceland, based on preliminary information presented to the NAMMCO-ICES workshop in 2010. The **SC recommends** that total by-catch estimates be attempted, and that assessments of sustainability proceed through the relevant WGs.

By-catch of marine mammals around the Faroes is likely of a smaller magnitude due to the absence of gillnets in coastal waters, and by-catch in Greenland is generally reported as direct catch, although the SC is still missing estimates of the extent to which by-catch is reported as direct catch.

The SC reiterated that by-catch are equally important as direct catch as removals. It therefore reiterated the importance to ensure that reliable by-catch reporting and estimate occur for all species in all areas. Irrespectively of sustainability, the SC also recommends that by-catch be reduced as much as possible.

From Russian side, PINRO initiated monitoring of marine mammals by catch in the Barents Sea in 2012. Tables of marine mammals by catch are filled out by captains of small vessels that fish in the Barents Sea and White Sea coastal zone. For vessels that fish in the Barents Sea open water, PINRO observers would record the by-catch of all marine mammals. Initial results are obtained in 2012, and can be presented at the next SC meeting.

8. SEALS AND WALRUSES STOCKS - STATUS AND ADVICE TO THE COUNCIL

8.1 Harp Seal

8.1.1 Update

Haug reported from the ICES/NAFO Working Group on Harp and Hooded Seals (WGHARP) that met during 15-19 August 2011 in St. Andrews, Scotland, to consider recent research and to provide catch advice on the White Sea / Barents Sea and Greenland Sea stocks of harp seals in response to a September 2010 request from Norway. WGHARP also responded to a request from NAFO to consider the impacts of the increasing northwest Atlantic harp seals on the number of seals near Greenland and reviewed some new information about this stock.

White Sea / Barents Sea

A Russian survey was carried out during 20-23 March 2010, and resulted in an estimate of 163,032 pups (95% C.I. 97 682 – 228 382). WGHARP concluded that the survey appeared to have been carried out very well, and discussed several hypotheses to explain the reduced pup production since 2004, including unobserved mortality of adults around 2004, high mortality of neonates prior to the aerial surveys, or declines in fecundity (*i.e.* pup production). Given the lack of evidence for a significant adult mortality event, the most parsimonious explanation for the continued low count of pups in surveys in both good and bad ice years appears to be a decline in fecundity. The existing population model could not account for the decline in pup production after 2003 with a fixed fecundity and maturity. A revised model with time-varying maturity and condition varying fecundity (i.e., as animal conditions improves, fecundity improves) provided a good fit to the observed pup counts. However, the model was considered preliminary and not ready to be applied. A modified version of the existing model with time-varying maturity and fecundity provided a transitional model form, and was considered to be an appropriate temporary analytic tool. This model provided a 2011 total population estimate of 1,364,700 (95% C.I. 1,230,384 – 1,498,916), and it is estimated that the sustainable catch for the White Sea/Barents Sea harp seal stock should be 15,827 *1+* animals or an equivalent number of pups (where one *1+* seal is balanced by 2 pups). In 2011 and 2012 PINRO performed ice condition monitoring in the White Sea/Barents Sea.

Greenland Sea

No new data have been collected since 2009, but the recent series of catch and reproductive data lead the WGHARP to still consider the stock to be data rich. Therefore, it is appropriate to use a population model to estimate abundance and evaluate catch options. All model runs seem to indicate a substantial increase in the population abundance from the 1970s to the present. Using the modified population model with time varying reproductive parameters, the total 2011 abundance of harp seals in the Greenland Sea is estimated to 649,570 (379,031 – 920,101). The estimate provided by the modified model is lower, but presumably more realistic, than estimates provided by the original, unmodified model. WGARP estimated sustainable catches of 16,737 *1+* animals or an equivalent number of pups (where one *1+* seal is balanced by 2 pups).

Since Greenland Sea harp seals are classified as data rich, ICES now find the Precautionary Approach framework developed for the management of harp and hooded seals appropriate for the population. Given that the most recent estimate of total population size is the largest observed to date, ICES suggest that the harvest level can be set to ensure a 80% probability that the population does not decline by more than 30% over a 10 year period. This approach estimates a catch level of 25,000 *1+* animals, or an equivalent number of pups (where one *1+* seal is balanced by 2 pups). Any allowable catch should be contingent on an adequate monitoring scheme to detect adverse impacts before it is too late for them to be reversed, particularly if the TAC is set at a level where a decline is expected.

2012 survey

New aerial surveys to assess harp seal pup production were conducted in the Greenland Sea in 2012. Reconnaissance surveys were flown by helicopter (18 March – 1 April) and two fixed-wing aircrafts (22 March – 1 April) in an area along the eastern ice edge between 67°55'N and 74°10'N. The reconnaissance surveys detected two patches of harp seal breeding. The general drift of the two patches were in a south westerly direction. Due to more scattered and loose drift ice in the northernmost patch, this patch drifted faster than the more southern patch. Thus, on 28 March the two patches had merged, yielding one large patch which was photographed by the two aircrafts. A total of 27 photo transects, spacing 3 nmi, were flown using both aircrafts in the area between 70º43'N/18º31'-18º15'W and 72º01'N/17º29'-17º29'W. The survey covered the entire area of the merged patches, and all transects were flown with cameras operated to ensure about 80-90 % coverage of the area along each transect line.

Northwest Atlantic

Request R-2.1.11 had been forwarded to the ICES/NAFO working group, that examined how a projected increase in the total population of Northwest Atlantic harp seals might affect the proportion of animals summering in Greenland.

There are no abundance data on harp seal from west Greenland. Catch statistics from an unrestricted seal hunt, was show a very strong correlation with population size through 2000 that explain more than 90% of the variation in the catch numbers. The correlation suggests that an increasingly larger number of the seals migrated to Greenland as the population increased. This relationship failed after 2000 when catches dropped, despite a continued increase in the population. The hunting effort has probably dropped somewhat in certain parts of Greenland since 2000, but it is also the general belief among hunters, that the number of harp seals has dropped considerably in South-west Greenland (south of 67^{o}N). This change in abundance coincide with a significant decrease in sea ice extend in the area between Canada and Greenland. Decreasing sea ice may affect the migratory pattern and seasonal abundance of harp seals in certain areas.

The data show that fairly precise predictions of seal abundance (catch numbers in Greenland) could have been calculated from the population size alone in the years up to 2000. After 2000, however, additional variables (*e.g.* changed sea ice extent) may have changed the distribution and local abundance of harps in Greenland waters. However, it is possible that changes in hunting effort during the latest decade may have contributed to the appearance of decline in abundance.

New estimates of abundance need to be developed to discriminate between actual and perceived changes in abundance. A time-series of surveys on seal abundance in Greenland waters would be a possibility. Seals will have to be surveyed at various times a year for a number of years. Such a model will, however, not be reliable before the time-series with the new variables is longer and include years with changing trends. Furthermore, it is possible that new variables become important as the population grow. The population is believed to approach carrying capacity and this is normally associated with new factors becoming important for a continued growth of the population. It is therefore uncertain whether the distribution of the seals in the years to come is predictable based on hind-cast analysis. Such analyses will, however, be important to describe how distribution patterns change as the population and the environment change.

Alternatively, a proxy of relative seal abundance (does abundance increase or decrease) might be found by selecting catch data from settlements where changes in hunting effort are likely to have been relatively small.

In conclusion, historically the abundance of seals in Greenland waters was positively associated with increases in the harp seal population. Since 2000, it appears that ecological and hydrographical changes have changed the relationship, and possibly led to decreases in harp seals. However, there are insufficient data available to adequately analyze the latter.

Poor sea ice conditions

WGHARP was informed that the total extent of ice suitable for whelping Northwest Atlantic harp seals in the Gulf of St. Lawrence and of the coast of southern Newfoundland during 2010 and 2011 were at, or near, the lowest since 1969. Upon examination on how harp seals responded to these poor ice conditions, it has been observed that seals used unsuitable ice, moved to other areas, extending the whelping period and pupping outside of historical areas. There was no evidence to indicate that harp seals whelped on land even in areas where ice was absent. Young seals that did drift to shore had high levels of abandonment and mortality. The specific responses of whelping seals to poor ice conditions were influenced by the amount and timing of ice development in the different whelping areas. It is likely that mortality of young was high in both years, but likely greater in 2010 and 2011.

Fecundity

Obtaining accurate estimates of fecundity are critical for estimating the population dynamics of a species. Annual estimates of late term pregnancy rates, fecundity and mean age of sexual maturity of Northwest Atlantic harp seals were obtained from samples collected off the coast of Newfoundland and Labrador between 1954 and 2008. Annual fecundity rates are highly variable. Although they remained high (>85%) until the late 1970s, they subsequently declined and remained low. WGHARP noted that the proportion of mature females that were pregnant was particularly low (<40%) in 2004, which was a survey year. Reproductive rates increased to approximately 70% in 2008, another survey year, which may account for the rapid increase in pup production, observed between these two surveys. Preliminary data from 2009 through 2011 indicate that fecundity rates have declined and may be in the order of 30% during the last two years.

An aerial survey to assess harp seal pup production had been conducted in the Northwest Atlantic in March 2012.

8.1.2 Future work

The WGHARP will meet again in August 2013, presumably in Murmansk, Russia, to review the status and assess the catch potential of harp seals in the Northeast Atlantic.

8.2 Hooded seal

8.2.1 Update

At their 2011 meeting, the WGHARP considered recent research and provided catch advice on the Greenland Sea stock of hooded seals in response to a September 2010 request from Norway. Some additional information about the northwest Atlantic hooded seal stock was reviewed.

Greenland Sea

The March-April 2007 Norwegian survey estimated 16,140 pups (SE = 2,140). This estimate is not significantly different from the estimate obtained with comparable methodology in 2005, but is considerably lower than the 1997 estimate. The model developed for the 2011 assessment is similar to the model assessing the abundance of the Barents Sea/White Sea harp seal population, modified to incorporate historical maturity curves and historical pregnancy rates. The available historical data on pregnancy rates were considered unreliable. Hence, the model was run for a range of pregnancy rates, in addition to a run using the original model assuming constant reproductive data. All model runs indicate a decrease in population abundance from the late 1940s and up to the early 1980s, and gave point estimates for the total population ranging between 85,000 and 106,000 animals, *i.e.*, a population currently well below the N_{lim} of 172,577 (30% of the N_{max} estimate of 575,257). Following the Precautionary harvest strategy previously developed by WGHARP, catches shall not occur for populations below N_{30}. Therefore, no catches should be taken from the Greenland Sea hooded seal stock (except for local catches in East Greenland).

2012 survey

During the aerial surveys conducted in the Greenland Sea in 2012, harp seal was the prime target species for the surveys since this population is still hunted. Hooded seals have been protected since 2007 due to the low pup production numbers – to assess the effect of protection on the pup production, more than 5 years are needed due to the usually 4-5 years age at maturity observed in the species. If possible, however, it was a secondary goal to obtain also a new abundance estimate for hooded seals in the area during the same survey. Evidently, given the available logistical resources and the priority of harp seals, the possibilities to obtain a hooded seal pup production estimate would require that hooded seal breeding occurred within the same main areas as the harp seal breeding. During the course of the survey, it proved possible to obtain data on the pup production of both harp and hooded seals which were both included in the photo transects run on 28 March.

Northwest Atlantic
WGHARP reviewed results from joint analyses of Norwegian and Canadian reproductive data (more than 2500 ovaries) from Northwest Atlantic hooded seal females collected between 1956 and 2006 (Frie *et al.* 2012). Estimate of mean age at first birth was observed to have increased from 4.2-4.5 years in 1956-78 to 6.1 years in 1989-95. Simultaneously, pregnancy rates showed a significant drop from 91-98 % in 1967-87 to 79-74% in 1989. Thus, not all mature hooded seal females produce offspring each year, and this seems to apply to all age groups. From the 1990s, further declining adult pregnancy rates are suggested.

8.2.2 Future work

At their planned 2013 meeting, WGHARP will review the status and assess the catch potential of hooded seals in the Northeast Atlantic.

8.3 Ringed seal

8.3.1 Update

In September 2011, 12 ringed seals (10 adults and 2 juveniles) were live-captured in Melville Bay, Northwest Greenland, and equipped with satellite-linked transmitters.
Lydersen reported of the deployment of 11 CTD-fluoro SRDL tags in Svalbard and these tags provide data on dive behaviour as well as hydrographic data (salinity and temperature) and information on primary production. During the life of the tags most of the animals were sedentary and stayed close of to a glacier front.

8.3.2 Future work

A new pilot project using ringed seals as collectors of environmental data by the use of CTD-SRDL's will be initiated in Greenland close to two large outlet glaciers in Jacobshavn Isfjord (near Ilulissat) and the Heilheim Glacier (near Tasiilaq).

8.4 Grey seal

8.4.1 Update

In reviewing the status of grey seals in the NAMMCO area in 2011, the SC observed that a model had been developed for estimation of total population size for Norwegian grey seals and projection of future population trajectories under various catch options. The model includes total pup production estimates in 2006-2008, estimated by-catch mortality rates and catch statistics, while age specific pregnancy rates were derived from a large study on Canadian grey seals. Haug informed that the model, which indicated an increase in abundance of the total Norwegian grey seal population during the last 30-years and suggested a total of a little over 8,000 animals (including pups) in 2010, is now accepted for publication in the ICES Journal of Marine Science.

Report of by-catch is mandatory in Iceland, but the data are often reported as unidentified seals, which makes it difficult to determine the exact level of by-catch for each species.

Samples from 30 grey seals collected in the Faroe Islands have been included in a holistic examination on stock delineations based on genetics. The final outcome is awaited in 2013. The year 2011 was the first season with mandatory reporting from the protective hunt of grey seals at aquaculture farms. The experiences from this first year demonstrate that the system needs some further adjustments. It has also turned difficult to get samples from the hunted animals, since they are usually not retrieved from the water.

8.4.2 Future work

A grey seal survey is scheduled in Iceland in the summer/autumn of 2012. Estimating the abundance of Faroese grey seals will be attempted in the coming future; it is expected that it will require more than one year of field work to generate a robust estimate. Norway and Russia plan a joint survey of grey seals in the Southern Barents Sea.

The SC **recommended** that the Grey and Harbour Seals WG meet in 2014, reflecting the recommendations to finalise the **Requests 2.4.2 and 2.5.2**.

8.5 Harbour seal

8.5.1 Update

The most recent abundance estimate of harbour seals in Norway is based on data obtained in 2003-2006. Aerial surveys aimed to obtain a new abundance estimate for the species in Norway were started in August 2011. The area of operation was the southern coast of Norway up to Trøndelag. The rest of the Norwegian coast will be covered in 2012-2013.

Eight harbour seals were equipped with satellite linked transmitters in 2009 and six in 2010 in South Greenland. Some of the transmitters were glued on the fur (these transmitters give position and measure depth, temperature and haul out periods) and some very small transmitters could be put on the flipper in a similar way as ear-tags on sheep and cattle. Some of these small tags (that only give position and haulout periods) are still transmitting.

The seals have stayed near a small group of islands near Cape Farwell for the most of the year, but adult seals swim about 250 km up the east coast and stay there in the breeding period (around mid June-mid July). This small group of harbour seals has been estimated to count around 40 seals.

An aerial harbour seal survey conducted in Iceland in the summer of 2011 gave an average haulout count of 4512 harbour seals and resulted in an estimate of 11,000 animals (95% CI 8,000-16,000). This is similar to the estimates that were made in 2003 and 2006 with comparable methodology. These results will be submitted to the NAMMCO WG on grey and harbour seals.

The results of the fifth comprehensive seal count in Vatnsnes peninsula, NW Iceland, on 25th of July resulted in a count of 1,033 harbour seals in 2011, marginally fewer than in 2010 when the result was 1,057 seals.

8.5.2 Future work

A few small groups of harbour seals have also been located up along the Greenland west coast. Cameras taking several pictures every day throughout the summer will be put up to monitor some of these locations. The plan is to move these cameras around so that known haulout localities will be monitored at least once every fifth year.

8.6 Bearded seal

8.6.1 Update

Two bearded seals; an adult or near adult male and an adult or near adult female were equipped with satellite-linked transmitters in Melville Bay, Northwest Greenland in September 2011. The transmitters on both seals are still transmitting.

Newly developed CTD-GPS-SRDL tags were attached to 5 adult bearded seals in Svalbard. Preliminary results are promising.

8.6.2 Future work

In May 2012 six transmitters are planned to be put on bearded seals in the pack ice in Baffin Bay, Northwest Greenland.
Five more CTD-GPS-SRDLs will be deployed in summer 2012 in Svalbard.

8.7 Walrus

8.7.1 Update

A joint Russian-Norwegian survey of the coastlines of the Pechora Sea and adjacent waters for walruses was conducted during August 2011. A total of 2,563 km of coastline was inspected using a combination of infrared techniques and visual observations. Hauled out walruses were found at three sites, one group on Vaygach Island and two separate haulout groups on Matveyev Island, with a total of 958 animals counted on the aerial photographs from these two sites. All three haulouts were occupied by only males. Measurements of dorsal curvilinear lengths, show that in addition to many adult males 14.5 % of the animals were shorter than 225 cm indicating good recruitment of younger age classes into this population. Using a correction factor developed for male walruses in Svalbard to account for animals that were at sea during the survey, according to date in August and weather conditions at the time of the surveys, the estimate of the number of walruses occupying this area is 3,906 (95% CI, 3,571-4,285). No females with calves were found during this survey implying that the population (or subpopulation) that uses the Pechora Sea during summer has a larger distributional area than encompassed by the survey. Extensive oil exploration, development and production are currently taking place in the Pechora Sea. Risks associated with these activities to walruses and their food base should be assessed, and the delineations of the population clarified.

Zabavnikov reported that the WWF, Russian Ministry of Natural Resources and Russian Council of Marine Mammals special Program on walrus monitoring in the Pechora Sea was initiated in 2010. The main purpose the Program is walrus status monitoring before and during oil raw materials exploitation in the Pechora Sea.

Heide-Jørgensen reported about recent walrus surveys performed in the North Water and about the satellite tagging programme designed to provide data for bias corrections.

Norway continued the camera monitoring of selected haulout sites of walrus haulout behaviour and potential impact of tourist activities.

8.7.2 Future work

GPS-Solar Cell tags for tusk mounting are under development by the company Sirtrack for the Norwegian Polar Institute and will be tested in Svalbard as soon as available.

The SC suggested performing a stock assessment of west Greenland walrus in 2013.

9. CETACEANS STOCKS - STATUS AND ADVICE TO THE COUNCIL

9.1 Fin whale

9.1.1 Update

Vikingsson reported that the process of rerunning the trials with 60% tuning of the RMP remains to be completed. A stock structure hypothesis testing will be included in the research proposal that Iceland will submit to the 64th meeting of the SC of the IWC in June 2012. The SC took note that progress is expected on these matters.

Despite the allocation of quotas, in 2011 and 2012 there was no catch of fin whales in Iceland in 2011 and, as yet, no decision on catches for 2012 has been made.

9.2 Humpback whale

9.2.1 Update

The SC noted that the recommended analyses to detect responsive movements to survey vessels in humpback whales will not be performed by Iceland.

The SC noted that Joiris (2011) documented that humpback whales are present in previously unsurveyed areas off East Greenland, in agreement with information provided by observers on seismic surveys.

9.3 Sei whale

9.3.1 Update

It was noted that sei whales are not a priority species for the coming surveys for Greenland, Norway, and the Faroes, and that Iceland has not yet decided on the matter.

9.4 Minke whale

9.4.1 Update

In 2010 the MC recommended calculating, as soon as possible, catch limits based on running the RMP on the Central North Atlantic medium area, with catch cascade allocation of catches to small areas. No progress on this has been made, partially because the quota set for Iceland coastal area alone has not been fully utilised. Catches in 2011 were 58 minke whales, well below the sustainable catch levels of 229 animals recommended by the NAMMCO SC.

Haug reported that in abundance estimation of minke whales, Norway intend to follow the RMP requirements. This implies sighting surveys conducted over 6-year cycles (2006-2013, 2014-2019) to cover the entire area. In the current period (2008-2013), subarea ES was covered in 2008 (good coverage), subarea EN was covered in 2009 (insufficient coverage), subarea CM was covered in 2010 (insufficient coverage) and subarea EW was covered in 2011 with good coverage. Due to changes in resource allocation there will not be a Norwegian sighting survey in 2012. To complete the current 6-year cycle, subarea EB will, therefore, have to be covered in 2013. It may also be necessary to resurvey some of the subareas with insufficient coverage in 2013.

The Norwegian Minke Whale DNA Register (NMDR) is a data base monitoring commercial harvest and trade of whale products. Haug reported the register's logistics and specifications have now been reviewed, and the potential to apply similar registers to control the exploitation of other marine species has been evaluated (Glover *et al.* 2011). The application of genetics for the management of natural resources is expanding, and within this field, DNA registers will play an increasing role. The NMDR, established in 1996, was designed primarily as a control system to detect any attempts at illegal trade of products derived from other stocks of minke whale, or other whale species, under cover of the legal Norwegian harvest originating from the Northeast Atlantic. The register contains genetic data for 7,644 of 7,751 whales landed in the period 1997–2010. Profiles are established from sequencing part of the mtDNA control region, analysis of 10 STRs and a sex determining marker. Probabilities of genotypes matching between two randomly selected whales are 6.0^{-04} and 3.0^{-08} for five and eight of the STR loci, respectively. This allows verification of traded whale products via match to the register. The NMDR possibly represents the only fully operational DNA register implemented to monitor the commercial exploitation of a marine species, at the individual sample level. The close interaction of the NMDR, regulatory authorities, and the whalers themselves provides an example of how a highly regulated marine harvest can be conducted, in addition to how an individual based DNA register can be implemented to monitor and control the sustainable harvest of marine resources. While not without operational and logistical challenges (a few whales not sampled which may lead to unregistered meat on the marked), the experiences gained through operation of the NMDR clearly illustrate that DNA registers to track individual samples are viable. The register has also been used in a number of *ad hoc* scientific studies resulting through the accumulation of genetic, demographic and biological data.

Lydersen reported that the Norwegian minke whale DNA register had been used successfully to trace the origin of minke whale blubber discards found in the stomachs of Greenland sharks.

Vikingsson reported that a similar DNA register for minke and fin whales has been established in Iceland.

9.5 Narwhal

9.5.1 WG report

A joint meeting of the NAMMCO Scientific Committee Working Group on the population status of narwhal and beluga in the North Atlantic and the Canada/Greenland Joint Commission on Conservation and Management of Narwhal and Beluga Scientific Working Group was held in Copenhagen on 13-17 February 2012 under the chairmanships of Rod Hobbs for NAMMCO and Steve Ferguson for JCBN.

The report from the meeting provides advice on the status of shared stocks of beluga and narwhal as well as for narwhals in East Greenland. The advice is based on estimates of current population size and trends, stock definition, biological parameters, current and historical harvest and other impacts. Advice on research and monitoring needs is also presented.

Genetic evidence of stock structure

Population structure in narwhals as inferred from mitochondrial DNA suggest that East Greenland is distinct from West Greenland and that West Greenland samples from Uummannaq appear different from samples collected in the Melville Bay and the Disko Bay. These two latter areas appear to be part of the same population, whereas samples from the North Water (Qaanaaq) appear to be separate. Genetic divergences were also detected among years in areas with large samples sizes (such as Qaanaaq) rendering the interpretation of the result somehow uncertain. Furthermore samples from Northern Hudson Bay seem to be distinct from samples from East Greenland and from a collection of localities in Baffin Bay. Narwhals from Jones Sound and the Somerset Island summering stock are differentiated, although this may be influenced by low sample numbers from especially Somerset Island.

The low genetic divergence among geographic areas does not imply high rates of gene flow/migration but could be due to historically high migration rates and/or common ancestry. If more contemporary estimates of gene flow/migration are required then another genetic approach will be required, such as kinship-based analyses.

Satellite tracking evidence of stock structure

<u>Baffin Bay</u>

Satellite tracking of narwhals from Admiralty Inlet (2009) and Eclipse Sound (2010-2011) revealed a similar timing of migration (in late autumn/early winter) to the Davis Strait and a similar home range as previously defined. One whale from Admiralty Inlet spent winter in northern Foxe Basin rather than the Davis Strait, as is typical for narwhals from this stock. This indicates a connection between the regions but not the stocks in Hudson Bay and Lancaster Sound since tracking studies have shown the stocks are geographically separated during the autumn-winter period. Thus there is no evidence of linkages of animals from these stocks. None of the other whales showed any indication of going to other wintering grounds than the known areas in Davis Strait.

<u>East Greenland</u>

Animals in East Greenland seem to have a yearly migratory schedule where they leave the fjords and move off the coast in winter. The whales in the Scoresby Sound area seem to belong to a stock separate from other narwhal aggregations in East Greenland. These apparent distinctions indicate that the East Greenland narwhals for management purposes should be separated into different stocks.

Other evidence on stock structure

Skin tissues collected from narwhals stocks in Canada and West Greenland were analyzed for stable isotopes to determine if chemical signatures can be used as another tool for defining narwhals to specific stocks. Stable isotopes varied among most narwhal stocks assessed, suggesting the technique may be useful for stock delineation. The location of the food ingested is what translates into the isotopic signature and if the origin of the food varies (migratory food species or feeding along a migration) the discrimination into stock units would be impaired. Also, the time lag for the appearance of a signal could have a strong influence on the results of the analysis. Overall, stable isotope analysis is a cost effective technique and in combination with satellite tracking and genetic techniques, may enhance our understanding of narwhal stock structure.

Management units

Baffin Bay

The JWG and the SC agreed to continue to use the metapopulation model of narwhals in Baffin Bay, Hudson Bay, and adjacent waters as a useful approach for identifying stocks/management units and aggregations of narwhals. The model also includes knowledge of seasonal movements and the relation between the stocks and the hunting localities (Figure 2). The model is based on data collected from two decades of satellite telemetry studies of narwhals tracked from six coastal aggregations in the eastern Canadian high Arctic, Hudson Bay and West Greenland, and on information on seasonal catches of narwhals in 11 Inuit communities. The tracking data suggest that disjunct summer aggregations of narwhals to some extent are demographically-independent sub-populations with minimal or no exchange with other summering aggregations and that these, for management purposes, should be considered separate stocks. Tracking results of whales that return to the summering grounds the following year suggest inter-annual site fidelity in narwhals. It is proposed that the narwhals in Canada constitute five separate stocks with some limited exchange between three of the stocks. Coastal summer aggregations in Greenland constitute two stocks in addition to two fall-winter aggregations supplied by narwhals from several summering stocks. Several of the narwhal stocks will be mixing on the wintering areas in Baffin Bay-Davis Strait but the metapopulation structure is maintained through a combination of life history traits and migratory routes, where mating most likely occur after the initiation of the return migration towards summering areas.

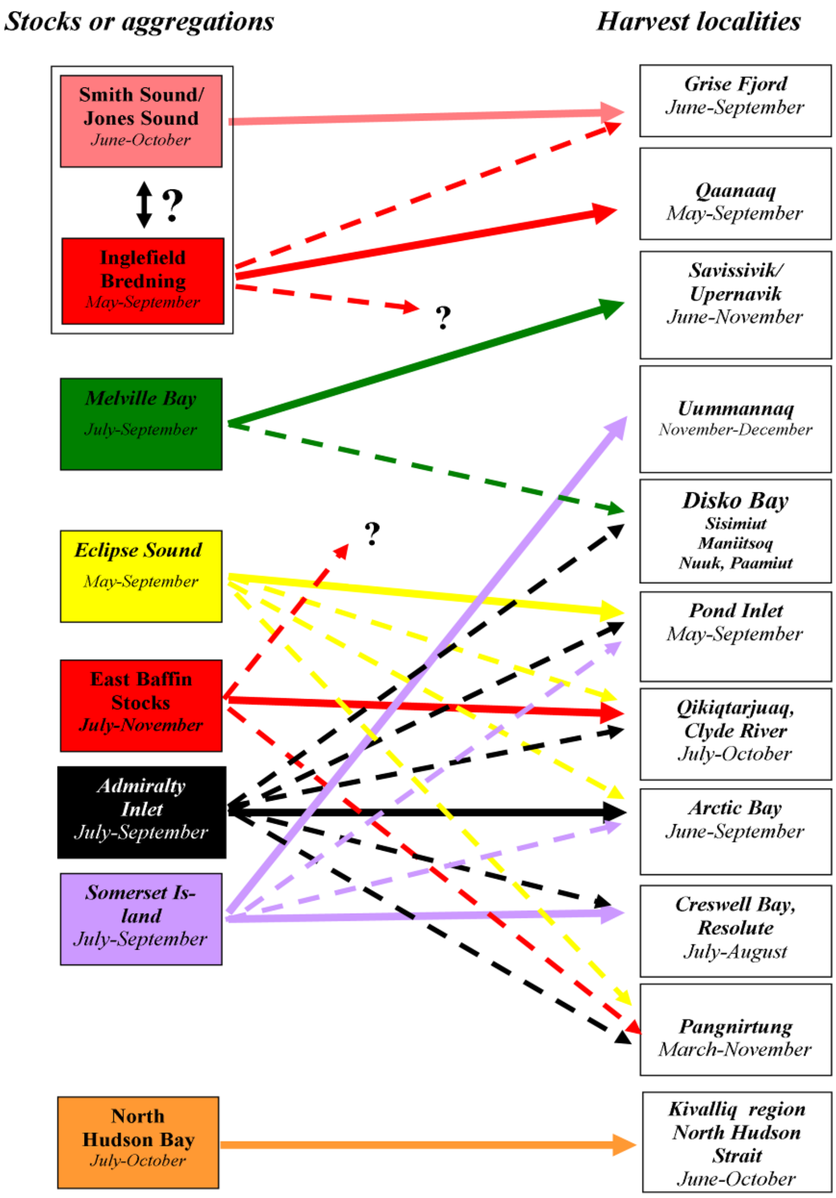

Figure 2. Diagram relating summer stocks and aggregations to hunt locations based on the metapopulation model. Solid lines have been verified by tagging studies, dashed lines are based on geography and inference from TEK and other sources.

East Greenland

The JWG and the SC agreed that management advice should be provided separately for narwhals in the Scoresby Sound (Ittoqqortormiit) and Kangerlussuaq-Sermilik (Tasiilaq) areas.

Meeting on procedures for the allocation of the harvest to the summering stock

It was not possible at the JWG to fully explore the allocation of harvest in the context of the metapopulation model and it was therefore recommended to establish a sub-group to i) review information on distribution, movements and harvest locations; ii) Develop an allocation model that will provide a mechanism for assigning harvested animals to stocks based on existing data; iii) Specify and quantify exchange rates between aggregations and stocks, and iv) Identify and quantify uncertainty in the allocation model and determine implications for management. This sub-group should meet before next JWG meeting.

Age estimation, biological parameters and population dynamics

A new racemization rate for narwhals have been estimated by regressing aspartic acid D/L ratios in eye lens nuclei against growth layer groups in tusks ($n = 9$) and the results were used in a large-scale study of age estimation of narwhals and estimation of life history parameters. Age at sexual maturity based on data from reproductive organs was estimated to be 8 years for females and 17 years for males. Age at first parturition was estimated to 9 yrs of age. Pregnancy rates for East and West Greenland were 0.42 and 0.38, respectively. Oldest pregnant female was 68 yrs of age. Maximum lifespan expectancy for narwhals was found to be ~100 years of age.

It was shown that age structure data are useful for estimating the exponential growth of both narwhals and belugas. A full assessment, with estimates of abundance and population growth, could, for example, be provided from a single abundance estimate and a single sample of the age structure. Furthermore, these models were developed so that they included estimates of the age-structured selectivity of the hunt. Similarly a model with life history traits based on age structure and fertility estimates and historical catch data from East and West Greenland can be used to estimate the minimum viable starting population in both areas in 1969 that would be required to endure the historical catch and still match current estimates of population size.

Catch statistics

Information on catches of narwhals is available from Greenland since 1862 although detailed statistics split by hunting grounds are missing for most of the years. There has been an overall increase in catches in West Greenland during the 20th century which is especially pronounced after 1950. However since 1993 a significant decline in overall catches has been observed. The decline was most pronounced in Uummannaq and Disko Bay and could not be detected in the other areas (Qaanaaq, Upernavik). Catches in East Greenland seem to have peaked during 1999-2006 but have declined after 2006. No new data was presented on the struck and lost rates in Canada or Greenland. No working paper on catches in Canada was presented but data were presented at the meeting and are included in the report. It was recommended that Canadian narwhal catches should be compiled with historic catch estimates for the different stocks to provide an updated catch history.

Abundance

An aerial survey of narwhals was conducted in the North Water in May 2009 and 2010 with the purpose of developing a fully corrected abundance estimate. The resulting abundance estimates were 10,677 narwhal (6,120-18,620) in 2009 and 4,775 narwhals (2,417-9,430) in 2010. The JWG and the SC approved that these abundance estimates can be used for assessment purposes of the Inglefield Bredning stock.

A study in Northern Hudson Bay found that narwhals spent approximately 32% of their time at the surface where they would be available to be seen by an aerial survey. When this correction factor was applied to the 2000 photographic aerial survey estimate of 1,778 (95% CI 1,688-2,015), an estimate of 5,627 narwhals (95% CI: 3,543 – 8,935) narwhals was attained.

Update of assessment for West Greenland

An age- and sex-structured population model with exponential or density regulated growth including recent abundance estimates, age structure data and catch history was used to update the assessments of narwhals in West Greenland. Several scenarios of stock delineations and harvest allocations were explored. While the age-structured models are the preferred assessment models for Greenland the models presented require further refinement especially in relation to stock structure and the allocation of catches not taken during summer. Some further testing of assumptions regarding the prior distributions of growth rate, birth rate and survival rate, and consideration of the inclusion of stochastic elements, are also required.

Recommendations

The **SC recommended**:

- continued work on survey correction factors,
- continued collection of age-data for improved assessments,
- studies for the estimation of struck and loss rates, and
- further development of the assessment model

Advice for West Greenland

The JWG and the SC agreed that the models explored at the current meeting, incorporating recent abundance estimates, updated age distribution data and new movement information from satellite tracking, confirmed that the current quotas in Greenland, for each stock area (Table 1), are sustainable:

Area	**Current quotas**
Inglefield Bredning	85
Melville Bay	81
Uummannaq	85
Disko Bay	59
Total	310

Table 1. Current quotas in Greenland for each stock area.

A new and updated advice is expected from the next JWG meeting, based on the allocation method to be developed at the proposed intercessional meeting. No advice on management was developed for any of the Canadian stocks.

Update of assessment for East Greenland

The JWG and the SC agreed that narwhals in Scoresby Sound (Ittoqqortormiit) and Kangerlussuaq-Sermilik (Tasiilaq) should be treated as two separate stocks. The age structure from animals collected between 2007 and 2010 in Ittoqqortormiit was applied to both areas, and the harvest was found to select older animals. It was estimated that narwhals in the Ittoqqortormiit area have increased slightly, while narwhals in the Tasiilaq/Kangerlussuaq area might be stable. The current growth rate in the absence of harvest was estimated to lie between 1.2% (95% CI:0–3.5) and 3.7% (95% CI:1.6–5.9), depending upon model and area.

Advice for East Greenland

The probability that total annual removals from 2012 to 2016 will ensure an increasing stock for the two stocks in East Greenland (Table 2) was estimated:

Narwhal	**Ittoqqortormiit**	**Kangerlussuaq**
Probability of increase	***Total removals***	***Total removals***
95 %	17	0
90 %	35	1
85 %	45	6
80 %	50	9
75 %	60	13
70 %	70	18

Table 2. The probability that total annual removals from 2012 to 2016 will ensure an increasing stock for the two stocks in East Greenland.

Impact of human made noise

In discussions on management advice it was noted that there is little information on the predicted response of marine mammal populations to changing arctic conditions including changes in sea ice, climate and forage species as well as increased human development activity in the arctic including seismic, shipping, drilling, and shore based development. The **JWG and the SC recommended** holding an international symposium on the effect of seismic and other development activities on arctic marine mammals with a focus on beluga and narwhal.

9.6 Beluga

9.6.1 Working Group Report

Stock structure

The Somerset Island stock supply the belugas overwintering in the North Water and off West Greenland, where the majority of the removals take place (Figure 3).

Although there are not enough data to quantify the influx of belugas from Cumberland Sound to West Greenland, it is unlikely that these animals contribute significantly to the exploited winter aggregation in Greenland.

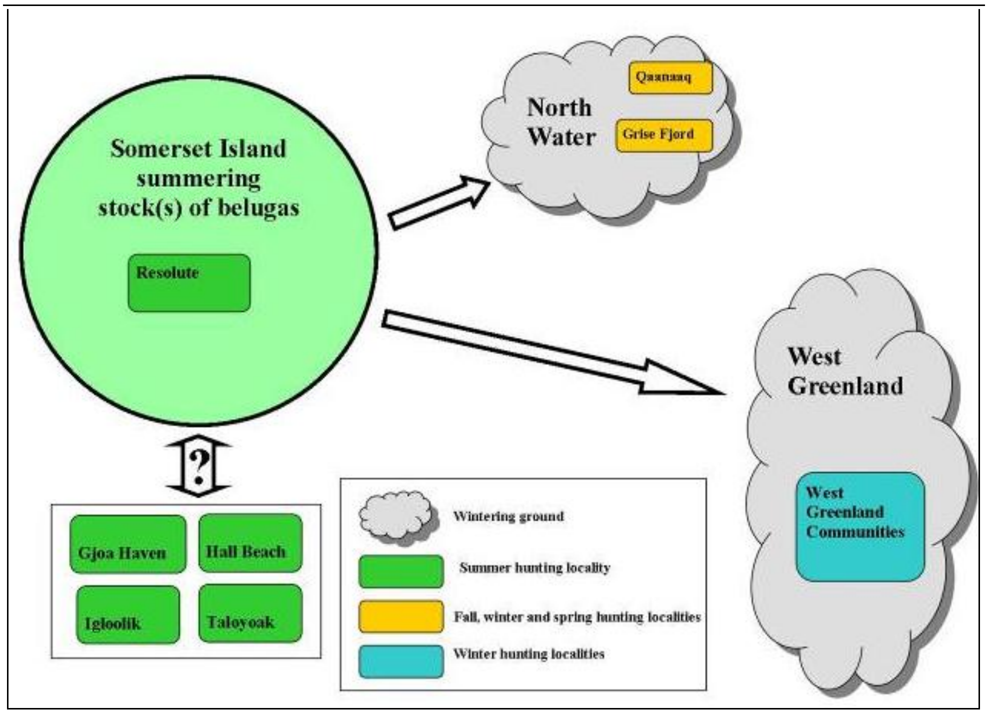

Figure 3. Beluga stock relation hypothesis. Summering stock around Somerset Island is known to travel to North Water and West Greenland based on satellite tracking data. The four Canadian communities (boxes) are thought to derive their harvest from the Somerset Island summering stock.

Age estimation, biological parameters and predation

JWG recommended at its 2009 meeting that separate workshop(s) were needed to address the problems with age determination of monodontids (9.6.2). No new biological parameters were presented for belugas, but it was agreed to apply an annual deposition rate of 1 growth layer group in tooth dentine for age estimations.

Polar bear predation on belugas was considered important as well as predation by killer whales. It was noted that receding sea ice caused an increase in the presence of belugas in shallow coastal areas. As a consequence the availability of belugas for polar bear predation also increases which warrants further investigation.

Catch statistics

Statistics on catches of belugas in West Greenland are available from 1862 to 2011. Catches declined during 1979-2011 from about 1,300 in the early 1980s to levels below 300 whales per year after 2004. Reported catches in East Greenland are considered erroneous. No working paper on catches in Canada was presented but data were presented at the meeting and are included in the report. It was recommended that

Canadian beluga catches should be compiled with historic catch estimates for the different stocks to provide an updated catch history.

There are no research plans for the quantification of struck and lost whales of belugas.

Abundance

Aerial surveys of belugas were conducted in the North Water in May 2009 and 2010 with the purpose of developing fully corrected abundance estimates. The resulting abundance estimates were 2,008 beluga (95% CI 1,050-3,850) in 2009, and 2,482 beluga (95% CI 1,439-4,282) in 2010. A low correction factor for availability bias may introduce a negative bias on the abundance estimate and it is suggested that specific correction factors for the Greenland beluga surveys are developed. The surveys might also be negatively biased because the surveys probably did not capture the entire population of belugas that winter in the North Water, since some of the whales would, by the time of the survey, have moved out of the North Water towards Lancaster Sound. The estimates were approved by the JWG and SC for assessment purposes.

Assessment for West Greenland

An age structured population dynamic model was used to assess the current status of beluga wintering in West Greenland. The analysis combined the historical catches from 1862, with the winter counts from 1981 to 2006, and age structure of the individuals in the catches from 1984 to 1997. Results from different scenarios of the model were presented, providing annual growth rate estimates from 3.2% to 5%, in the absence of harvest. The depletion ratio for 2012 was estimated to 44% (95% CI: 16%–88%), with a yearly replacement of 510 (95% CI:170–780) individuals.

It was agreed that while the age structure data improved the estimates annual survival and growth rates, there were no data on birth or juvenile survival rates for this population. The JWG did not come to a consensus on the preferred modelling approach but discussed analysis alternatives including the use of birth and survival data from other beluga populations to inform prior distributions for this population.

<u>Recommendations</u>

The SC recommended:

- the collection of new age-data for improved assessments,
- studies for the estimation of struck and loss rates, and
- further development of the assessment model in relation to prior distributions

<u>Advice</u>

Relating to **Request-3.4.11**, on updated advice when new data is available, the JWG considered, and SC agreed, that the revised assessment models, which incorporate the age structure data but no new abundance estimate, confirmed that the current removals based on the 2009 advice are sustainable. Based on a 70% probability of population increase, it is concluded that a total annual removal of 310 beluga in West Greenland (excluding Qaanaaq), is sustainable. A new and updated advice is expected at the next meeting based on a new abundance estimates from the spring survey in 2012, and the

SC noted that new abundance estimates for assessments should be available at least every 10th year.

No specific advice was given on the North Water (Qaanaaq), since the current removals remain at a low level relative to the population size. No advice was given for the harvest in Canada.

Relating to **Request-3.4.13**, the JWG and the SC reiterated the recommendations for seasonal closures:

- Northern area (Uummannaq, Upernavik and Qaanaaq): June through August
- Central area (Disko Bay): June through October
- Southern area (south of Disko Bay to 65°N): May through October.
- The area south of 65°N, closed for hunting.

The purpose of these closures is to allow for the possibility of reestablishment of local aggregations of belugas in Greenland.

9.6.2 Other updates

NAMMCO Monodontid Age Workshops

Recognizing that there are a number of problems with age determination for both beluga and narwhal, three age determination workshops were organised. The first in Tampa (Florida, USA) examined the state of the art of general aging techniques for marine mammals and other species; the second in Beaufort (North Carolina, USA) focussed on age estimation of belugas using teeth; the third in Copenhagen focussed on the use of tusks for age estimation in narwhals.

Workshop 1 in Tampa, Florida

The report (Annex 3) made it clear that the breadth and depth of the workshop presentations indicated that most issues concerning monodontid age estimation are not unique. Many researchers investigating many taxa have considered a diversity of methods and a diversity of tissues to reveal biological records of age. Aside from the biological materials, accuracy and precision of the counts or metric, have been considered, as well as their interpretation.

The workshop members agreed on several aging methods which are or may be applicable to monodontids, including potential new methods which, depending on the type of tissue required for analysis, may be applicable both to living and dead animals. Presently, tooth Growth Layer Groups (GLG) are only useable in belugas, and the Aspartic Acid Racemization (AAR) technique is very promising in narwhals. More work needs to be undertaken on embedded tusks of young animals to help tune the AAR rate for narwhals. The AAR method should also be applied to beluga eye lenses to provide a correlation with beluga tooth GLG. Such a study might provide more reliability on the narwhal AAR work presently done.

A further method that is accurate and can be used for calibration is that of bomb radiocarbon, ^{14}C. However, the main limitation is that the teeth or hard tissues must come from animals that were born after the fallout commenced, *i.e.*, post-1958.

Currently, the workshop agreed that an annual deposition rate of tooth GLG was to be the accepted standard in belugas.

The proceedings from the workshop are scheduled to be published in a volume of the NAMMCO Scientific Publication Series, entitled *Age estimation in marine mammals with a focus on monodontids*. The approval for the proposed volume had already been taken in NAMMCO, and the likely publication date would be in 2013.

Workshop 2 in Beaufort, North Carolina

The second workshop comprised 3 parts. The first part consisted in the reading of 60 images circulated to the workshop participants. The images originated from different stocks and were prepared using various techniques corresponding to the typical practices of the contributing laboratories. The participants were asked to estimate the age of each individual represented by the tooth image and provide an assessment of relative quality and readability. These estimates were used as input data for a statistical analysis of the discrepancies and errors in reading. The second part included readers from several laboratories. Based on the findings during the laboratory sessions and subsequent discussion the group recommended best practices for tooth and section preparation, reading, imaging and documenting the counts. Document SC/19/18, Annex 4 to this report, presents a summary of the main results, conclusions and recommendations from this exercise.

The third part, which will take place later in 2012, is a second reading exercise by the whole group, based on a standardised set of scanned images, representing a selection of features and levels of reading difficulty.

A third, shorter, workshop was held in Copenhagen, Denmark, in conjunction with the JWG meeting and concentrated on the preparation techniques and reading of narwhal tusks.

The **SC recommends** the AAR technique to be applied to belugas, to included known history/age animals in the analyses in order to calibrate the technique and provide an alternative aging method for beluga. Furthermore, it was recommended that with respect to beluga age estimation from teeth GLGs, there should be standardisation of GLG readings among laboratories with inter-laboratory calibrations, and the setting up of reference collections ideally accessible to all for standardisation of age estimation.
The final report from workshop 2 will be published in the NAMMCO Scientific Publications Series.

9.7 Bottlenose whale

9.7.1 Update

The Faroese T-NASS 2007 data have been analysed together with data from CODA for a model based estimate of abundance.

9.8 Killer whale

9.8.1 Update

Studies into the genetic differentiation of north Atlantic killer whales and acoustic signals produced by killer whales were conducted in Icelandic waters in 2011 (Foote *et al* 2010, Samarra 2012).

9.9 Pilot whale

R-3.8.5 – 2010: The Scientific Committee is requested to assess the status of long-finned pilot whales in West Greenland waters and provide minimum estimates of sustainable yield.

R-3.8.6 – 2011 (new): The Scientific Committee is **requested** to continue work to complete a full assessment of pilot whales in the North Atlantic and provide advice on the sustainability of catches, as soon as necessary further information becomes available, with particular emphasis on the Faroese area and East and West Greenland. In the short term, the Scientific Committee was requested to provide a general indication of the level of abundance of pilot whales required to sustain an annual catch equivalent to the annual average of the Faroese catch in the years since 1997.

9.9.1 Update

Mikkelsen reported about a tracking study carried out in the Faroe Islands, where 8 animals in a pod of 40 were tagged in late May 2011. The longest-lasting tag lasted only 14 days, over which the animal had moved SW for 400 nmi to Rockall. This reveals a different pattern from earlier tracking, where animals have moved north into the Norwegian Sea.

The SC appreciated the effort by the Faroe Islands and encouraged the continuation and the improvement of the tagging. The SC discussed that it is preferable to tag animals from intact pods but that tagging animals from a partially exploited pod could be an alternative, especially if the first option is not available.

Relating to **R-3.8.6** the SC agreed that it was unlikely that a full assessment could be attempted in the near future. Regarding a short term advice, the SC noted that both the AWMPc procedure (which has been used for preliminary advice for baleen whales in West Greenland by NAMMCO and the IWC), as well as the PBR approach, could be used for an inverse advice calculation of the minimum abundance required to sustain the average take by the Faroese.

With the average annual catch by the Faroese since 1997 being 678, and the CV of the latest abundance estimate being 0.27, the AWMPc procedure estimates that an abundance estimate around 50,000 pilot whales and a similar precision is required to sustain the catch. In comparison, the PBR approach (r_{max} of 3% & recovery factor of 1) calculates an abundance estimate around 80,000 whales. These calculations reflect precautionary estimates of the minimum abundance estimates required to sustain the Faroese hunt. However, the geographical range of the stock(s) that supply the Faroese hunt is unknown, and it is unresolved how the calculated estimates compare with the accepted estimate of 128,000 (95% CI: 75,700-217,000) pilot whales from the

Icelandic and Faroe Islands area of T-NASS.

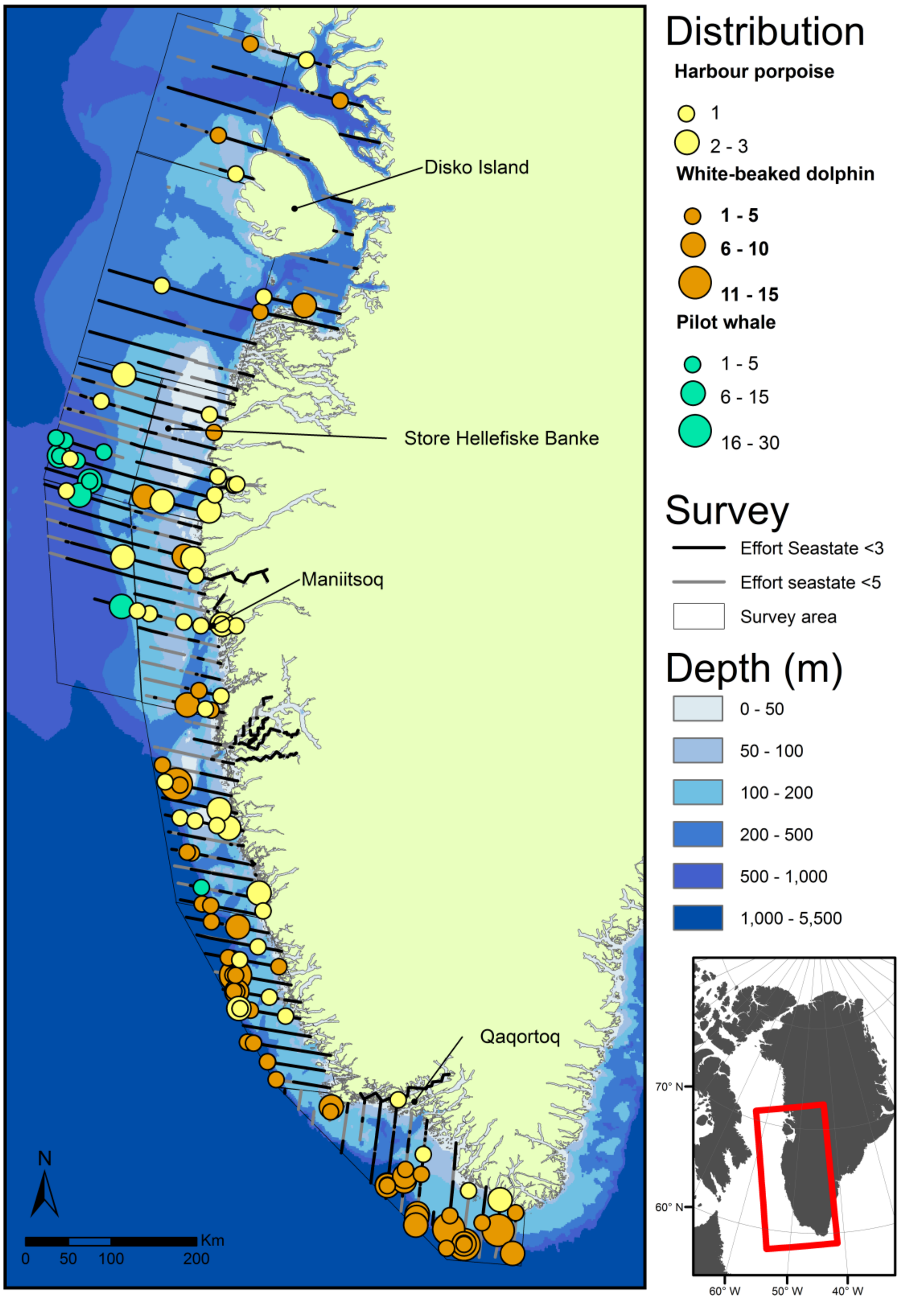

Figure 4. Realised survey effort from the 2007-survey in West Greenland. Lines flown in Beaufort sea state less than 5 are indicated in grey and sea state less than 3 in black. Distribution of pilot whales, white-beaked dolphins and harbour porpoises are shown in relation to depth.

The average annual catch of long-finned pilot whales in West Greenland during 1993-2007 was 126 whales. An aerial survey conducted in 2007 with partial coverage of the potential pilot whale habitat (Figure 4, above) revealed an abundance of 7,440 animals (95% CI 3,014-18,367) which has been approved by the NAMMCO SC. Applying a PBR approach (r_{max} of 3% & recovery factor of 1), it is suggested that a sustainable harvest level of pilot whales taken from this abundance would be around 50 whales per year. An estimate based on the AWMPc procedure, suggests that an annual take 70 whale is sustainable. However, the survey did not cover the entire range of pilot whales in West Greenland and the summer aggregation in West Greenland cannot be considered an isolated stock. Instead, it is likely connected to pilot whales along Labrador and at Newfoundland, and the occurrence and abundance in West Greenland is probably influenced by the sea temperature regimes in the area (Fullard *et al*. 2000), although the extent of this is not known.

9.9.2 Future work

Mikkelsen reported that efforts have been done to improve tag design, especially with regards to antennas, and that more trackings will be attempted in the future.

The SC was informed that the monitoring of the catch recommended by the SC over a 3-year period, which is needed for the definition of a long term monitoring programme, had not been implemented yet, although a small *ad hoc* sampling was performed from some of the landed schools. The SC reiterated its recommendation to timely implement this monitoring and underlined that an *ad hoc* sampling of the catch as performed so far would not fulfil the requirements of the recommendation.

Regarding trends in abundance, the SC reiterated its recommendation that survey estimates from 1989, 1995 and 2007 (including CODA), *i.e.*, only from the three widest surveys, are divided into comparable blocks so that recent estimates and trends can be investigated on a larger area than what has been done so far and for the areas close to the Faroese.

9.10 Dolphins

9.10.1 Update

The average annual catch of white-beaked dolphins in West Greenland during 1993-2007 was 30 dolphins (Hansen 2010). An aerial survey conducted in 2007 revealed an abundance of 11,801 animals (95% CI 7,562-18,416) which has been approved by the NAMMCO SC. Applying a PBR approach (r_{max} of 3% & recovery factor of 1) suggests that the sustainable harvest level of white-beaked dolphins taken from this abundance would be around 125 whales per year.

In 2011 the first stranding of a bottlenose dolphin in Iceland was recorded, which is also the first confirmed record of the presence of bottlenose dolphins in Icelandic territorial waters.

9.10.2 Future work

In the Faroe Islands samples were collected from the drive fisheries in 2001-2009 and the analyses will be finalised within the next couple of years.

9.11 Harbour porpoise

There is an open request (**R-3.10.1)** for the assessment of the harbour porpoises throughout its North Atlantic range.

9.11.1 Update

A total annual by-catch estimate of 6,900 harbour porpoises in Norway was reported. This estimate is substantial, and it raises concerns that the by-catch of harbour porpoises in Norway may not be sustainable. Therefore the SC recommended initiating an assessment of harbour porpoises in Norway. This process should include *i)* reviewing the by-catch estimates *ii)* examining the relevant abundance estimates *iii)* assessing the need for coastal surveys of harbour porpoises in Norway *iv)* investigating the use of satellite tracking for stock delineation, and *v)* evaluating the use of acoustic deterrents ("pingers") in the gillnet fishery in order to reduce the by-catch.

Greenland reported that they had sufficient data for an assessment of harbour porpoises in West Greenland. A catch history is available, a recent abundance estimate, as well as two samples of the age structure (from 1995 and 2010). The SC also noted the existence of abundance estimates from both Iceland and the Faroe Islands, as well as some estimates of by-catch in Iceland.

9.11.2 Future work

The SC **recommended** that assessments of harbour porpoise be attempted for all areas by the WG on Harbor Porpoise. This will require at least two meetings. The first meeting could provide a full assessment for West Greenland, and initiate the process for Norway, including a review of the method used for obtaining total by-catch estimates. The second meeting should focus on by-catch in Norway and Iceland, attempt to finalize assessments for Norway, Iceland and the Faroes, and could, if feasible, evaluate methods for reducing by-catch.

9.12 Sperm whale

9.12.2 Update

Acquarone reported on the financial and temporal need in relation to a reanalysis of the acoustics data from the 2007 T-NASS survey (SC/19/O/06). The data could be reanalysed at end of 2012. These will then be available for abundance estimation. With the production of the data being paid for by NAMMCO it is expected that abundance estimates will be derived by Iceland and the Faroe Islands in a timely manner.

9.13 Bowhead whale

9.13.1 Update

The Spitsbergen stock of bowhead whales has been considered severely depleted for centuries, but there are currently signs of low levels of sightings in the area especially along the East Greenland coast. One whale tagged west of Svalbard in April 2010 moved south towards an area off Liverpool Land in East Greenland where it stayed during the summer (Lydersen *et al*. 2012). This area was known by the bowhead whalers as the Southern Whaling Ground. Winter positions were obtained in

November-December and then the whale was back in the area west of Svalbard, known by the whalers as the Northern Whaling Ground. The tracks of this whale confirm that the historical movement patterns of bowhead whales are maintained in the Greenland Sea. Passive acoustic monitoring reveals that bowhead whales are present in the Fram Strait year-round, and the amount of vocalizations may suggest that the population may be larger than what the levels of sightings indicate (Moore *et al.* 2012).

One dead bowhead whale washed ashore at Kong Oscars Fjord in East Greenland in 2009 or 2010.

In West Greenland a genetic mark-recapture estimate revealed an abundance in 2009 of 1,410 bowhead whales (95% CI: 783−2,038) (Wiig *et al.* 2011) which confirm the increase observed in previous aerial surveys (Heide-Jørgensen *et al.* 2007). One male tagged in Disko Bay in May 2010 moved into the Northwest Passage where it spend a couple weeks in September 2010 in close proximity of a bowhead whale tagged in Alaska in spring the same year (Heide-Jørgensen *et al*. 2011). Both returned to their normal seasonal range, but the excursions suggest that bowhead whales from the Pacific and the Atlantic occasionally may be connected in years with little sea ice in the Northwest Passage.

One bowhead whale entangled in wires from a crab trap was found dead in Disko Bay in April 2011.

9.13.2 Future work

Based on an increase in sightings the **SC recommends** monitoring of abundance trends for the East Greenland - Svalbard population. Norway will continue the passive acoustic monitoring with two extra devices in the northern Fram Strait and north of Svalbard.

A new abundance estimate for west Greenland based on aerial surveys and genetic mark-recapture will be available later in 2012.

10. GENERAL MODELS FOR MANAGEMENT

No progress was made in this field.

11. SURVEY PLANNING

11.1 WG report

The Survey Planning WG met in Reykjavik, 10-12 January 2012. Scientists from all the member countries and the UK and Canada were present, and the US and IWC head of science by skype.

The SC had identified 3 tasks to be completed before and considered during this meeting:

TASK 1	Spatial analysis of all previous NASS for use in survey planning. Funds had not been available for such contract work.
TASK 2	Information on the seasonal occurrence of cetaceans in all survey areas. One new paper addressed this issue in coastal Icelandic waters based on aerial surveys. Earlier reference papers had considered shipboard surveys.
TASK 3	Documents describing advantages and disadvantages of different survey methodologies for aerial and for shipboard surveys. The Secretariat contracted papers to be prepared (titled *reviews of methodologies from earlier surveys*) and these were available before or at the meeting.

The WG reiterated the importance for management of continued periodic survey conducted in a single year in July-September covering the maximum possible area and coordinated at least at the level of the 2007 T-NASS, while recognizing differing national priorities.

Coordination should ensure that national survey areas are contiguous, and every effort made to cover any gaps, from the shores of Europe across the North Atlantic to Greenland and North America. This should minimize the confounding effect of migrations and variations in the seasonal distribution of animals on observed changes in distribution, abundance estimates, detection of trends and ecosystem monitoring. Practical advantages of coordination include the joint development of methodological protocols and equipment, centralized purchasing, which can result in cost savings, and more efficient joint data compilation, analysis, and dissemination. It was noted that T-NASS should co-ordinate with activities in the US, SCANS-III, the ACCOBAMS-Mediterranean area, and the Saint-Pierre and Miquelon area.

Current survey plans

The most optimal year for a large scale coordinated survey is 2015. The survey plans for the different countries were generally similar to those of the last T-NASS survey, except the following considerations:

Iceland and Faroes may consider surveying later in the summer. Although this would exclude the possibility of using a redfish survey platform, it would increase the chances of gathering high-quality data on sei and pilot whales, especially if an extension of the survey area to the south were included in the design. Biopsy collection from fin whales and tagging will be considered during the surveys. The plan is not to repeat the modifications of the 2007 aerial survey for including harbour porpoises as target species.

Greenland is planning an aerial line transect with a Twin Otter, double-platform and camera, ideally for August-September 2015. Coverage is planned to include the traditional survey area in West and Southwest Greenland, with a possible extension of the area farthest north because of recent catches of minke whales in Siorapaluk. This survey would not extend to include areas for other species (*e.g.,* westwards for pilot whales). Satellite telemetry is applied to reduce the variance of the abundance estimate by obtaining a new correction factor for time not at surface.

Canada is currently planning that a survey from the northern tip of Labrador to the U.S. border would be conducted after 2015, but will consider the possibility of moving the survey to 2015. Platforms include one Twin Otter in the north and another Otter and/or Partenavia P-68 Observer in the south, with double-platform and video camera coverage of the trackline. The eastern Arctic portion of Canadian waters may also be surveyed given the large-scale industrial developments proposed recently for northern Canada.

As for the previous T-NASS, the Russian Federation plan for one or two observers on a Russian Redfish survey vessel and two additional observers being available. The inclusion of an Antonov AN-26 survey aircraft is a possibility. Marine mammal sightings will be recorded during the Ecosystem surveys in the Barents Sea.

The possibility of a “*SCANS*-III” survey of European Atlantic waters is in the early planning phase. The requirements are driven primarily by the demands of the Habitats Directive. Results will also inform management issues related to the rapidly increasing deployment of wind, tidal, and wave energy developments. The ideal year is considered to be 2015, but it is currently unclear whether or not shelf and offshore waters can be surveyed in the same year.

A complete survey of the whole Mediterranean Sea and Black Sea is being planned within ACCOBAMS. It is the plan that most of the effort will be covered by aerial survey. Small vessels will use towed acoustics to survey for sperm whales. The dates have not been defined yet but the indicative period is around 2015.

The WG also took note of the multi-year extensive French aerial survey programme both in the mainland and overseas territories.

USA non-summer surveys are of high priority with secured funding for aerial surveys in March-April 2012 and Oct-Nov 2012. Aerial surveys are planned during Jan-Feb 2013, March-April 2014, and Oct-Nov 2014. A shipboard and aerial survey in June-Aug 2013 may be pushed back a year or so. Passive and active acoustic equipment are used during shipboard surveys.

Review of methodology from previous surveys

The state of the art in aerial survey for cetaceans was reviewed from 48 surveys. Aerial surveys were used for all types and sizes of cetaceans, except deep divers such as sperm and beaked whales. The majority of surveys used a single-platform configuration with one observer on each side; the remainder used either a full or partial double-platform. Most surveys used visual line transect methodology, and only a small proportion used cue counting or data on time in view during the survey with data on availability based on surfacing frequency and dive profiles from external studies to correct for availability bias. The correction of perception bias requires either a double-platform configuration or the circleback technique. In the latter, the correction combines perception and availability bias. Improvements in declination and bearing measurement methodology, as well as increased precision and automation of data acquisition, are important. Still or video photographic methods have great potential as camera and data storage technology has improved greatly in recent years. The potential of using photography as a second platform on smaller aircraft is particularly promising. Finally, unmanned aerial vehicles are undergoing rapid development and becoming commercially viable.

In discussion it was emphasized that a double-platform configuration was essential to quantify perception bias for all species. For this a photographic platform might also be feasible. It was recognized that additional and more detailed data on dive profiles of target species were required from all areas to facilitate the application of corrections for availability bias. The WG and **SC recommends** that efforts be made to obtain these data in Iceland, Greenland, and Canada.

Recognizing the difficulties in training observers for species identification on aerial survey, the WG recommended the compilation of a photographic identification guide for observers. The SC discussed that observer experience was essential, and that photos may be useful only for some species, while videos of cues would be required for other species like minke whale. Collaboration on a compilation of photos and videos to be used for observer training was recommended.

A review of the implementation of the double-platform mode in shipboard surveys was conducted from more than 50 surveys. The currently most-used methods are the Independent Observer configuration (IO mode), with two-way independence between symmetrical teams of primary observers, and the Trial Observer configuration (BT mode), with one-way independence of the tracker team from a primary team. Identification of duplicate sightings based on timing and position may be done *in situ*, requiring an observer dedicated to the task, or later.

Biases in distance data introduce bias in abundance estimates, and the WG and SC considered that the measurement of distance by precision instruments represent a considerable progress that should be pursued. The technical logistical requirements underlying shipboard sighting surveys have become increasingly complex. Planning must include increased and thorough testing of the equipment both on land and *in situ*, and a thorough training regime for the both the cruise leaders and the observers.

Two Technical Working Groups, one for aerial and one for shipboard surveys, were established to seek a wide cooperation on the joint development of protocols, techniques and equipment, with specific terms of reference compiled from the general recommendations provided in the review. Initial reports were received by the SC, which recommends that member countries relate to the recommendations. The reports will be considered in detail at the next meeting of the planning WG.

Seasonal occurrence

Information on seasonal distribution of cetaceans around Iceland was examined. Large variation in minke whale presence between years and an apparent northward shift in distribution observed in the midsummer surveys (June-July) complicates comparison, but a peak later than July but before September cannot be ruled out. For fin and pilot whales a somewhat later peak is also possible and for sei whales a later survey could be needed.

Recommendations

Based on the WG report with reference to the Council's decision that a new large-scale T-NASS survey of cetaceans in the North Atlantic is desirable within the near future, the SC discussed how best to approach such a large scale survey effort.

Based on experience from past surveys agreement was reached on the following specifications for a proper survey that could inform and improve management decisions:

- The survey should to the extent possible cover the potential range of the target species to provide robust abundance estimates useful for management
- The following species were identified as being targets: long-finned pilot whales, humpback whales, fin whales, sei whales and minke whales
- The survey should include all previously surveyed areas and it should be designed so that shifts in occurrence can be detected and that previously unsurveyed areas are covered if they are considered potentially important for abundance estimation
- Fully corrected abundance estimates should be developed for all the areas and this will include double-platform design of survey vessels and aircrafts
- It should early in the planning stage be attempted to include Canada and Russia and neighbouring countries in surveying parts of the Atlantic to ensure that all important areas are covered intensively
- The survey should be planned for 2015 to ensure sufficient time for preparations and because other areas of the Atlantic likely will be covered by surveys conducted by the US and by EU. Seasonal timing will be agreed upon at a later meeting.

The geographical extent of the survey is depicted on the map below (Figure 5). In addition to areas covered in the past the following new areas were considered critically important to include in a TNASS-15 survey:

- The East Greenland shelf from Kap Farvel to the about 80^{o}N where significant numbers have been detected by platforms of opportunity in recent years.
- The offshore areas between the Labrador coast and the shelf areas of West Greenland that has not been surveyed in the past
- The areas between Iceland and Jan Mayen (CM) should be surveyed in case it is not included in the Norwegian mosaic surveys, which is important for minke whales
- Areas south of the Irminger Sea and generally south of 55^{o}N where sei whales and pilot whales occur

- Areas north of 70^{o}N in West Greenland where recent catches of minke whales have been taken
- Areas between east Iceland and Norway depending on the Norwegian mosaic survey effort
- Areas in the northeast Barents Sea, Pechora Sea where Russian surveys have indicated increased presence of cetaceans.

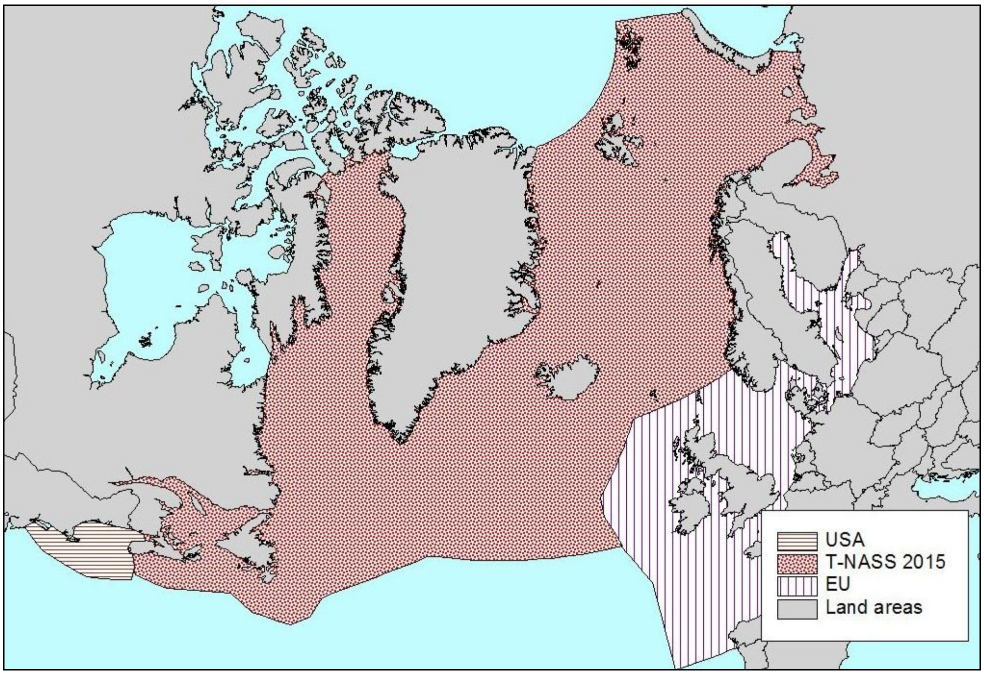

Figure 5. Extension of the proposed T-NASS 2015 and associated surveys.

Proper coverage of all areas of importance will ensure that unbiased estimates are obtained. The use of double-platforms will further reduce the bias of the estimates and provide a more accurate abundance estimates. Both approaches are critical for achieving a survey that will be of long-term value for the management of whales in this area. Such a large-scale survey will also be able to detect major shifts in abundance caused by ongoing climatic perturbations in the North Atlantic. Trends in important areas with time-series will be examined and if necessary calibrations will be conducted to ensure compatibility with past surveys. Finally the survey will provide critically important information of several of non-target species and provide abundance estimates for some of those.

An example of how the results of this planned survey will be fundamental to the interpretation of observed changes in abundance is the minke whales around Iceland. A significant decline in abundance in coastal areas of Iceland was detected in the TNASS-07 survey compared with previous surveys. However, critical areas north of Iceland and the East Greenland coast were not included in the survey effort in TNASS-07. It is therefore impossible to say if the decline represents a catastrophic drop in population abundance or if it constitutes a shift in occurrence, perhaps in response to oceanographic changes. In the survey planned for 2015 all areas will be covered and major shifts in abundance should be detectable. This is just an example, but it illustrates that regional or local surveys anywhere in the North Atlantic may give rise to questions about shifts in abundance that cannot be answered unless survey coverage is improved.

The cost of the coordination of such a large survey was also discussed. Desportes, who had been asked to act as temporary coordinator of TNASS-2 at the last SC meeting, presented a budget for the coordination effort up to the survey and beyond. There was disagreement within the committee about the necessity of such coordination and the level of work required. To avoid any conflicts of interests she was asked by the Chair to leave the room during the following discussion of the budget-proposal for T-NASS-2015.[9]

Based on experience from past surveys the SC has estimated the costs for a large scale to be in the magnitude of 50mill NOK. In comparison the total cost of the T-NASS-07 survey was 30mill NOK, when corrected for inflation to 2012. Partial funding of the survey could cause gaps in coverage that will leave areas without data that cannot be included in the abundance estimates and will also reduce the options for detecting shift in abundance between areas and will hamper the assessment of whale stocks.

Aside from already planned national survey activities there are also plans for surveys of cetaceans funded by oil companies in areas where oil exploration is planned and there are also expected participations from Russia, Canada and other countries. However, the expenses for a large scale TNASS-15 cannot solely be covered by current national budgets or by NAMMCO funding. It is unlikely that funding for such an effort can be secured from scientific funding agencies and SC seeks the advice from the Council on if it is desired that SC continues its planning of a large scale TNASS-15 and on possible avenues for ensuring proper funding of the survey.
The SC recommended a meeting of the Survey Planning WG in 2013.

[9] *Comment received from Desportes on May 10 at the acceptance of this report:* Desportes noted that, based on the recommendation from previous T-NASS WG and SC meetings, and the approval by Council, the budget she presented for the coordination was for a large synoptic survey coordinated at least at the level of T-NASS, as she explained during the meeting. This means coordinated internally and also coordinated with other American and European dedicated cetacean surveys, as well as other non-dedicated surveys simultaneously occurring in the area. The budget she prepared was based on the level of coordination effort carried out for T-NASS and the experience gained from that survey as agreed upon in the following WG and SC meetings. She further noted that the much lower coordination budget subsequently agreed upon by the Scientific Committee in Desportes' absence (presented under point 16.2) was unrealistic to achieve the so far recommended level of coordination - at least at the level of T-NASS, for an even larger survey. She regretted that the principle discussion and scientific arguments sustaining that approach of a less coordinated survey were not reflected in the SC report, as it is essential to specify which kind of project the SC is supporting and thereby continuing the coordination work, whatever its level.

12. NAMMCO SCIENTIFIC PUBLICATIONS

Acquarone reported on progress in the publication of walrus volume. In the proposed publication plan there are 21 chapters of which 10 have been received by the editors. The submitted articles are presently being sent for review and the editorial team has decided to go ahead with the online publication of the single chapters as soon as possible without waiting for all the planned chapters to be available.

Documents from the Age Determination Workshops (see item 9.6.1) are planned to be published in a new NAMMCO Scientific Publication Series (SPS) volume, and Lawson has been charged to coordinate the publication of unpublished 2007 T-NASS work.

The SC discussed improvements to the publication system with the objectives of speeding up publication time so that it would become more attractive for scientists to publish in NAMMCO SPS. The **SC recommends** supplementing the existing system with fast online publication in annual volumes that are not topic specific. Such a system could accept any submission of relevance, including working papers from WG meetings, with papers being published shortly after acceptance. The SC does not think it necessary that these annual volumes are published as paper volumes. This will only increase costs, while most scientists will be using the online version only. It is recommended that the possibility of special topic volumes within the SPS series is maintained, and these volumes could be published in paper format if Council wishes.

13. DATABASES ON ABUNDANCE AND CATCHES

13.1 Abundance

The SC agreed that the large whale abundance survey data can best be kept within the IWC system and encouraged the member Countries to submit all the data that might still not have been submitted. Regarding small cetaceans survey data, some NAMMCO Countries communicated that they will not be able to follow the same route, because of their non-recognition of the IWC as the management authority for small cetaceans.

The SC reiterated its recommendation to submit, collate and preserve at the Secretariat approved abundance estimates (Appendix 3), including the necessary metadata (such as the coverage area).

13.2 Catches

The SC reiterated its recommendation that catch data submitted through the progress reports are presented in a format suitable for direct use in the planned Stock Status list website.

14. WORK PROCEDURES IN THE SC

The SC encouraged its members to submit to the Secretariat for circulation within the Committee the details of upcoming meetings, conferences and symposia of interest.

The SC agreed that presentations at the SC meeting can be enhanced by PowerPoint, and the use of audiovisual systems for presentations is encouraged.

15. FUTURE WORK PLANS

15.1 Review of Active Request

The active requests were examined and reported under the relevant items.

15.2 Scientific Committee

Iceland is in turn for the next SC meeting, with a suggested period being 15-28 April 2013.

15.3 Working groups

The SC **recommended** that the following Working Groups meet before its next meeting, noting that other meetings may be held depending on new requests received from the Council:

Harbour Porpoise Working Group

The SC **recommended** a first assessment meeting for harbour porpoise to provide a full assessment for West Greenland and to initiate the process for Norway, including a review of the method used for obtaining total by-catch estimates. The meeting could be held in February/March 2013, most likely in Norway. *Chair: Bjarni Mikkelsen*

Working Group on Walrus Assessment

The **SC recommends** that a small WG meeting be held to update the advice for walrus in West and Northwest Greenland. Time: Winter 2012/13, Location: Copenhagen or Norway. *Convenor: Lars Witting; Chair: Øystein Wiig*

Working Group for Planning Future Surveys

The **SC recommends** that the Survey Planning WG meets in 2013, either before or after the next SC meeting. ToR would be to plan the possibility of extended coverage, including funding possibilities, and to continue the work on technical details of both the aerial and ship-board platforms. *Chair: Þorvaldur Gunnlaugsson/Geneviève Desportes*

WG meetings recommended to be held later than the 2013 SC meeting include:

Narwhal and Beluga Catch Allocation Meeting

The **SC recommends** that a small WG is held in 2013/14, before the next JWG meeting, to provide a framework for the catch allocation within the multi-stock model for Canadian and West Greenland narwhals. The Terms of Reference of this group should be:

- Review information on distribution, movements and harvest locations.
- Develop an allocation model that will provide a mechanism for assigning harvested animals to all summer stocks based on existing data.
- Specify and quantify exchange rates between aggregations and stocks.

- Identify and quantify uncertainty in the allocation model and determine implications for management.
- Recommend future work to resolve uncertainties within the model structure.

This group should ensure a useful catch allocation model given the current knowledge and data, and it would report back to the JWG at its next meeting. The location is likely to be Copenhagen. *Convenor: Mads Peter Heide-Jørgensen; Chair: Rod Hobbs.*

Narwhal and Beluga Symposium

To address **R-3.4.9** (see below) the Scientific Committee recommends that an international symposium on the effects of seismic exploration and shipping activity on narwhals and belugas is being organized by NAMMCO in 2014. Among other things, the symposium should relate to the increasing pressure from the oil industry in Greenland, and it could include studies on other species where information is missing on narwhals and belugas. Funding should be sought from industry and stakeholders.

The *Steering Committee* would include *Mads-Peter Heide-Jørgensen (NAMMCO SC)* and *Randall Reeves (Chair).* Other relevant scientists for the Steering Committee include Malene Simon, Anders Mosbech, Susanna Blackwell, and Kate Stafford, but the final decision on members is left for Mads-Peter and the Chair to decide.

R.3.4.9 NAMMCO/15-2005 (ongoing) **-** NAMMCO asked its Scientific Committee to provide advice on the effects of human disturbance, including noise and shipping activities, on the distribution, behaviour and conservation status of belugas, particularly in West Greenland. In 2009 (NAMMCO/18) it was further specified that there was no need for a broad assessment for all marine mammals, and that focus would be on walrus, narwhal and beluga.

Grey and Harbour Seal Working Group

The SMC recommended in 2010 that the WG on coastal seals perform assessment for grey and harbour seals in all areas and develop a common management model for both species in all areas. A second meeting, which could be held in 2013/14, is needed in order to finalize assessments and to agree on a common management model for all areas. *Convenor: Tore Haug; Chair: Kjell Tormod Nilssen.*

Working Group on Large Whale Assessment

Remaining items of on the agenda for this WG include fin whale simulation trials for the Central North Atlantic applying the 60% tuning of the RMP, as well as further studies on the stock structure hypotheses for North Atlantic fin whales. It includes also a recommended catch calculation with catch cascading for minke whales in the Central North Atlantic medium area. This work is currently not prioritized by Iceland for the coming year, and a next meeting of the assessment WG thus currently not scheduled. *Convenor: Gísli Víkingsson; Chair: Lars Walløe.*

Pilot Whale Working Group

The SC recommend that a pilot whale WG meeting be held to perform assessments and aim at providing advice on sustainable removals for pilot whales around the

Faroes Islands and West Greenland, as relating to **R.3.8.1, R.3.8.2** and **R.3.8.5**. This meeting awaits progress on abundance estimates and stock structure from the Faroes (see recommendations under agenda item 9.9).

15.4 Other matters

Zabavnikov and Lydersen informed the SC about the seventh Marine Mammals in the Holarctic Conference to be held in Suzdal, Russia http://mmh2012.2mn.org 24-28 September 2012.

16. BUDGET

16.1 Spending in 2011/12

The SC examined the spending for the 2011 and 2012 presented by the Secretariat and noted that there are about 50,000 NOK left on the budget until the end of 2012.

16.2 Budget for 2012/13 and T-NASS-15 budget up to 2016

A budget for the rest of 2012 and 2013 was prepared and approved. In order to clarify the financial implications of a T-NASS in 2015 the SC prepared a general budget spanning from the present to 2016, the year after the proposed survey effort.

17. ANY OTHER BUSINESS

17.4 Election of officers

The SC thanks Witting (Greenland) for serving as Chair and welcomes Gunnlaugsson (Iceland) as Chair and Haug (Norway) as Vice-Chair.

17.5 NAMMCO Stock Status List Update

No progress.

18. MEETING CLOSURE

18.1 Acceptance of report

This report was approved in a preliminary form at end of the meeting and was accepted by correspondence on 10 May 2012.

18.2 Closing remarks

The Chair thanked the Participants, the Observers and the Secretariat for an efficient meeting. Everybody joined the Secretariat in thanking Witting for his term in office as SC Chair and welcome the Chair-elect Gunnlaugsson.

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Appendix 1

AGENDA

1. CHAIRMAN’S WELCOME AND OPENING REMARKS

2. ADOPTION OF AGENDA

3. APPOINTMENT OF RAPPORTEUR

4. REVIEW OF AVAILABLE DOCUMENTS AND REPORTS
   - 4.1 National Progress Reports
   - 4.2 Working Group Reports
   - 4.3 Other reports and documents

5. COOPERATION WITH OTHER ORGANISATIONS
   - 5.1 IWC
   - 5.2 ASCOBANS
   - 5.3 ICES & NAFO
   - 5.4 JCNB
   - 5.5 Others

6. ROLE OF MARINE MAMMALS IN THE MARINE ECOSYSTEM
   - 6.1 Update
   - 6.2 Future work

7. BY CATCH OF MARINE MAMMALS
   - 7.1 Update
   - 7.2 Future work

8. SEALS AND WALRUSES STOCKS - STATUS AND ADVICE TO THE COUNCIL
   - 8.1 Harp Seal
     - 8.1.1 Update
     - 8.1.2 Future work
   - 8.2 Hooded seal
     - 8.2.1 Update
     - 8.2.2 Future work
   - 8.3 Ringed seal
     - 8.3.1 Update
     - 8.3.2 Future work
   - 8.4 Grey seal
     - 8.4.1 Update
     - 8.4.2 Future work
   - 8.5 Harbour seal
     - 8.5.1 Update
     - 8.5.2 Future work
   - 8.6 Bearded seal

8.6.1 Update
8.6.2 Future work
8.7 Walrus
8.7.1 Update
8.7.2 Future work

9. CETACEANS STOCKS - STATUS AND ADVICE TO THE COUNCIL
9.1 Fin whale
9.1.1 Update
9.2 Humpback whale
9.2.1 Update
9.3 Sei whale
9.3.1 Update
9.4 Minke whale
9.4.1 Update
9.5 Narwhal
9.5.1 WG report
9.6 Beluga
9.6.1 WG report
9.6.2 Other updates
9.7 Bottlenose whale
9.7.1 Update
9.8 Killer whale
9.8.1 Update
9.9 Pilot whale
9.9.1 Update
9.9.2 Future work
9.10 Dolphins
9.10.1 Update
9.10.2 Future work
9.11 Harbour porpoise
9.11.1 Update
9.11.2 Future work
9.12 Sperm whale
9.12.2 Update
9.13 Bowhead whale
9.13.1 Update
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10. GENERAL MODELS FOR MANAGEMENT
11.1 Update
11.2 Future work

11. SURVEY PLANNING
11.1 WG report

12. NAMMCO SCIENTIFIC PUBLICATIONS

13. DATABASES ON ABUNDANCE AND CATCHES
    13.1 Abundance
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14. WORK PROCEDURES IN THE SC

15. FUTURE WORK PLANS
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    15.4 Other matters

16. BUDGET
    16.1 Spending in 2011/12
    16.2 Budget for 2012/13

17. ANY OTHER BUSINESS
    17.4 Election of officers
    17.5 NAMMCO Stock Status List Update

18. MEETING CLOSURE
    18.1 Acceptance of report
    18.2 Closing remarks.

Appendix 2

LIST OF DOCUMENTS

Document no	**Title**
SC/19/01	Draft List of Participants
SC/19/02	Provisional Annotated Agenda
SC/19/03	Draft List of Documents
SC/19/NPR-F	National Progress Report – Faroe Islands
SC/19/NPR-G	*National Progress Report – Greenland (Not received)*
SC/19/NPR-I	National Progress Report – Iceland
SC/19/NPR-N	National Progress Report – Norway
SC/19/NPR-C	National Progress Report – Canada
SC/19/NPR-J-1	National Progress Report – Japan – Large cetaceans
SC/19/NPR-J-2	National Progress Report – Japan – Small cetaceans
SC/19/NPR-R	National Progress Report – Russian Federation
SC/19/04	Observer's report on activities in ICES
SC/19/05	Report of the Working Group on Harp and Hooded Seals (WGHARP) - 15 - 19 August 2011, St. Andrews, Scotland, UK
SC/19/06	Report of the stakeholders meeting of the TXOTX (FP7) project, Bilbao, 12-13 May 2011
SC/19/07	Observer's report: 63nd meeting of the IWC Scientific Committee
SC/19/08	Report of the NAMMCO Working Group on Survey Planning, January 2012
SC/19/09	NAMMCO Scientific Committee Expenses 2011/12 and Budget 2012/13 and beyond
SC/19/10	Summary of requests by NAMMCO Council to the Scientific Committee, and responses by the Scientific Committee, Annual Report 2010
SC/19/11	Observer's Report from the 26th Conference of the European Cetacean Society, Galway March 2012
SC/19/12	Observer's Report of the ASCOBANS AC19 meeting, Galway March 2012
SC/19/13	NAMMCO Scientific Publications Series: progress report
SC/19/14	Report of the Joint Scientific Working Group of the Canada-Greenland Joint Committee and NAMMCO Scientific Working Group on narwhal and beluga - February 2012.
SC/19/15	Report on progress in the Modelling Exercise under the Marine Mammals and Fisheries Interactions Working Group
SC/19/16	Report on progress in the NAMMCO Stock Status List
SC/19/17	Report of the NAMMCO Age Estimation Workshop 1 – Tampa, FL, USA.
SC/19/18	Report of the NAMMCO Age Estimation Workshop 2 – Beaufort, NC, USA. A summary.
SC/19/19	Observer's Report from the 19th Biennial Conference of the Society for Marine Mammalogy, Tampa, December 2011
SC/19/20	Report of the Technical Working Group on Aerial Surveys

SC/19/21	Summary of the Report of the Technical Working Group on Aerial Surveys
SC/19/22	Summary of the Report of the NAMMCO Working Group on Survey Planning, January 2012
SC/19/23	Report of the Technical Working Group on Shipboard Surveys

BACKGROUND DOCUMENTS

Document no	**Title**
SC/19/O/01	Excerpt from IWC 63 SC report – Annex L (Small Cetaceans): 8.2 Harbour porpoise.
SC/19/O/02	Bjørge, A., Godøy, H. and Skern-Mauritzen, M. 2011. Estimated by-catch of harbour porpoise *Phocoena phocoena* in two coastal gillnet fisheries in Norway. Working paper SM18 for the IWC 63 SC meeting, Tromsø.
SC/19/O/03	Frie, A.K., Stenson, G.B. and Haug, T. 2012. Long-term trends in reproductive and demographic parameters of female Northwest Atlantic hooded seals (*Cystophora cristata*): population responses to ecosystem change? *Can. J. Zool.* 90:376-392.
SC/19/O/04	Glover, K.A., Haug, T., Øien, N., Walløe, L., Lindblom, L., Seliussen, B.B. and Skaug, H.J. 2011. The Norwegian minke whale DNA register: a data base monitoring commercial harvest and trade of whale products. *Fish Fish.* DOI: 10.1111/j.1467-2979.2011.00447.x.
SC/19/O/05	Joiris, C.R. 2011. A major feeding ground for cetaceans and seabirds in the south-western Greenland Sea. *Polar Biol.* 34:1597-1607.
SC/19/O/06	Email correspondence with René Swift on the reanalysis of T-NASS 2007 acoustics data.
SC/19/O/07	Proposal for NORA 2011: MarEcoModelling – Ecosystem monitoring tool for sustainable management of marine resources.
SC/19/O/08	Outcome from NORA 2011 application SC/19/O/07.
SC/19/O/09	Proposal for NORA 2012: MarEcoModelling – Ecosystem monitoring tool for sustainable management of marine resources.
SC/19/O/10	Proposal for FP7 2011: MarEcoModelling – Ecosystem Monitoring Toolbox for Sustainable Management of Marine Resources.
SC/19/O/11	Outcome from FP7 2011 application SC/19/O/10
SC/19/O/12	MarEcoModelling Final Report to Nordic Council of Ministers (AG-Fisk)
SC/19/O/13	AWMPc
SC/19/O/14	Report of the 18th meeting of the NAMMCO Scientific Committee meeting, Gjøgv, Faroe Islands, 2-5 May 2011.
SC/19/O/15	MacNeil *et al.* 2012. Biology of the Greenland shark *Somniosus microcephalus*. *J. Fish Biol.* 80:991–1018.

Appendix 3

Abundance estimate from T-NASS (2007) endorsed by NAMMCO (updated 2012)

Survey Areas	West Greenland	Iceland Coastal **(Faroese coastal)**	Iceland-Faroes	Canada GSS	Canada NL	Norwegian mosaic 2002-7
Species / Survey	Aerial	Aerial	Shipboard	Aerial	Aerial	Shipboard
Fin whale	4,359 n,j (1,879-10,114)	-	20,613 n,j (14,819-25,466) 26,117 pj (17,401-39,199)	462 n,j (270-791)	1254 p,j (765-2,059)	To be done
Minke whale	16,609 pa[1] ,j (7,172-38,461) 22,952 pa[2]j (7,815-67,403)	14,638[3] pa, l (7,381-24,919) 20,834[4] pa, l (9,808-37,042)	10,782 n,k (4,733- 19,262)	1,927 j (1,196-2,799)	3,748 pj (2,214- 6,345)	IWC 108,140 (69,299-168,752)
Minke whale 2009		9,588 pa, l (5,274-14,420)				
Humpback whale	3,272 pa,j (1.230-8.710)	1,242 p,j (632-2,445)	11,572 n,j (4,502-23,807)	653 j (385-1,032)	3,712 p,j (2,536-5,428)	To be done
Pilot whale	**2,976 n,j (1,178-7,515)**	-	**Not accepted**	6,134 n,j (2,774-10,573)	-	To be done
Sperm whale	-	-	To be done	-	-	To be done
Bottlenose whale	-	-	To be done	-	-	To be done
Harbour porpoise	**33,271 pa,j (15,939-69,450)**	**43,179 pa, l (31,755-161,899)**	-	3,667 n,j (1,565-6,566)	958 n,j (470-1,954)	To be done
Harbour porpoise		**5,175 pa, l**				

Faroes 2010		**(3,457-17,637)**				
White-beaked dolphins	**9,827 p,j (6,723-14,365)**	To be done	To be done	-	-	To be done
White-sided dolphin	-	-	To be done	4,289 n,j (cv = 0.210)	3,086 p,j (1,781-5,357)	To be done
Common dolphin	-	-	-	53,049 n,j (34,865-80,717)	613 p,j (278-1,355)	-

Estimates in bold are first estimates for the species in the area. Estimates in blue have been endorsed at the 18th SC meeting, estimates in black have been endorsed at previous meetings. For details about the remaining or recommended supplementary analyses see NAMMCO (2011), pp. 307-8, Appendix 4.

n, uncorrected for bias; p, corrected for perception bias; a, corrected for availability bias.

[1] Availability bias is adjusted using aerial photographic images taken in Iceland.

[2] Availability bias is adjusted using satellite tagging data from three different areas.

[3] Using both primary observers

[4] Using only the most effective primary observer (much higher sighting rate)

i, Endorsed at the NAMMCO WG on Abundance Estimate, Copenhagen, April 2008, and subsequent SC Meeting (NAMMCO, 2009)

j, Endorsed at the NAMMCO WG on Abundance Estimate, Quebec, October 2009, and subsequent SC Meeting (NAMMCO, 2011)

k, Endorsed at the NAMMCO WG on Assessment, Copenhagen, March 2010, and subsequent SC Meeting (NAMMCO, 2011)

l, Endorsed at the NAMMCO WG on Abundance Estimate, Copenhagen, March 2011.

ANNEX 1

JOINT MEETING OF THE

NAMMCO SCIENTIFIC COMMITTEE WORKING GROUP ON THE POPULATION STATUS OF NARWHAL AND BELUGA IN THE NORTH ATLANTIC

AND THE

CANADA/GREENLAND JOINT COMMISSION ON CONSERVATION AND MANAGEMENT OF NARWHAL AND BELUGA SCIENTIFIC WORKING GROUP

17-21 February 2012 in Copenhagen, Denmark

REPORT

Chairs
Rod Hobbs for NAMMCO and Steve Ferguson for JCBN

EXECUTIVE SUMMARY

The Scientific Working Group of the Joint Commission on the Conservation and Management of Narwhal and Beluga met 17-21 February 2012 in Copenhagen, Denmark. The meeting was held jointly with the NAMMCO Scientific Committee Working Group on the Population Status of Narwhal and Beluga in the North Atlantic. The group, referred to as the Joint Working Group (JWG), reviewed 19 working papers on stock structure, catches, movements, behaviour, abundance, and population dynamics of narwhal and beluga in the greater Baffin Bay region. General population trends of both beluga and narwhal in the region have shown positive demographic signs of population growth over the past decade.

The Terms of Reference adopted outlined as objectives for the meeting to update the stock assessment for narwhal and beluga from recent years and to review and evaluate results of recent research in order to improve our understanding of narwhal and beluga populations in Canada and Greenland.

BELUGAS

The JWG agreed to a stock structure model for Baffin Bay beluga that describes a summering aggregation in the Somerset Island area and two wintering aggregations in the North Water and in east Baffin Bay. Although no new genetic studies of Baffin Bay beluga have been conducted, the JWG reviewed alternative approaches to defining beluga population structure which could assist in allocating proportions of beluga harvests in various communities to source summer stocks. No new information on beluga biological parameters and reproductive rates was available for review from the region; however recent information from Alaska provided estimates of population growth rates (4%), age of female sexual maturity (9 y), interbirth interval (3 y), and calf age of independence (2 y). Future research planned for other regions that will inform beluga knowledge of demographic rates include hormone work to understand female reproductive cycles and estimates of survival rates and fecundity. Recent acoustic research on beluga is providing knowledge of feeding events that will assist in determining interactions with emerging fisheries. The JWG welcomed this study and suggested using satellite tagging to retrieve detailed information on the migration routes of the animals; developing quantitative methods to estimate feeding using acoustics and behaviour; including other species in this investigation; and documenting the noise level of the area.

Updates were provided on a recent series of NAMMCO workshops to examine aging techniques for marine mammals with particular interest in beluga and narwhal ageing methods. Techniques such as genetic telomere length, aspartic acid racemisation, endogenous fatty acid ratios, and historic hunting artifacts were reviewed. The preferred method, where applicable, was using hard structures, such as teeth or ear plugs that provide regular episodic growth layers. Precision, accuracy, and quality control were considered essential for development of an appropriate aging programme. The workshop participants agreed that the annual deposition of tooth GLGs was the accepted standard approach to be used for belugas. Proceedings of the workshop, entitled *Age estimation in marine mammals with a focus on monodontids*, are under compilation.

Mortality of beluga included a discussion of predation impacts by killer whales and polar bears. Recent catch statistics from Greenland and Canada were reviewed and a recommendation that catch statistics be made available one month prior to the next meeting would assist with the assessment process. Catches in West Greenland have remained below 300 belugas per year since 2004, whereas in Canada catches have remained below 200 belugas per year. For East Greenland, reported beluga catches may be erroneous and should perhaps be added to the narwhal catches. The JWG recommended studies by both countries to better quantify struck and lost rates for both beluga and narwhal. For future assessments, the JWG recommends separating catches from the North Water from those off West Greenland.

Recent abundance estimates included two aerial surveys of beluga (and narwhal) in the North Water in May 2009 and 2010 that provided corrected estimates of 2,008 and 2,482 respectively.

The assessment for West Greenland used an age structured population dynamic model that included historical catches from 1862, with winter aerial survey results from 1981 to 2006. Model results indicate an historic population size of 26,000 in 1862, to a minimum of 9,300 in 2004, to a projected abundance of 13,000 in 2017. No new data were available to update advice provided in 2009 and the JWG determined that the revised assessment models that incorporated age structure data did not require new advice on current removals of belugas from West Greenland. A survey is planned for 2012 and an updated population assessment will be prepared for the next meeting. The JWG reiterated the previous advice to seasonally close the northern area in June through August, the central area in June through October, the Southern area in May through October, and the area south of 65oN remained closed to protect the few animals that may form a summer aggregation in West Greenland.

NARWHALS

Genetic stock structure findings from mtDNA and nuclear DNA have provided a consistent pattern of genetic separation among three narwhal populations (East Greenland, Baffin Bay, and Northern Hudson Bay) with a suggestion of differences between the North Water narwhal from other Baffin Bay stocks. In contrast to other cetaceans, narwhals are characterized by very low genetic diversity that dates back 50,000 years which may limit the usefulness of genetics as a tool to understand population sub-structure and provide information required to allocate catches to summer aggregations. Recommendations were to decide on a quantitative definition of a stock and to use new emerging genotyping technologies with biomarker data, such as fatty acid, isotope, and contaminant data to improve assignment testing. Last, use of genetic information to better understand relatedness would provide knowledge of pod structure and social inferences.

Recent satellite tracking studies in Canada (Admiralty Inlet in 2009 and Eclipse Sound in 2010 and 2011) and Greenland (Scoresby Sound in 2010 and 2011) provided evidence of stock structure as well as more information on discreteness of summer aggregations. For example: one whale tagged in Admiralty Inlet spent winter in northern Foxe Basin rather than Davis Strait; many narwhals tagged in Eclipse Sound made use of Admiralty Inlet; and whales of Scoresby Sound seem to belong to a stock separate from other narwhal aggregations in East Greenland. Recent tracking results were used to update the metapopulation structure model (now referred to as stock aggregation model) that indicates disjunct summer aggregation areas of narwhal representing somewhat demographically-independent sub-populations for management purposes (*i.e.* minimal or no exchange of animals among other summer aggregations and year-to-year site fidelity). For management purposes the JWG recommends subdividing the Baffin Bay population into six separate summering aggregations: four in Canada (Somerset Island, Admiralty Inlet, East Baffin, and Eclipse Sound) and two in Greenland (Melville Bay and Inglefield Bredning with the latter having a currently unspecified linkage to Smith Sound/Jones Sound). Winter hunting only occurs in Greenland with autumn-winter aggregations occurring in two areas in Baffin Bay-Davis Strait that provide narwhals from a number of summer aggregations. Mating occurs in late winter-early spring in these areas and population sub-structure is maintained through a combination of life history traits and migratory routes of narwhal to various summer aggregations. Inuit hunting of narwhal occurs both along these migration routes and at the summer aggregations depending on different seasonal hunting areas. It is important to identify which narwhal stocks contribute to which subsistence hunts in order to assess the sustainability of those hunts to individual summer aggregations.

The JWG makes the following recommendations:

- a continuation of tagging studies to elucidate the location of the summering grounds for the animals belonging to the stock harvested in the Uummannaq area;
- tagging studies to understand where the animals summering in East Baffin, Jones/ Smith Sound spend the winter and are possibly hunted;
- develop alternative tagging options that are less costly and less intrusive;
- investigate the possibility of using alternative markers (*e.g.* ectoparasites, tusk phytoplankton;
- investigate the use of photo-id, (*e.g.* aerial or vessel platform);
- develop a glossary of definitions to assist discussions of management stocks and summer/winter aggregations.

The JWG recommends a meeting be convened to develop common procedures for the allocation of the harvest to all six summering stocks of the Baffin Bay population, tentatively in early March 2013, and to include a group of less than 10 participants (*e.g.* Heide-Jørgensen, Ferguson, Hobbs, Witting, Richard, successor to Richard, Hansen, Lee, Laidre). The suggested location is Copenhagen. The Terms of Reference of this group are to

- review information on distribution, movements and harvest locations of narwhal;
- develop an allocation model that will provide a mechanism for assigning harvested animals to all summer stocks based on existing data;
- specify and quantify exchange rates between aggregations and stocks;
- identify and quantify uncertainty in the allocation model and determine implications for management; and
- recommend future work to resolve uncertainties within the model structure.

This group would report back to the JWG at its next meeting.

The aging of narwhal using eye lenses was reviewed. A species-specific racemization rate for narwhals has been updated and more sampling of tusks and matching eyes are needed to improve the estimated values. Updated life-history parameters included asymptotic body lengths, age at asymptotic body lengths, asymptotic tusk length and age at asymptotic tusk length for East and West Greenland narwhals. Also, updated are reproductive (age at sexual maturity, age at first parturition, and pregnancy rate) and longevity estimates for the species.

A Bayesian assessment model was developed to estimate the exponential growth rate of a whale population based on a single abundance estimate and a single sample of the age structure. Results illustrated the usefulness of the Bayesian assessment approach based on age-structured data to inform precautionary management advice.

A population life history matrix (*i.e.* Leslie matrices) model was developed to estimate population age or class structure. Using an individually tested stochastic model with life history and historical catch data from East and West Greenland improved estimates of the starting population of narwhal in both areas in 1969 that would account for the historical catch and match current estimates of population size. Unusual mortality such as ice entrapments will be added. The JWG considers this model to improve the relation between the original population sizes and future projections and noted the similarity of results to the Bayesian model currently used for stock assessment.

In order to understand diving behaviour of the Northern Hudson Bay narwhal, nine whales were tagged with satellite tracking devices in the Repulse Bay area in August of 2006 and 2007 that provided time at depth of 0 to 2 meters of water. Narwhals spent approximately 32% of their time at the surface where they would be available to be seen by an aerial survey and this correction for availability bias was applied to the estimate from the photographic aerial survey in 2000. The JWG noted that dive behaviour has both species characteristics and characteristics dependent on location, season, behaviour and available prey and encouraged continued collection of these data with emphasis on dive interval and time-at-surface data in areas to be surveyed at the time of the survey.

Canadian and Greenland catch statistics were presented although catch statistics for Canada represent landed animals and did not include “struck and lost” estimates. The JWG encourages Canada to build a time series of catch statistics using the historical catch estimates that could be used in assessment models. Information and trade statistics on catches of narwhals in Greenland since 1862 provided a time series of somewhat realistic catch levels. There has been an overall increase in catches in West Greenland during the 20th century which is especially pronounced after 1950. During the period since adoption of the hunting reporting system (Piniarneq) a significant decline in overall catches has been observed. Catches in East Greenland peaked during 1999-2006 but have declined after 2006. The JWG requests that Greenland data include the sex of the landed animals when available and that both countries complete studies to determine “struck-and-lost” rates with various hunting methods and circumstances. Overall, for the Baffin Bay population that is shared by Canada and Greenland the average annual take for the past 5 years has been 335 narwhal by Greenland and 422 by Canada.

In November 2008, an ice entrapment event occurred off the coast of Bylot Island, Nunavut near the community of Pond Inlet that resulted in a collection of 250 skin and blubber samples from over 600 harvested whales. Dietary differences by sex or age did not occur; however, distinct feeding groups were evident, work is underway to determine the relatedness of these groups. Emaciation was evident and not thought to be the result of the entrapment period. While the later arrival of the freeze up is well documented, the relation to and mechanism of entrapment remain unclear. The JWG recommended monitoring ice entrapments and freeze-up along migration paths to understand the environmental mechanisms leading to entrapments.

An aerial survey of narwhals, conducted in the North Water in May 2009 and 2010 and accounting for both perception bias of the observers and the availability of animals to be observed, estimated 10,677 (0.29) and 4,775 (0.36), respectively. Two aerial surveys were completed in August 2010 to assess the summering stock of narwhals in Admiralty Inlet. Combining the estimates from the two surveys using an effort weighted mean of estimates yielded a population estimate of 18,049 (CV=0.23, 95% C.I.=11,613-28,053) and a new recommended Total Allowable Landed Catch (TALC) for the Admiralty Inlet narwhal stock of 233 animals. The JWG recommended ensuring that at least one of the authors of key documents such as these is present at the meetings.

Planned aerial surveys include (1) an aerial survey off West Greenland from 26 March to 15 April 2012 that includes a systematic survey design that samples using east-west transects from glaciers to the fast ice across the open water area; (2) an aerial survey in Melville Bay is planned for 30 July-6 August, 27 August-4 September, 20-28 September before, during and after seismic activities in the Kanumas West area using a systematic sampling with transects from glaciers to the fast ice across the open water area; (3) tentative Canadian plans for the next 5 years include Cumberland Sound for beluga, and Jones Sound, Somerset Island, East Baffin Island for narwhal. The Canadian delegation reported evidence of narwhal range extension into the western Canadian Arctic and were hunted in 2011 in areas where hunting of narwhals is unusual (Cambridge Bay).

The JWG reviewed assessments of narwhals in West Greenland and Uummannaq which used a Bayesian model that incorporated recent abundance estimates, historical catches , age-structure data , and an age- and sex-structured population model with exponential or density regulated growth. While the JWG indicated that the approach had merit but deferred assessment until the assessment models could be revised according to the summer aggregation model for West Greenland. This implied separate models of the two summer aggregations (Inglefield Bredning and Melville Bay), as well as models of the fall hunt in Uummannaq and the winter hunt in Disko Bay.

Inglefield Bredning was modelled as an isolated summer aggregation model and assumed that these animals are not hunted elsewhere. It applied the summer estimates from the area, the spring count from 2009, and the 2007 age structure for West Greenland as a whole. It estimated a rather stable Inglefield Bredning aggregation since the 1960s, with an average abundance around 10,000 individuals, and a current exponential growth rate of about 1.2% in the absence of removals.

The JWG determined that Melville Bay should be modelled as a distinct summer aggregation that is distributed south along the west coast of Greenland during other seasons. The model assumed that all of the catches from Melville Bay, plus 14% of the catches were from fall and winter in Disko Bay, and 12% of the catches were from winter in Uummannaq are considered to be taken from the Melville Bay aggregation. These proportions were calculated on the assumption that Admiralty Inlet, Eclipse Sound and Melville Bay supply the hunt in Disko Bay in proportion to their respective stock sizes. Similarly Uummannaq is presumed to be supplied by whales from Somerset Island and Melville bay. Besides the catch history, the model was based on the 2007 abundance estimate (6,200; cv: 0.85), and the 2007 age structure for West Greenland. Based on the information in the age structure, the narwhal abundance in

Melville Bay was estimated to have increased slightly since the 1960s, with an exponential growth rate of 1-2%/y in the absence of removals.

The model for Uummannaq relates to the hunt on stock components that arrive in the area during fall and likely overwinter in the Baffin Bay outside Uummannaq. This component was estimated at 6,070 (cv: 0.37) individuals in 2006, the model includes the age structure from animals caught in the area in 1993, and the Uummannaq catch history. This model estimated a rather stable population until the 1990s, where the numbers declined due to high catches, and a subsequent stable or increasing population thereafter. The growth rate with no catches was estimated to approximate 2% per year.

The model for the Disko Bay area relates to the hunt on the stock components that overwinter in the area. The model is based on the series of winter surveys in the area, the Disko Bay catch history, and the 2007 age structure for West Greenland as a whole. It is assumed that 14% of the Disko Bay catches are taken from the Melville Bay stock, and that the rest are taken from Canadian stocks, primarily from Eclipse Sound and Admiralty Inlet. Unlike the other areas, no absolute abundance estimates were available for this area, and it was not possible to construct a successful model.By allocating catches from the fall and wintering grounds of Uummannaq and Disko Bay to the Melville Bay stock and Canadian summer stocks, it should be possible to use this model framework for advice on sustainable catches of narwhals in all areas in West Greenland and Canada.

The JWG agreed that age-structured models are the preferred assessment models for Greenland narwhal and beluga because they provide information on the survival and growth rates of the population and in some cases on abundance. However, the models presented require further refinement especially in relation to stock structure, the allocation of catches not taken during summer and assumptions regarding the prior distributions of growth rate, birth rate and survival rate, and the inclusion of stochastic elements.

The JWG reiterated its previous advice for West Greenland (Inglefield=85, Melville=8, Uummannaq=85, Disko=59) since the new assessment models required further development. The models explored at the current meeting, incorporating recent abundance estimates, updated age distribution data and new movement information from satellite tracking, confirmed that the current quotas in Greenland, for each stock area, are still sustainable.

The JWG considered allocating the hunt in Canada and Greenland following the concept of a summer aggregation (metapopulation) model and inclusion of age structures. However, the JWG concluded that further work is required before these elements can be incorporated in the modelling approach and recommended a meeting of a subgroup of the JWG be convened as described above. For Inglefield Bredning, a new assessment should include new information on abundance from the recent survey of Smith Sound and the possibility that the stock may be shared with Jones Sound.

For East Greenland, the dynamics of narwhals at the two hunting areas, *i.e.* the Ittoqqortormiit and Tasiilaq/Kangerlussuaq areas, the Bayesian assessment model used the 2008 age structure from Ittoqqortormiit. Results indicate that the harvest was selective against the take of animals younger than 20 years of age. It was estimated that narwhals in the Ittoqqortormiit area have increased slightly, while narwhals in the Tasiilaq/Kangerlussuaq area are likely stable. The current growth rate in the absence of harvest was estimated to lie between 1.2 and 3.7%, depending upon model and area. A more conservative result was chosen for Tasiilaq because of the general lack of data for the area and the uncertainty on the growth of the population. Recommended total removals of narwhals from East Greenland Ittoqqortormiit remain the same as the previous assessment (95% confidence of an increasing stock=17; 90%=35; 85%=45; 80%=50; 75%=60; 70%=70) and for narwhal from East Greenland Tasiilaq/Kangerlussuaq area (95% confidence of an increasing stock=0; 90%=1; 85%=6; 80%=9; 75%=13; 70%=18).

The JWG recommends:

- Regular monitoring of population sizes (at least every 5-10 years) for each summer aggregation, and
- Satellite tracking that includes dive behaviour of 20-50 animals per aggregation every 5 years are key to developing the allocation model and providing accurate advice on allowable removals.
- Development and testing of an allocation model for shared narwhal stocks between Canada and Greenland, and
- Further development and testing of the assessment models using simulations where necessary to determine the impact of assumptions and identify potential biases.

Canada continues to assess Total Allowable Harvest Levels based on the Precautionary Approach that requires using Potential Biological Removals since the five summer aggregations/stocks are considered Data Poor (*i.e.* limited time series of abundance surveys and limited age/sex structure and reproduction information).

OTHER ADVICE

The JWG notes that measurement of noise effects of seismic, drilling, shipping and other human activities on arctic marine mammals and the implications for population dynamics are not well understood for cetaceans in general and suggests that NAMMCO include this as a topic in an international symposium on human impacts. The inclusion of other species (*i.e.* walrus or bowhead) to the work of the JWG was discussed but it was not deemed desirable.

MAIN REPORT

1. OPENING REMARKS

Chairmen Steve Ferguson (JCNB) and Rod Hobbs (NAMMCO) welcomed the participants (Section 5.6) to the fifth joint meeting of the Canada/Greenland Joint Commission on Conservation and Management of Narwhal and Beluga (JCNB) Scientific Working Group and the North Atlantic Marine Mammal Commission (NAMMCO) Scientific Committee Working Group on the Population Status of Narwhal and Beluga in the North Atlantic (hereafter referred to as the Joint Working Group or JWG).

Section 2 of the Memorandum of Understanding between the Department of Fisheries and Oceans of the Government of Canada and the Ministry of Fisheries and Industry of the Greenland Home Rule Government on the Conservation and Management of Narwhal and Beluga signed in 7 December 1989 states that:

"The Joint Commission will be entrusted with the following functions:

- To establish terms of reference for the scientific working group;
- To be responsible for the exchange of data and information and the coordination of such research project as the Parties have agreed to carry out jointly;
- To submit to the Parties proposals concerning scientific research to be undertaken jointly or separately;
- To submit to the Parties recommendations respecting the conservation and management of stocks.

The scientific working group will be responsible for the provision of scientific advice as requested by the Joint Commission and will coordinate the exchange of data and assessment of research results."

The Scientific Working Group of the *Joint Commission on the Conservation and Management of Narwhal and Beluga* has met 13-17 February, 2012, in Copenhagen, Denmark. The meeting has been held jointly with the *North Atlantic Marine Mammal Commission Scientific Committee Working Group on the Population Status of Narwhal and Beluga in the North Atlantic*. These two Scientific Working Groups, known collectively as the Joint Working Group (JWG) have reviewed several working papers that address scientific questions relevant to shared stocks of narwhal and beluga in the greater Baffin Bay region.

This Report provides advice on the status of shared stocks of beluga and narwhal, including estimates of current population size and trends, stock definition, current and historical harvest and other impacts. Advice on research and monitoring needs is also presented. The advice formulated by the Joint Working Group in this report will be presented to the next meeting of the *Joint Commission on the Conservation and Management of Narwhal and Beluga,* whose role is to provide management recommendations to both parties in respect of research, conservation and management.

The Objectives for the meeting of the JWG were to:

- Update the stock assessment for narwhal and beluga from recent years;
- Review and evaluate results of recent research in order to improve our understanding of narwhal and beluga populations in Canada and Greenland;
- Review several working papers prepared in response to questions arising from the last Joint Commission on the Conservation and Management of Narwhal and Beluga meeting in Nuuk, Greenland, in May 2009 and include:
    - Impacts of killer whales on behaviour and survival of narwhal and beluga.
    - Impacts of fish removal and fishing activity on beluga and narwhal.
    - Impacts of feeding by beluga and narwhal on commercial fishing.
    - Identify calving areas and further document stock identification and stock structure of narwhal and beluga.
    - Determine reproductive parameters of narwhal and beluga populations.
    - Impacts of changing sea ice conditions on beluga and narwhal.
    - Determine "struck-and-lost" rates with various hunting methods and circumstances.
    - Recommend collection of information on effect of noise pollution and other human activity on populations.

This Report will be prepared and presented at the Twelfth meeting of the *Canada/Greenland Joint Commission on the Conservation and Management of Narwhal and Beluga* to be held in Iqaluit, Nunavut in 2012. At that time, the Commission will review the JWG Final Report and provide management recommendation to both Parties.

2. ADOPTION OF JOINT AGENDA

The Agenda (Appendix 1) was adopted.

3. APPOINTMENT OF RAPPORTEURS

Mario Acquarone was appointed as rapporteur for NAMMCO. Participants from the Canadian delegation shared the task of rapporteuring for JCNB. Other members assisted as required.

4. REVIEW OF AVAILABLE DOCUMENTS

Documents that were available for the meeting are listed in Appendix 2.

5. BELUGA

5.1 Stock structure

Document NAMMCO/SC/19-JCNB/SWG/2012-JWG/O/03 presented an update of the most recent knowledge on stock structure for belugas in Nunavut. The aggregation previously called the Baffin Bay stock, identified as summer aggregation B in the document, is supposed to be the origin of most of the belugas overwintering in the North Water and off West Greenland, where the majority of the removals take place. Although there are not enough data to quantify the influx of belugas from Cumberland Sound to West Greenland, it is unlikely that these animals contribute significantly to the exploited winter aggregation in Greenland (Figure 6, below). Therefore, for management purposes, the JWG considered it sufficient to base the calculation of removals on the winter and spring abundance estimates from Greenland.

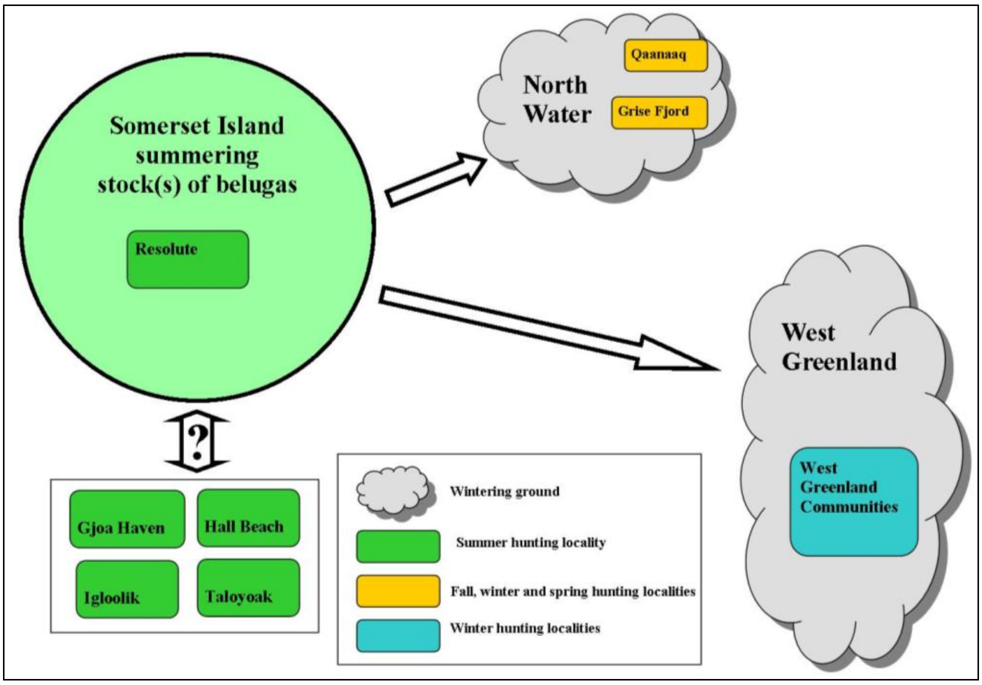

Figure 6. Beluga stock relation hypothesis. Summering stock around Somerset Island is known to travel to North Water and West Greenland based on satellite tracking data. The four Canadian communities (boxes) are thought to derive their harvest from the Somerset Island summering stock.

<u>**Recommendations**</u>
The JWG recommends performing further tagging, in new sites, in Canada to investigate the origin, within the summer aggregations, of the animals present on the winter grounds off Greenland.

Genetics
Analysis using the BEAST analysis software (Drummond and Rambaut 2007, BMC Evolutionary Biology) which includes a spatial and temporal framework incorporating both contemporary and ancient DNA to reconstruct population history, indicated that

beluga showed high levels of genetic diversity and geographic structuring. Data from Greenland, Canada, Svalbard, the North Sea and the Barents Sea indicate that the beluga has lost genetically diverse lineages, present in the North Sea during the Late Pleistocene, which could be attributed to genetic replacement through drift, or population loss.

A recently published paper (Turgeon *et al*. 2012) presents an approach to allocate proportions of beluga harvests in various communities to source summer stocks. There is potential to expand this method to other beluga stocks, specifically in the Canadian High Arctic and West Greenland. However, this method will not be suitable for narwhal as the genetic diversity is too low and we have less understanding of social structure and behaviour in narwhal as compared to beluga.

5.2 Biological parameters

- NAMMCO: Identify calving areas and further document stock identification and stock structure of beluga.

No new information was presented and the JWG did not advance any research proposals.

5.2.1 Age estimation

- NAMMCO: Age estimation workshop on belugas

Recognizing that there are a number of problems with age determination for both beluga and narwhal and that these need to be studied in more detail, at its 2009 meeting the JWG recommended that a steering group (chaired by Lockyer and including Hobbs, Hohn and Stewart) work by e-mail to scope the problems and produce draft terms of reference for one or more workshops. The steering committee was set up as recommended and it organized three workshops: the first one in Tampa (FL, USA), in conjunction with the Biennial Conference of the Society for Marine Mammalogy, to examine the state of the art of general aging techniques for marine mammals and other species; the second in Beaufort (NC, USA) focussed on age estimation of belugas using teeth; the third one in Copenhagen, in conjunction with the meeting of the JWG, focussing on the use of tusks for age determination in narwhals.

Workshop 1 in Tampa, Florida

The **first workshop** was a 2-day event organised immediately before the biennial conference in Tampa. NAMMCO funding enabled participation of 4 invited experts and also supported the organization and logistics associated with the workshop. The breadth and depth of the workshop presentations made it clear that most issues concerning monodontid age estimation are not unique. Many researchers investigating many taxa have considered a diversity of methods and a diversity of tissues to reveal biological records of age. Aside from the biological materials, accuracy and precision of the counts or metric, have been considered, as well as their interpretation.

Relative age can be estimated using biological or chemical changes if the rate of change is known. Attempts to use **genetic telomere length** to estimate age show telomere lengths provide a measure of individual body fitness and condition rather than age, as environment, migration, health and reproduction affect telomere length. The method has potential but is still under investigation. Reviews of **aspartic acid racemisation (AAR) aging techniques** on harp seals, fin whales, harbour porpoises and bowhead whales indicated potential but warned that the presence of cataracts in the eye lens could seriously bias the age estimation and give falsely old ages. In narwhal, tusk GLG (Growth Layer Groups) correlated well with AAR age. The AAR method is potentially relatively accurate, but species-specific racemisation rates are essential for accurate age estimation. Age models using **endogenous fatty acid (FA) ratios** have been successfully derived for killer whales and also humpback whales and preliminary results using a single fatty acid ratio for Cook Inlet belugas correlated with age from tooth GLG for physically immature animals. Future work using two FA ratios in belugas is expected to provide more precision in age. It may be possible to use bone density as a proxy for age in beluga and narwhal flippers. The method would need to be calibrated with reference to beluga teeth GLG and AAR ages in narwhal. The recording of **historic hunting artifacts** recovered in bowhead whales in Alaska has presented an opportunistic and remarkable insight into longevity of this species which exceeds 100 yr. Micro-CT scanning of teeth demonstrated great potential for investigating internal structure of tooth and other hard tissue specimens that are difficult or not possible to section, because there is no destruction of the specimen and 3-D viewing is possible.

Counts of presumed annual markers can provide a more accurate (absolute) estimate of age than other tissues which show gradual changes with age. Hard structures that show **regular episodic growth** are the most commonly used tissues to investigate for records of age that can be estimated from **growth layer groups (GLG).** These can include bones, otoliths, claws, and ear plugs although teeth are most widely used. **Ear plugs in baleen whales** provide a permanent record of total age from GLG therein, as long as there is no damage. Apart from longevity, life history parameters of age at sexual maturity and possibly physical maturity can be identified form the GLG patterns. Such patterns might exist in some teeth, and should be investigated. Ear plug extraction from carcasses of minke whales is facilitated by a new method which increases the possibility of extracting whole and undamaged ear plugs. This method should be tried in bowhead whales for which ear plugs are very soft and fragile.

Teeth GLG are commonly used to age carnivorous mammals, including marine mammals. Techniques for preparing teeth vary. All are directed to obtaining the most complete record of clear laminae and it is important that the quality of tooth section preparations includes correct orientation providing a central section through crown and root when dentine is examined. A review of aging in sirenians indicated there are many internal similarities between dugong tusks and beluga teeth, and also perhaps narwhal tusks. GLG deposition rate in dugongs is annual. The most suitable method of age estimation in belugas is thin untreated sections (ca 150-200 micron). GLG patterns in sperm whales and belugas are very similar.

In belugas, counts of **GLG in dentine** as seen in medial longitudinal sections of teeth are the standard method and completely consistent with methods used in other taxa.

Discussion on the use of **cemental GLG** for estimating age, which was not so usual for cetaceans, might, in the case of belugas where cement is thick, be used to help estimate age when the dentine is worn down at the crown.

The most direct age estimation technique is following recognizable individuals through time. **Long-term photo-ID monitoring** and surveys of the Gulf of St Lawrence belugas resulted in a mass of reliable data on life history, age, reproduction, growth and colour change. Necropsies on recovered known-age and -history animals on death, have provided teeth for verifying age and validating GLG deposition rate. Several other studies confirmed the value of long-term monitoring of known animals for validation of age.

Precision and accuracy are essential in age estimation from GLG counts. The repeatability of the GLG counts and validating age are not the same as precision. **Quality control** is essential for both in the age estimation of aquatic animals, and there must be regular monitoring of an aging programme. The best measures of age precision are coefficient of variation (CV), average percent error (APE) and index of dispersion (D); the least reliable is percent agreement among readers which is usually the most commonly used. A permanent reference collection of aging materials *e.g.* known-age beluga teeth, is the key to effective quality control. In an investigation of precision and bias in aging on belugas with reference to tooth age data, it was concluded that errors in estimation of parameters can arise from errors in aging with both negative and positive bias and varying degrees of variance. In turn these translate to errors in estimation of growth rates. Efforts should be made to quantify bias and precision.

One of the most persistent debates in age estimation of a monodontid, the beluga, has been about the accurate translation of GLG counts into time units (years). The **measurement of radiocarbon, ^{14}C,** in laminated hard structures of animals has been a precise and successful method for validating age in many species, including **belugas where GLG deposition rate is unquestionably annual.** Necropsies on recovered known-age and -history belugas on death, have provided teeth which have verified age and also support an annual GLG deposition rate. Investigation of the age from teeth of known-history captive belugas, together with data on **tetracycline time-marking of teeth** generally also supported an annual deposition rate of GLGs. However, GLG definition was unclear in some specimens, particularly in the juvenile phase.

Information claimed in support of 2 GLG per year deposition rate through examination of growth and reproduction in Cumberland Sound belugas was criticized on a number of counts and did not agree with other evidence presented at the workshop based on GLG calibration using radiocarbon techniques and photo-ID studies of known-age and -history belugas for which teeth were available.

Future research was identified in several areas to fine tune our understanding. One potential technique for estimating total age from worn beluga teeth using **the angle of the boundary layers at the dentin-cement junction relative to the pulp cavity edge** appeared very promising, and should be followed up. Of a broader nature is the potential to understand the ecological correlates to lamina formation. **Laser ablation (ICPMS) for trace elements** in beluga tooth GLG indicated some elements show periodic oscillations. Investigation of **stable isotope ratios** ^{13}C and ^{15}N in beluga teeth were also promising. The point of weaning can be identified from the ^{15}N depletion up to this point. Oscillations of elements in the teeth may be linked to ecology and movements associated with feeding and migration, although these may not be annual, and thus cannot be used as an age proxy presently.

A number of **specific recommendations for monodontids** were made at the workshop, including inter-method comparisons of alternative aging methods free-living known-age animals. The number of samples of known age captive beluga from which teeth can be collected should be augmented and comprehensive sampling of other materials useful for age determination. A focus on the on the immature phase of growth in teeth in beluga with reference to captive animals to determine GLG patterns is desirable. Reference collections (hard parts) should be established, and digital image exchange for calibration and training among labs be considered. Quality control routines should be established in counting. Periodic exchanges among labs and inter-laboratory calibration for all aging techniques are essential. Comparison of tooth preparation methodologies among labs is desirable. A new study to estimate crown wear from angles of boundary layers at the dentin-cement junction relative to the pulp cavity edge in beluga teeth in order to determine the maximum number of GLG that have disappeared should be initiated. Chemical time-marking for age calibration of hard parts and bomb radiocarbon validation of hard parts and eye lenses should be encouraged. A comparison of GLG structure among stocks (free-living and captive) is desirable.

In conclusion, the workshop members agreed on several aging methods which are or may be applicable to monodontids, including potential new methods which, depending on the type of tissue required for analysis, may be applicable both to living and dead animals.

Overall, tooth GLGs are judged to be the best and most precise method. Presently, tooth GLG are only useable in belugas, but the AAR technique is very promising in narwhals. More work needs to be undertaken on embedded tusks of young animals to help tune the AAR rate for narwhals. The AAR method should also be applied to beluga eye lenses to provide a correlation with beluga tooth GLGs. Such a study might provide more reliability on the narwhal AAR work presently done.

A further method that is accurate and can be used for calibration is that of **bomb radiocarbon.** However, the main limitation is that the teeth or hard tissues must come from animals that were born before the fallout commenced, *i.e.* pre-1958.

Currently, **the workshop agreed that an annual deposition rate of tooth GLGs was to be the accepted standard in belugas.**

Finally, it was agreed to publish the proceedings from the workshop in a volume of the NAMMCO Scientific Publication Series, entitled *Age estimation in marine mammals* *with a focus on monodontids*. The approval for the proposed volume had already been taken in NAMMCO, and the likely publication date would be in 2013. The editors would comprise the members of the Steering Committee for the workshop in addition to the technical editor, Mario Acquarone.

Workshop 2 in Beaufort, North Carolina

The second workshop comprised 3 parts. The first part consisted in the reading of 60 images circulated to the workshop participants. The images originated from different stocks and were prepared using various techniques corresponding to the typical practices of the contributing laboratories. All images were considered to be usable for the purpose of estimating age. The participants were asked to estimate the age of each individual represented by the tooth image and provide an assessment of relative quality and readability. These estimates were used as input data for a statistical analysis of the discrepancies and errors in reading. The second part was held at the NOAA Laboratory in Beaufort (NC, USA) December 5-9, 2011. Participants included: 2 readers from DFO Canada, 2 readers from the Wildlife board of Nunavik in northern Quebec, 1 experienced reader and 3 inexperienced from NMFS Alaska Fisheries Science Center, an experienced reader from the North Slope Borough (AK, USA), 1 experienced and 1 inexperienced readers from NAMMCO and an experienced reader at the Beaufort Laboratory. In-kind support was provided by the Beaufort lab in the form of laboratory space and equipment, a laboratory technician and logistical support. General financial support was provided by NAMMCO. Document NAMMCO/SC/19-JCNB/SWG/2012-JWG/20 presents a summary of the main results, conclusions and recommendations from this exercise. The third part will be completed in the first half of 2012 and consists of a second reading exercise by the whole group, based on a standardised set of scanned images, representing a selection of features and levels of reading difficulty. The results will be analysed in a similar way to the pre-workshop reading exercise and will assess the efficacy of the standardisation of the preparation and reading methods agreed upon during the workshop. The results of this last part of the workshop will be presented at the next meeting of the JWG.

A third, shorter, workshop has been held (Wednesday, 15 February 2012) in Copenhagen (Denmark) in conjunction with the JWG meeting and concentrated on the preparation techniques and reading of narwhal tusks.

Discussion

It was noted that a challenge in correct age determination is posed by the wear of the crown of middle to old age animals. Brodie suggested during Workshop 1, to use GLG angles at the midline of the tooth sections to estimate the number of missing GLGs, as these increase with age. Stewart reported that he had tried this and did not appear to be applicable because of the challenges of standardisation and calibration; however the JWG recommended re-examining this possibility.

It was suggested to employ the Aspartic Acid Racemization (AAR) technique to belugas as this would give better estimates for old animals where only minimum age estimates are possible due to crown wear. Additionally it was observed that, as opposed to narwhals, calibration of the AAR technique for belugas would be cheaper and feasible as these animals are more accessible and the biological material needed for the calibration does not have a high commercial value as in the case of narwhal tusks. Additionally it might be possible to obtain eye lenses of belugas from known history animals from the St. Lawrence (ref. Robert Michaud), from wild animals in Greenland and in Alaska (ref. Robert Suydam).

Recommendations

Considering that age distribution data from removals at this meeting were found informative for the assessment the JWG recommended applying the AAR technique to belugas, to included known history/age animals in the analyses in order to calibrate the technique and provide an alternative aging method for beluga.

Furthermore, it was recommended that with respect to beluga age estimation from teeth GLG, there should be standardisation of GLG readings among laboratories with inter-laboratory calibrations, and the setting up of reference collections ideally accessible to all for standardisation of age estimation.

5.2.2 Reproductive rates

- **NAMMCO:** Determine reproductive parameters beluga populations.

The JWG noted that there is no new information on reproductive rates and that standard values are used in the modelling:

- Population growth rates: 4% (from aerial counts in Bristol Bay);
- Mean age at sexual maturity: 9.25 yr (Suydam 2009);
- Inter-birth interval: 3 yr (several sources);
- Mother-calf association: about 2 years (from aerial photographs, Suydam 2009).

Future research

A study is in course in the St Lawrence estuary where biopsies of blubber will be analysed for hormones to detect pregnancy. Additionally a photo-id study which will detect survival rates and estimate fecundity is in progress in Cook Inlet.

5.2.3 Other information

- **NAMMCO:** Impacts of killer whales on behaviour and survival of beluga.

Document NAMMCO/SC/19-JCNB/SWG/2012-JWG/O/20 presented a model-based estimate of killer whale predation on monodontids and other marine mammals in Hudson Bay. Although predation on monodontids seems important in Canada, it is also recognized that the mixed foraging strategy used by killer whales includes seasonal predator specialization. Killer whale predation may not be constrained by a regulatory functional response.

Recommendations

The JWG discussed polar bear predation on belugas and suggested that it might be important as well as that performed by killer whales. It also noted that receding sea ice caused an increase in the presence of belugas in shallow coastal areas. As a consequence the availability of belugas for polar bear predation also increases which warrants further investigation. Since polar bears have also been observed to take belugas from breathing holes in the ice, changes in coverage and thickness of ice may impact predation of this type as well.

5.3 Recent catch statistics

- **NAMMCO:** Determine "struck-and-lost" rates with various hunting methods and circumstances.

Information and statistics including trade statistics on catches of white whales or belugas in West Greenland since 1862 are presented in document NAMMCO/SC/19-JCNB/SWG/2012-JWG/14. The period before 1952 was dominated by large catches south of 66°N that peaked with 1,380 reported kills in 1922. Catch levels in the past five decades are evaluated on the basis of official catch statistics, trade in mattak (whale skin), sampling of jaws and reports from local residents and other observers. Options are given for corrections of catch statistics based upon auxiliary statistics on trade of mattak, catches in previous decades for areas without reporting and on likely levels of loss rates in different hunting operations. The fractions of the reported catches that are caused by ice entrapments of whales are estimated. During 1954-1999 total reported catches ranged from 216 to 1874 and they peaked around 1970. Correcting for underreporting and killed-but-lost whales increases the catch reports by 42% on average for 1954-1998. If the whales killed in ice entrapments are removed then the corrected catch estimate is on average 28% larger than the reported catches. Catches declined during 1979-2011 from about 1,300 in the early 1980s to levels below 300 whales per year after 2004. Reported catches in East Greenland are considered erroneous and should perhaps be added to the narwhal catches.

Regarding the quantification of "struck and lost", the JWG noted that there are no research plans for this subject, but that it should probably fall under the jurisdiction of the Administration authorities, to attempt at quantifying the phenomenon. It also noted that a narwhal "struck and lost" study has been ongoing in Canada since 2007, however there has not been any programme specifically aimed at belugas.

Recommendations

The JWG requests that recent Canadian beluga catches be compiled with historic catch estimates for the different stocks to provide an updated catch history.

The JWG recommends the separation of the North Water catches from those off West Greenland and that the results be used in the assessments. Likewise the JWG recommended providing two separate advices for removals for the two areas.

The JWG recommends gathering information on "struck and lost" for all areas in Canada and Greenland and to evaluate the compliance to the self-reporting system.

The JWG recommends that a deadline of at least 1 month prior to the JWG meeting be established for removals and "struck and lost" data to ensure proper review and assessment analyses. Data on catches and "struck and lost" from the Greenland Home Rule were presented very late for the purpose of this meeting. Because of time constraints there was no time to validate and verify these data. Also, Canadian catch data had not been made available to the Group prior to the meeting, but arrived during the meeting. As data on catches are necessary to the assessment they have to be made available for calculations at least one month ahead of the meeting.

5.4 Abundance

5.4.1 Recent and future estimates

Aerial surveys of belugas were conducted in the North Water in May 2009 and 2010 with the purpose of developing fully corrected abundance estimates (NAMMCO/SC/19-JCNB/SWG/2012-JWG/16). The region of interest covered an area of 54,840 km^2 in 2009 and 51,223 km^2 in 2010. The abundance estimators took into account both the perception bias of the observers and the availability of animals to be observed. The resulting abundance estimates were 2,008 beluga (cv=34%) in 2009 and 2,482 belugas (cv=28%) in 2010. The combined estimate of the two surveys (Table 3) was 2,245 (cv=11%, 95% CI 1,811-2,783). The impact of the analysis decisions and bias factors on these abundance estimates was investigated. A relatively low factor for correction for availability of 0.43 (cv=9%) developed from satellite tracking of belugas tagged in northern Canada, was used. This low correction factor may introduce a negative bias on the abundance estimate and it is suggested that specific correction factors for the Greenland beluga surveys are developed. The surveys might also be negatively biased because the surveys probably did not capture the entire population of belugas that winter in the North Water, since some of the whales would, by the time of the survey, have moved out of the North Water towards Lancaster Sound.

BELUGA	2009	2010	Combined 2009+2010
Abundance	2,008 (34%)	2,482 (28%)	2,245 (11%)
CI	1,050-3,850	1,439-4,282	1,811-2,783

Table 3. Abundance estimates (cv's shown in parenthesis) and corresponding 95% confidence intervals (CI) corrected for perception bias and availability bias.

Discussion

Some concerns were expressed regarding the efficiency of multi-species surveys at providing accurate estimates of abundance for each species. However, the double platform design should account for this bias.

Measures of time-in-view for beluga are available both for Greenland and Cook Inlet beluga. However there are no data on time-at-surface or dive interval for many areas. The lack of these data resulted in an analysis approach that may introduce a small positive bias.

The JWG approved these abundance estimates for assessment purposes.

Future research
The JWG recommends investigating time-at-surface and dive intervals for the areas and the time of the year of future surveys and the range of this population during the survey period using satellite linked location and dive recorders.

5.5 Assessment update

5.5.1 West Greenland

Document NAMMCO/SC/19-JCNB/SWG/2012-JWG/13 used age-structured population dynamic modelling to assess the current status of beluga wintering in West Greenland. The analysis combined the historical catches from 1862, with the winter counts from 1981 to 2006, and five data sets over the age structure of the individuals in the catches from 1984 to 1997. The catch was found to be age-selective, perhaps because hunters prefer larger whales when a choice is available. From 1984 to 1993 there was a clear selection against individuals younger than approximately 10 to 20 years of age. Then, starting in 1994 and continuing through 1997, there was an apparent shift towards even older animals (a shift that may have other causes than hunter selection). A short-term model of exponential growth, that included the age-structured data, estimated a 2012 growth rate of 5% (95% CI:4.1–6.9) or 3.5% (95% CI:2.6–6.1), depending upon whether the average adult survival of the prior was assumed as 0.98 or 0.97. A density-regulated model with no age-structured data, estimated an abundance that declined from a population dynamic equilibrium with 26,000 (95% CI:17,000–48,000) individuals in 1862 to a maximal depletion of 9,300 (95% CI:5, 800–18,000) in 2004. It is expected that the population will increase to a projected abundance of 13,000 (95% CI:6,100–23,000) individuals in 2017 (assuming yearly post-2011 catches of 204). This model estimated a 2012 depletion ratio of 0.44 (95% CI: 0.16–0.88) and a yearly replacement of 510 (95% CI:170–780) individuals.

Discussion
It was discussed that the models may be overly optimistic in the birth rate prior, and perhaps also on the survival prior. It was noted that while the age structures provided information on the survival rates, there were no data on birth rates or neonate survival rates for this population. Some members of the JWG stated that it was important that the priors of population models were constrained within the limits of the known biology observed in other beluga populations, while the author indicated that an artificial bias would be introduced into the analysis unless the prior distributions for birth rates and survival rates were symmetrical around their expected parameter values. The author conducted new analysis runs of the assessment model that addressed this problem which were presented in the extension to JWG/13. These showed, that the estimated current growth rate declined (from a point estimate of 4.2% to 3.2%) when an upper prior limit of 33% on the maximal birth rate was imposed. A uniform prior on the maximal growth rate from 1 to 7% (and no explicit prior on the birth rate) gave essentially the same estimate as the original model with a uniform prior from 0.21 to 0.45 on the maximal growth rate, and no explicit prior on the growth rate. While it was clear that constraining the priors for birth rate did affect the outcome of the analysis, the JWG did not come to a consensus on the preferred modelling approach but discussed analysis alternatives including the use of birth and

survival data from other beluga populations to inform prior distributions for this population.

Recommendations
No new data were available to provide updated advice and the JWG considered that the revised assessment models incorporating age structure data show that the current removals based on the 2009 advice are set at a sustainable level (Table 4). New updated advice is expected at the next meeting based on new abundance estimates resulting from a survey later in 2012 and an updated population structure (Figure 6 above).

Probability of increase	**Total Catch**
95%	180
90%	210
80%	265
70%	310
60%	355
50%	400

Table 4. Advice on current removals of beluga for West Greenland.

The JWG recommends further investigation of the impact of choice of prior distributions on the outcomes of assessment models for future advice so that the JWG can resolve the issue of choice of these critical distributions.

The JWG reiterates the previous advice from 2005 about seasonal closures. The following seasonal closures are recommended:
- Northern: June through August
- Central: June through October
- Southern: May through October.
- For the area south of 65°N, it is recommended that no harvesting of beluga be allowed at any time.

The function of these closures is to protect the few animals that may remain from earlier summer aggregations in Greenland, and to allow for the possibility of reestablishment of the aggregations.

No specific advice was given on the North Water, presupposing that the removals remain at a low level relative to the population size derived from the 2009-2010 surveys in the North Water and around Somerset Island in 1996.

5.5.2 Other stocks
No new information.

5.6 Other information (see items 7-10 below)

6 NARWHALS

6.1 Stock structure

6.1.1 Genetic information

Information on narwhal genetics including ancient mtDNA and recent findings on nuclear DNA was presented to the JWG.

The assumed population structure in narwhals off West Greenland is inferred from mitochondrial DNA and is based upon the works of Palsbøll *et al.* (1997) and NAMMCO/SC/19-JCNB/SWG/2012-JWG/O/19. The East Greenland population is highly distinct. Within West Greenland fall samples collected in the Uummannaq district appear different from samples collected in the Melville Bay (during the summer) and the Disko Bay (winter/spring samples) areas. These two latter areas appear to be part of the same population, whereas samples from the North Water (Avannaarsua district) appear separate. Genetic divergences were also detected among years in areas with large samples sizes (such as Avannaarsua).

In contrast to other cetaceans, narwhals harbour remarkably low levels of genetic diversity based on mtDNA (Palsbøll *et al.* 1997), which may date back 50,000 years (Garde *et al.* in press). No evidence was found of a bottleneck in the recent history of the species, through BEAST analysis (Drummond and Rambaut 2007, BMC Evolutionary Biology): a spatial and temporal framework incorporating both contemporary and ancient DNA to reconstruct population history. Further analysis with more biologically realistic methods (Approximate Bayesian Computation - ABC analysis, Cornuet *et al*. 2008 Bioinformatics) is pending.

Postma presented on behalf of Petersen a work on the population structure of narwhal based on genetics (NAMMCO/SC/19-JCNB/SWG/2012-JWG/O/04). To identify stock structure, narwhals from the Canada-Greenland range were genetically profiled using 12 microsatellite markers in the nuclear DNA. Bayesian analysis to determine the number of genetic clusters without sampling location data was unable to resolve population structure at any level. This was in spite of significant genetic differentiation among the Baffin Bay, Northern Hudson Bay, and East Greenland populations (F_{ST} values between 0.011 and 0.028). These results support the population divisions previously established by mitochondrial sequences, contaminant analysis, and satellite telemetry. Within Baffin Bay, partial support was found for the existing stock designations using multivariate analysis to differentiate groups. The analysis suggests that narwhals from Jones Sound and the Somerset Island summering stock are differentiated, although the Somerset Island finding may be influenced by low sample numbers. Increased sampling of most stocks is suggested in order to increase the understanding of how stocks are related and at what rate migration among stocks may occur.

Discussion (Comments on genetic studies by Palsbøll and Olsen)

Bottlenecks probably happened throughout the history and the population size has probably been low. The problem of the current analytical methods is that they cannot handle this kind of model. The number of breeding females influences the effects of the population size when looking at the low mtDNA diversity.

Novel mutations accumulate slowly and hence the low genetic diversity through 50,000 years may be due to a bottleneck preceding the oldest samples analysed by Garde *et al.*(in press). The possible alternate explanation, of repeated population bottlenecks during the last 50,000 years could result in the observed wide geographical of the same mtDNA haplotypes if there was/is gene flow among areas. It was also suggested that the wide geographical distribution of a few closely related mtDNA haplotypes could be due to selection for a specific maternal lineage. The genetic effect of such a selective sweep is in essence the same as a severe demographic bottleneck. In both cases the current (during the last 50,000 years) matrilines descend from a small ancestral female population (genetically and/or demographically).

The low genetic divergence among geographic areas does not necessarily imply high rates of gene flow/migration but could be due to historically high migration rates and/or common ancestry (*i.e.* current populations descend from the same ancestral population). If more contemporary estimates of gene flow/migration are required then another genetic approach will be needed, such as kinship-based analyses (Palsbøll 1999, Waples and Yokota 2007, Peery *et al.* 2008, Okland *et al.* 2010, Palsbøll *et al.* 2010).

Use of genetic data

Stock structure

In order to use genetic data for stock delineation a quantitative definition of a stock is required (Waples and Gaggiotti 2006, Palsbøll *et al.* 2007); in particular, at which migration rate(s) areas are to be viewed as a different/same stock. Once such parameters are defined, then population genetic simulations can be undertaken to assess the amount of samples and genetic data that need to be collected to infer stock structure at the desired levels of migration (Hoban *et al.* 2012).

The potential for matrilineal herd/pod structure should be assessed in order to avoid (or estimate the degree of) bias in the estimation of stock structure (Palsbøll *et al.* 2002).

Assignment of non-summer area catches to summer areas

One desirable use of genetic (and other biomarkers) data is to assign harvested individuals to summer areas (Paetkau *et al.* 1995; Pritchard *et al.* 2000). The current amount of data (12 microsatellite loci) is insufficient to conduct such individual assignments, even at the highest levels of population structure (eastern Canadian Arctic, Baffin Bay and East Greenland). With the new emerging genotyping technologies it is feasible to type thousands of single nucleotide polymorphisms (SNPs) in each individual sample, which may provide sufficient statistical power to assign harvested individuals to summer areas. Current estimates of genetic divergence may be utilized as a basis to simulate such large data sets with the observed degree of divergence and thereby assess if indeed such large SNP data sets are likely to yield the desired level of rigour in individual assignments of harvested individuals (Hoban *et al.* 2012).

Individual multi-locus genotypes may also be combined with other biomarker data, such as fatty acid data, isotope and pollutant data, to augment individual assignments. The time scale of the different classes of biomarkers need be assessed in order to ensure that all data used in such a combined assignment reflect summer area origin.

Recommendations (by Palsbøll and Olsen)

- Combining a suite of different markers (Stable Isotopes, Fatty Acids, contaminants, and genetics) to see if this leads to a stronger method for assigning summer aggregations to harvested wintering stocks to identify the most effective markers in relation to the desired signal.
- Use the existing genetics, microsatellite data in simulation runs to test if it is possible to discriminate between the summering stocks and if yes how many markers would be necessary. If successful then biopsy sampling to develop genetic profiles of the stocks.
- Evaluate pod structure to highlight kinship within the pod, the social structure of the pods, using relatedness analysis as these factors may bias population genetics inferences of stock structure if unaccounted for.

6.1.2 Satellite tracking

West Greenland-Canada

Watt presented NAMMCO/SC/19-JCNB/SWG/2012-JWG/21 on satellite tracking of narwhals from Admiralty Inlet (2009) and Eclipse Sound (2010-2011). Narwhals are annually hunted in Greenland and Canada and are an important component of Inuit diet. Narwhal populations are divided into stocks based on their summer distribution in order to set hunting quotas for sustainable management. Satellite tracking of narwhals has been particularly useful for defining narwhal stocks. From this data, researchers have defined at least nine independent narwhal summering aggregations and three shared overwintering grounds. Although this data has been invaluable, only a small number of narwhals from some aggregations and none from others have been satellite tracked. This study tagged and tracked 19 narwhals in 2009-2011 from the Admiralty Inlet and Eclipse Sound narwhal stocks, in order to gain a better understanding of narwhal movements. Tracks revealed a similar timing of migration (in late autumn/early winter) to the Davis Strait and a similar home range as previously defined. Summer range of narwhals from Eclipse Sound was larger and more variable than previously identified, with many narwhals travelling into Admiralty Inlet. One whale from Admiralty Inlet spent winter in northern Foxe Basin rather than the Davis Strait, as is typical for narwhals from this stock. Overall, narwhal may have a more diverse summer range than previously identified; however, the sample size is small and continued monitoring of narwhal movements is required before making any definitive conclusions on these narwhal stocks.

Discussion

The one tagged animal which swam westward and went on to enter Foxe Basin indicates a connection between the regions but not the stocks in Hudson Bay and

Lancaster Sound since tracking studies have shown the stocks are geographically separated during the autumn-winter period. Thus there is no evidence of linkages of removals of the animals from these stocks. None of the other whales showed any indication of going to other wintering grounds than the known areas in Davis Strait and the fall migration visits more of the fjords of Baffin Island. It was noted that the Eclipse Sound tagging programme is ongoing.

East Greenland

In NAMMCO/SC/19-JCNB/SWG/2012-JWG/18 fourteen narwhals were captured in set nets and tagged with mk10A backpack satellite transmitters at Hjørnedal in the Scoresby Sound fjord in East Greenland. Live captures and instrumentations followed methods used in similar studies in Canada and West Greenland. The tags were programmed to transmit every other day in order to extend battery life. Daily average positions were calculated from all good quality positions (NQ>0). If no good quality positions were available low quality positions were used. Distance travelled per hour was estimated based on the daily average positions and the 48hrs elapsed between positions. The narwhals used the entire fjord complex during the open water season and they visited most of the side-fjords during that period. Several of the whales circumnavigated Milne Island during the period they were inside Scoresby Sound. The whales apparently preferred the deeper parts of the fjord and when moving out of the fjord system they used the southern part where water depths range between 500 and 1,000 m. All the whales left the fjord in the first week of November (2010) or the last weeks of October (2011) and they went straight to the wintering ground south of 69°N off the Blosseville Coast. All narwhals wintered in the same general area on the Greenland shelf along the slope that over short distance increases from 500 to 1,500 m. Within Scoresby Sound the maximum depths of dives during 24 hr (for every other day) was usually less than 900 m and often less than 500 m. After the wintering area was reached and usually after December when sea ice forced the whales further offshore, the maximum depth of dives increased to 1,500 m. One whale provided at-surface time data useful for correcting visual aerial sighting surveys and it spent 34.96% (cv=0.06) at depths <2 m during August and during the time period from 12:00 to 24:00 GMT (corresponding to 10:00-22:00 local time).

Discussion

Animals in East Greenland seem to have a yearly migratory schedule and generally move slowly (1 km/hr). The whales in the Scoresby Sound area seem to belong to a stock separate from other narwhal aggregations in East Greenland. These apparent distinctions indicate that the different narwhal aggregations along the East coast of Greenland should be divided into separate management units (stocks).

Recommendation

The JWG recommends that the East Greenland narwhals for management purposes be separated into different stocks according to satellite tracking data and that the corresponding discrete abundance estimates in the areas where narwhals are hunted be obtained for stock assessment purposes.

6.1.3 Other information

Watt presented NAMMCO/SC/19-JCNB/SWG/2012-JWG/08. An understanding of narwhal populations for assigning narwhals to specific stocks is essential for providing management advice to ensure hunting quotas for northern communities meet subsistent goals. These stocks are principally defined based on satellite tracking results; however only a small proportion of possible subunits of this large population (approximately 80,000 individuals) have been studied using satellite tracking. Carbon and nitrogen have naturally occurring stable isotopes and the ratio of the heavy to light isotopic forms can provide detailed information regarding the integrated dietary and geographic information of a species. Nitrogen ratios are often used as indicators of the relative trophic position of an organism, while carbon ratios are used to evaluate the source of carbon (*i.e.* benthic versus pelagic or inshore versus offshore). These isotopes are commonly used in dietary reconstruction, but can also be used as spatial markers. If specific summering areas that distinct narwhal stocks use vary in their isotopic signature, or if different narwhal aggregations incorporate different prey species or proportions of these prey in their diet, isotope analysis may be another tool for delineating narwhal stocks. Skin tissues collected by Inuit hunters from narwhals defined as independent stocks in Canada and Greenland waters, were analysed for stable isotopes to determine if these chemical signatures can be used as another tool for assigning narwhals to specific stocks. Stable isotopes varied among most narwhal stocks assessed, suggesting the technique may be useful for stock delineation. Overall, stable isotope analysis is a cost effective technique and in combination with satellite tracking and genetic techniques, may enhance our understanding of narwhal stock structure.

Discussion

It was recognized that the method is promising and in the future might even allow discrimination of the origin of individuals taken around the same mixing ground; however, there could be bias in assigning animals to a group when samples were collected in different seasons (ice edge migration versus summer aggregations). The discriminating factors used in this study are standard factors and can be improved by performing a feeding experiment, which is not likely to happen. Discrimination among stocks is likely dependent on different prey choice and geographical origin of the narwhals. The time lag for the appearance of a signal could have a strong influence on the results of the analysis when samples are collected over different seasons. Studies on other animal models indicate a turnover rate the order of magnitude of a year, which could have strong implications for the interpretation of the analyses reported in this study.

It was mentioned that care should be taken when considering stable isotopes for stock delineation as the location of origin of the food ingested is what translates into the isotopic signature. If the origin of the food ingested is varied (migratory food species or feeding along a migration) the discrimination into stock units would be impaired. Similarly, given the same caveats, trace elements could help in discrimination.

Recommendations

It was suggested that the investigator consider restricting the time period for the choice of West Greenland samples and possibly to include in the study samples from Inglefield Bredning to improve the reliability of the approach. This approach could be a useful addition to a multi-dimension discrimination analysis for stock identity.

6.1.4 Management units

- NAMMCO: Identify calving areas and further document stock identification and stock structure of narwhal.

A model of the metapopulation structure of narwhals in Baffin Bay, Hudson Bay, and adjacent waters is proposed based on data collected from two decades of satellite telemetry studies of narwhals tracked from six coastal aggregations in the eastern Canadian high Arctic, Hudson Bay and West Greenland (NAMMCO/SC/19-JCNB/SWG/2012-JWG/17). In addition, information on seasonal catches of narwhals in 11 Inuit communities provides information on the occurrence of narwhals in these areas. The tracking data suggest that disjunct summer aggregations of narwhals to some extent are demographically-independent sub-populations with minimal or no exchange with other summering aggregations and that these, for management purposes, should be considered separate stocks. Tracking results of tagged whales that return to the summering grounds the following year suggest inter-annual site fidelity in narwhals. It is proposed that the narwhals in Canada constitute five separate stocks with some limited exchange between three of the stocks. Coastal summer aggregations in Greenland constitute two stocks in addition to two fall-winter aggregations supplied by narwhals from several summering areas. Several of the narwhal stocks will be mixing on the wintering areas in Baffin Bay-Davis Strait but the metapopulation structure is maintained through a combination of life history traits and migratory routes, where mating most likely occurs after the initiation of the return migration towards summering areas. A metapopulation structure in Baffin Bay narwhals will be impacted differentially by Inuit hunting, depending on the migratory schedule of narwhals and dates at which whales occur in different seasonal hunting areas. It is therefore important to identify which narwhal stocks contribute to which subsistence hunts in order to assess the sustainability of those hunts. This paper proposes a preliminary stock model for this purpose.

Discussion

The JWG agree to continue using the metapopulation model (now referred to as the stock aggregation model) as a useful approach for identifying stocks/management units and aggregations of narwhals in this area as well as indicating current knowledge of seasonal movements related to the areas where they are hunted (Figure 7). The JWG acknowledged that the model should be refined by additional research and that it was not possible to quantify the exchange rates at this meeting.

Recommendations

There is still uncertainty on the location of the summering grounds for the animals belonging to the stock harvested in the Uummannaq area. The JWG recommends a continuation of the tagging studies to elucidate this question. Similarly it is unclear where the animals summering in East Baffin, Jones and Smith Sound spend the winter and are possibly hunted. The JWG encourages effort to increase information on this question but recognizes that this is logistically challenging.

Future research efforts

- Tagging in Uummannaq, Jones Sound, Admiralty Inlet, Eclipse Sound, Somerset Island and East Baffin.
- Develop alternative tagging options for Canada: less costly and less intrusive.
- Investigate the possibility of using alternative markers such as ectoparasites and fouling phytoplankton on narwhal tusks.
- Investigate the use of photo-id, (*e.g.* from an aerial or vessel platform).

The JWG recommends that an acceptable glossary of definitions be developed to assist in maintaining acceptable discussions. For example, there is a need to define differences between management stocks and summer/winter aggregations.

Meeting on procedures for the allocation of the harvest to the summering stock

Before the next JWG meeting and tentatively in early March 2013, it is recommended to convene a group of up to 6 participants (Heide-Jørgensen, Ferguson, Hobbs, Witting, Richard, successor to Richard, Hansen, Lee, Laidre, and possibly others). The suggested location is Copenhagen.

The Terms of Reference of this group are:

- Review information on distribution, movements and harvest locations;
- Develop an allocation model that will provide a mechanism for assigning harvested animals to all summer stocks based on existing data;
- Specify and quantify exchange rates between aggregations and stocks.
- Identify and quantify uncertainty in the allocation model and determine implications for management.
- Recommend future work to resolve uncertainties within the model structure.

This group would report back to the JWG at its next meeting.

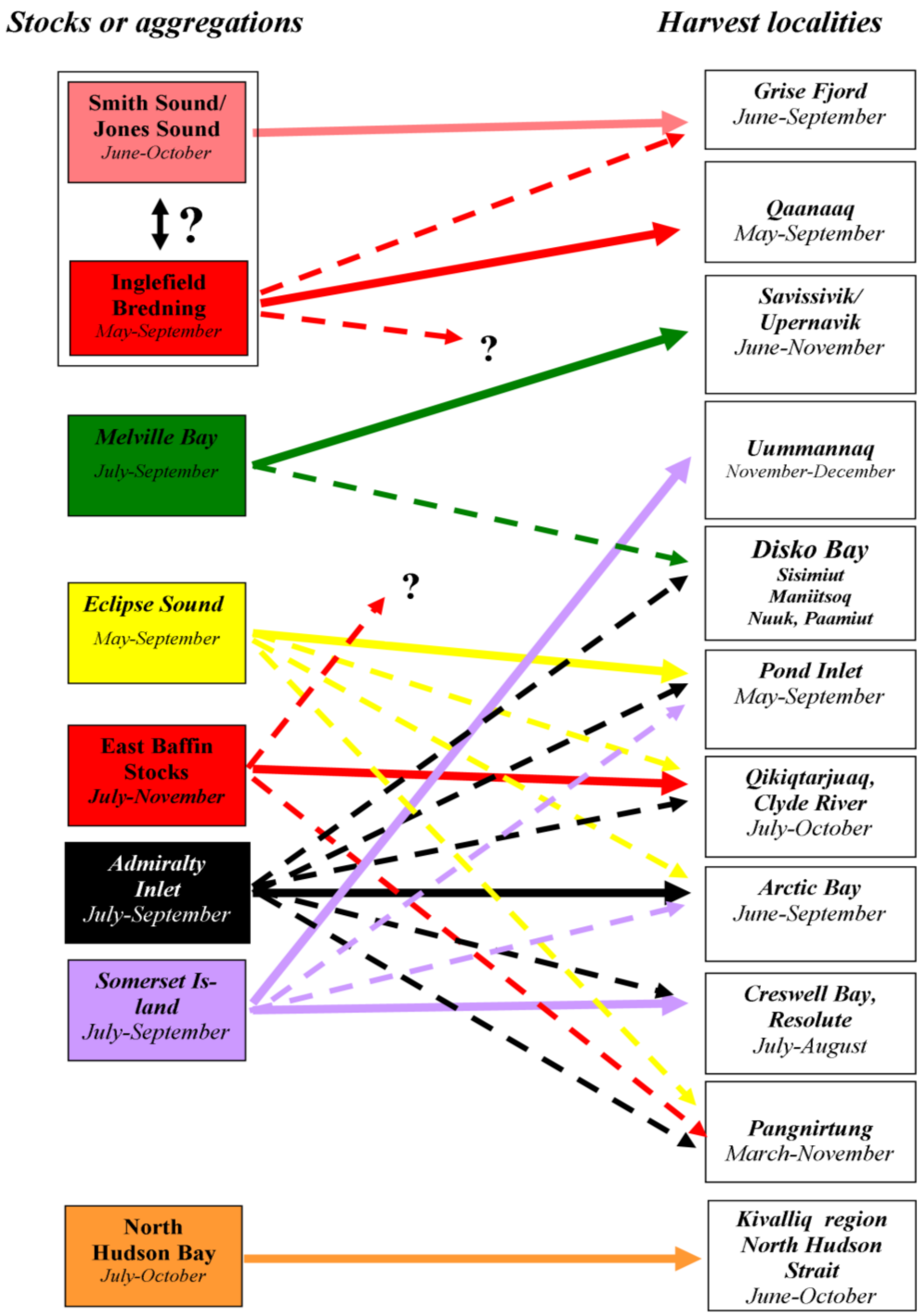

Figure 7. Diagram relating summer stocks and aggregations to hunt locations. Solid lines have been verified by tagging studies, dashed lines are based on geography and inference from traditional ecological knowledge and other sources.

6.2 Biological parameters

6.2.1 Age estimation

A new species-specific racemization rate for narwhals has been estimated by regressing aspartic acid D/L ratios in eye lens nuclei against growth layer groups (GLG) in tusks (n = 9). The racemization rate was estimated based on a bootstrap study, taking into account the uncertainty in the age estimation (r^2 was in all cases between 0.88 and 0.98). The $2k_{Asp}$ value from the bootstrap study was found to be 0.00229 +/- 0.000089 SE, which corresponds to a racemization rate of 0.00114^{-yr} +/- 0.000044 SE. The intercept of 0.0580 +/- 0.00185 SE corresponds to twice the $(D/L)_0$ value, which is then 0.0290 +/- 0.00093 SE. The previous estimated racemization rate for narwhals, based on data from narwhals and fin whales, was 0.001045^{-yr} +/- 0.000069 SE (Garde *et al.* 2007).

		Female		Male	
		EGl	WGl	EGl	WGl
Growth	Asymp. body length	405	399	462	456
	Age at asymp. body length	22	25	42	28
	Asymp. tusk length	-	-	162	186
	Age at asymp. tusk length	-	-	50	53
Reproduction	Est. age at sexual maturity	8	8	17	17
	Length at sexual maturity	~ 340	~ 340	≥ 400	≥ 400
	Est. age at first parturition	9	9	-	-
	Oldest pregnant female	39.5	67.9	-	-
	Pregnancy rate	0.42	0.38	-	-
Longevity*	Age	83.7	101	79.7	94.9

Table 5. Life history parameters for narwhals (Garde *et al.* unpublished data). Ages were estimated using the aspartic acid racemization (AAR) technique. Age at sexual maturity and first parturition as well as the pregnancy rate were estimated based on analysis of length, weight and number of corpora scars of ovaries and length and weight of testes as well as from data on fetuses. *Longevity is interpreted as the oldest individuals in the sample. Abbreviations: East Greenland (EGl); West Greenland (WGl).

The above values were used in a large-scale study of age estimation of narwhals using the aspartic acid racemization technique. The obtained ages were used to construct age distribution and estimate life history parameters. Eyes and reproductive organs were collected from 280 narwhals in East and West Greenland in 1993, 2004, and 2007 – 2010. Measures of body length, fluke width, tusk length and lengths of fetuses were obtained. Asymptotic body length was estimated to be 405 cm for females and 462 cm for males from East Greenland, and 399 cm for females and 456 cm for males from West Greenland. Age at sexual maturity, based on data from the reproductive organs, was estimated to be 8 years for females and 17 years for males. Age at first parturition was estimated to 9 years of age. Previously, Garde *et al.* (2007) estimated age at sexual maturity for females and males to be 6-7 yrs and 9 yrs of age, respectively based on growth curves and Laws (1956) who found that cetaceans attain sexual maturity at about 85% of their physical maturity. Pregnancy rates estimated in this study for East and West Greenland were 0.42 and 0.38, respectively. Oldest pregnant female was 68 yrs of age. Maximum lifespan expectancy for narwhals was found to be ~100 years of age (Table 5 above).

Discussion

This study has provided a calibration of AAR to tooth GLG providing a consistent means to age narwhal landed in the hunt. It also demonstrated a strong similarity between the growth characteristics of the narwhal on the east and west coasts of Greenland, with the difference between the longevity explainable by greater hunting pressure on the west Greenland stocks.

Recommendations

The JWG encouraged the continuation of this work, to increase the sample size of paired tusk/eye specimens (from the same animal) to improve the calibration of AAR and test for stock differences. In particular it would be important to obtain samples with tusks of different sizes and especially large tusks, making sure that tusks are whole from tip to base, to investigate a method to estimate the missing GLGs from the taper of the broken tusk and also collect right-side embedded tusks where possible to develop a method for males with a broken tusk or that can be applied to female narwhal.

Bayesian assessment

Document NAMMCO/SC/19-JCNB/SWG/2012-JWG/09 analyses the possibility of estimating the exponential growth rate of a population from a Bayesian assessment that is based on a single abundance estimate and a single sample of the age structure. Applying a whale-like life-history, it is shown that the Bayesian assessment provides unbiased estimates of the exponential growth rate, when given a uniform survival prior that is symmetrical around the true survival rate. If the survival prior is biased low, the estimated growth rate will be negatively biased, and it will be positively biased if the survival prior is biased towards values that are larger than the true survival rate. It is also shown that unbiased estimates are obtained independently of a bias in a uniform growth rate prior, and independently of a bias in a uniform prior on first year survival. This illustrates that Bayesian assessments based on age-structured data can be applied for precautionary management advice when the average value of a uniform prior on adult survival is smaller than or equal to the true survival rate.

Comments

While presented under the narwhal section this result applies to any long lived multiparous population with similar data limitations. The author noted that results are sensitive to the prior distribution of survival rate, consequently an estimate of survival rates derived from other stocks or species is necessary to inform the prior. A review of published and unpublished survival rate estimates in seven species of baleen whales and killer whale found an average point estimate 0.981 (1x0.96; 1x0.97; 2x0.98; 4x0.99).

Recommendation
Investigate the impact of various priors on management advice and develop a conservative method for selecting the priors when little information is available.

6.2.2 Reproductive rates
See Table 5 above.

Recommendation
The JWG noting the similarity between the east and west Greenland population age parameters suggests combining reproductive information from Greenland and Canada to estimate species wide reproductive parameters of narwhals, especially from samples around the age of sexual maturity and then test for stock differences.

6.2.3 Population Dynamics
Harding showed how population life history matrixes (*i.e.* Leslie matrixes) can be used to estimate population age or class structure and how it could help establishing if an event is age-independent or not. For example, the Phocine Distemper Virus infecting the harbour seals in Northern Europe in 1988 and 2002 was age dependent, infecting juvenile individuals at a lower than expected ratio. She also presented a model that predicts the future of the ringed seal in the Baltic based on estimated climate changes with declines in reproductive habitat due to temperature increases.

By using an individually tested stochastic model with life history traits based on age structure and fertility estimates from Garde's work and historical catch data from East and West Greenland it is possible to estimate the minimum viable starting population in both areas in 1969 that would be required to endure the historical catch and still match current estimates of population size. Since ice entrapment mortality is not yet included in the model, these starting populations (~2,600 in EGL, ~17,500 in WGL) are probably rather significantly underestimated, but this could be remedied with refinement of the model in the near future.

Discussion
The input data to the model have been taken from Garde 2012 (submitted). Natural mortality such as ice entrapments has yet to be added as an external factor, for example as a random mortality or as a part of the natural mortality. Alternatively it could be included as an increase in variance of the natural mortality or a density dependent factor.

The JWG appreciated the model presented and its potential for the understanding the relation between the original population sizes and future projections. On the other hand it noted the sensitivity of such a model to the input data.

6.2.4 Diving behaviour
Some information is presented in Westdal (NAMMCO/SC/19-JCNB/SWG/2012-JWG/07) on Availability bias in population survey of Northern Hudson Bay narwhal.

Population estimates are important for development of management plans of harvested species and thereby ultimately important for species sustainability. Aerial surveys are one method used in preparing population estimates. For marine mammals, aerial population surveys require that animal biology is understood in order to account for availability bias. Availability bias in this case derives from animals that are invisible to the survey due to diving behavior. In order to understand diving behavior of the Northern Hudson Bay narwhal, nine whales were tagged with satellite tracking devices in the Repulse Bay area in August of 2006 (n=5) and 2007 (n=4). Seventeen interviews with hunters and elders in the community of Repulse Bay were also conducted in order to gather local knowledge of the Northern Hudson Bay narwhal as it relates to this topic. Of specific interest was time at depth of 0 to 2 meters of water, the depth at which Richard *et al*. (1994) discovered that whales could be distinguished at the species level during an aerial survey. The proportion of time spent in 0 to 2 meters of water was then used to correct the population estimate from aerial survey. This research found that narwhals spent approximately 32% of their time at the surface where they would be available to be seen by an aerial survey. When this correction factor was applied to the 2000 photographic aerial survey estimate of 1778 (95% CI 1688-2015), an estimate of 5627 narwhals with 95% confidence limits of 3543 to 8935 narwhals and 90% confidence limits of 3817 to 8295 is attained. Data gathered from local hunters and elders suggests that timing of aerial surveys with regards to the narwhal hunt and presence of killer whales in the area can affect surface times as well as push narwhal distribution outside of the survey area.

Recommendations

The JWG noted that dive behaviour has both species characteristics and characteristics dependent on location, season, behaviour and available prey and encouraged continued collection of these data with emphasis on dive interval and time-at-surface data in areas to be surveyed at the time of the survey.

<u>6.2.5 Other information</u>

No new information at this meeting.

6.3 Catch statistics

<u>6.3.1 Canadian and Greenland catch statistics</u>

Canadian catch statistics were presented in document NAMMCO/SC/19-JCNB/SWG/2012-JWG/23 (Appendix 3). Catch statistics for Canada represent landed animals and do not include “struck and lost”.

Information and statistics including some trade statistics on catches of narwhals in Greenland since 1862 are reviewed in document NAMMCO/SC/19-JCNB/SWG/2012-JWG/15. Detailed statistics split by hunting grounds are missing for most of the years. For the northernmost area, the municipality of Qaanaaq, only sporadic reporting exists. Based on statistics from the most recent three decades a time series is constructed for West Greenland with catches split into hunting grounds and corrected for under-reporting detected from purchases of mattak (low option), for periods without catch records (medium option) and from rates of killed-but-lost whales (high option). This reveals a time series 25 of somewhat realistic catch levels from 1862 through 2011. There has been an overall increase in catches in West

Greenland during the 20th century which is especially pronounced after 1950. During the period with the new hunting reporting system (Piniarneq) a significant decline in overall catches has been observed (p=0.0001). The decline was most pronounced in Uummannaq (p=0.0001) and Disko Bay (p=0.001) and could not be detected in the other areas (Qaanaaq p=0.172, Upernavik p=0.29). Catches in East Greenland seem to have peaked during 1999-2006 but have declined after 2006.

Recommendations
The JWG requests that Greenland data include the sex of the landed animals when available.

6.3.1 Struck and lost

- NAMMCO: Determine "struck and lost" rates with various hunting methods and circumstances.

No new data were presented on the "struck and lost" rates in Canada or Greenland.

Recommendations
The JWG recommends gathering information on "struck and lost" for all areas in Canada and Greenland and to evaluate the compliance to the self-reporting system.

6.3.2 Ice entrapments

In November 2008, an ice entrapment event occurred off the coast of Bylot Island, Nunavut near the community of Pond Inlet (NAMMCO/SC/19-JCNB/SWG/2012-JWG/O/05). Hundreds of narwhals attempted to travel outside of the inlets and fjords in the area before becoming entrapped by thickening ice. As a result, a humane Inuit harvest of animals occurred before the whales drowned. In total, 250 skin and blubber samples were collected from over 600 harvested whales. The entrapment event provided a unique sample because the individuals were likely closely related and many were females trapped with their young, whereas typically samples obtained from Inuit subsistence hunts are biased towards males. A dietary study was initiated to determine if diet differed among age classes and between sexes, and to determine if diet could be utilized to elucidate social structure in narwhals. Skin samples were analysed for stable isotopes of carbon and nitrogen, which provides information on foraging location and trophic level, and dietary fatty acids in blubber were used to identify primary prey items. Non-parametric statistics identified differences in isotopic signatures among age classes of narwhals, but no difference between sexes. Principal component analysis of fatty acids resulting from dietary intake qualitatively assessed the feeding ecology of these narwhals and determined that there were no dietary differences between sexes or among age classes; however, distinct feeding groups were evident and genetic work is underway to determine the relatedness among these groupings. Emaciation appeared to have no significant impact on the fatty acid or isotopic signatures of samples from the entrapment event compared to published results, although more work is required to validate these conclusions.

Discussion
It was surprising to notice how the animals in this entrapment presented some symptoms of emaciation according to a necropsy conducted by a veterinarian. While

the entrapment continued over several weeks prior to the harvest, the JWG could not agree that the entrapment period was long enough for the animals to starve had they been in optimal body conditions.

Freeze up conditions

Document NAMMCO/SC/19-JCNB/SWG/2012-JWG/O/10 shows that the date of the 50% freeze-up occurred later and later in recent years. The authors postulate that if narwhals stay longer in the summering grounds they might be more likely to get caught up when the freeze-up.

Discussion

While the later arrival of the freeze up is well documented the relation to and mechanism of entrapment remains unclear. However speculation by the JWG suggested that a number of factors may be acting, including the novel freeze-up time in the experience of the whales, a change in the sequence of freeze-up so that the narwhals are blocked in by an area that according to prior experience would have remained open, or the general suddenness of a later freeze-up.

Recommendations

Monitor ice entrapments and freeze-up of migration paths to understand the environmental mechanisms leading to entrapments and how they relate to the speed and sequence of freeze-ups.

6.4 Abundance

6.4.1 Recent estimates

An aerial survey of narwhals was conducted in the North Water in May 2009 and 2010 with the purpose of developing a fully corrected abundance estimate (NAMMCO/SC/19-JCNB/SWG/2012-JWG/16). The region of interest covered an area of 54,840 km^2 in 2009 and 51,223 km^2 in 2010. The abundance estimators took into account both the perception bias of the observers (mark-recapture techniques) and the availability of animals to be observed (obtained from satellite-linked time-depth recorders). This is the first fully corrected abundance estimate from the North Water (Table 6) and it demonstrates the importance of this high latitude open water area to narwhals.

NARWHAL	2009	2010	Combined 2009+2010
Abundance	10,677 (0.29)	4,775 (0.36)	7,726 (0.38)
CI	6,120-18,620	2,417-9,430	2,032-8,572

Table 6. Abundance estimates (CVs shown in parenthesis) and corresponding 95% confidence intervals (CI) corrected for perception bias and availability bias

Discussion

There was a discussion on the advantages and disadvantages of combining the estimates for the two years. The opinions diverged and it was recommended to keep all three estimates: each year separately and the two years combined. Also, there was concern that the complete range of this stock was not surveyed so that an unknown portion of the population was missed.

As with beluga, some concerns were expressed regarding the efficiency of multi-species surveys at providing accurate estimates of abundance for each species. However, the double platform design should account for this bias.

Measures of time-in-view, time-at-surface or dive interval are not available for this area. The lack of these data resulted in an analysis approach that may introduce a small positive bias.

The JWG approved these abundance estimates for assessment purposes.

Future research

The JWG recommends investigating time-at-surface and dive intervals for the areas and the time of the year of future surveys and the range of this population during the survey period using satellite linked location and dive recorders.

Comments

The JWG noted that document NAMMCO/SC/19-JCNB/SWG/2012-JWG/O/01 presenting the results from the latest aerial surveys in Admiralty Inlet was submitted as a “for information” document. This document presented a new abundance estimate, and is the report of the survey that provided the results above. This placed the JWG in a difficult position of accepting abundance estimates and providing advice, without actually having had the opportunity to review the survey from which they were derived.

Recommendations

The JWG recognized the challenge and the importance of obtaining reliable information to translate into availability bias corrections. Unfortunately drift in instrument readings could add up with circadian differences in the diving habits and blur the correction factors. Because availability is the largest contributor/scaling factor for the abundance estimates the JWG recommended that this problem be tackled as a priority. In association with the populations being surveyed it is suggested to use time-depth recorders (TDR) to provide better dive profile data and obtain data on both time at depth and time at surface.

The JWG acknowledges the need for national governments to complete internal reviews of research necessary to management advice, however consistent and independent review and advice from the JWG requires that the JWG be provided the opportunity to review the key research results as well. Abundance estimates and their surveys and analysis should be provided as working papers, not as papers for information.

The JWG recommended ensuring that at least one of the authors of key documents such as these is present at the meetings.

Two aerial surveys were completed in August 2010 to assess the summering stock of narwhals in Admiralty Inlet. The surveys used an adaptive sampling plan which combined visual line-transect sampling of the entire inlet and aerial photography of aggregations of more than 50 animals. The two surveys yielded estimates of 24,398 (CV=0.25) and 13,729 (CV=0.40) narwhals. The differences between the two survey estimates are likely due to sampling variation related to survey coverage, sea state and animal movement. Combining the estimates from the two surveys using an effort weighted mean yielded a final Admiralty Inlet narwhal estimate of 18,049 (CV=0.23, 95% C.I.=11,613-28,053). This estimate was used to calculate a new recommended Total Allowable Landed Catch (TALC) for the Admiralty Inlet narwhal stock of 233 animals.

Discussion

This document included a new population estimate, significantly higher than the previous one, and a corresponding increase of the catch advice (the original TALC from 2008 based on the 2005 survey estimate was 28).

6.4.2 Estimates by management units

The surveys at the North Water (NAMMCO/SC/19-JCNB/SWG/2012-JWG/O/07 and NAMMCO/SC/19-JCNB/SWG/2012-JWG/O/11) provided abundance estimates of the Inglefield Bredning management unit (see above) and these were approved for assessment purposes.

Methods for estimating other management units will be addressed by the allocation working group.

6.4.3 Future survey plans

An aerial survey off West Greenland (Figure 8 below) will take place from 26 March to 15 April 2012 and will cover 242,000 km^2 with almost 12,000 kilometres planned effort. Aerial surveys have been conducted in the Disko Bay area since 1981 but this survey will be the first attempt to survey the Melville Bay in winter and spring as well as the offshore areas in Baffin Bay. The survey design will be a systematic sampling with east-west going transects crossing density gradients from glaciers to the fast ice across the open water area.

The platform will be a twin otter aeroplane with bubble windows with a double platform design with no visual or audio contact between observers. Continuous photographs of the trackline will serve as quantification of sea ice and as control for observations on or close to the trackline.

An aerial survey in Melville Bay (Figure 9 below) will take place on 30 July-6 August, 27 August-4 September, 20-28 September before, during and after seismic activities in the Kanumas West area (blue area in Figure 8) using the same setup as described above. The survey design will be a systematic sampling with transects crossing density gradients from glaciers to the fast ice across the open water area.

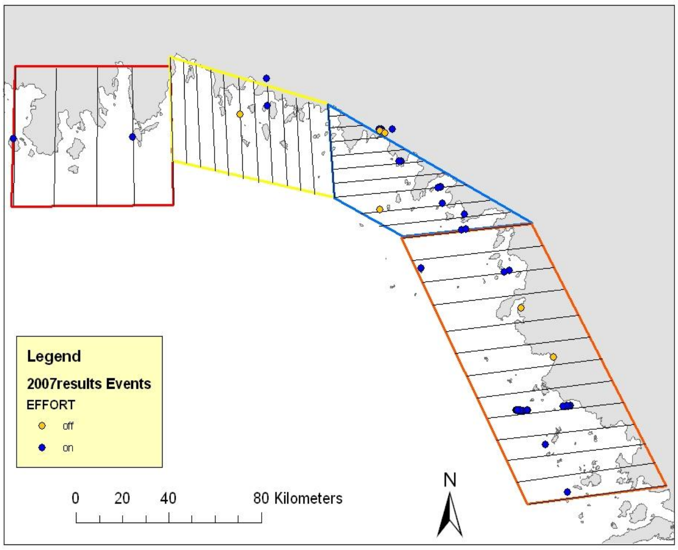

Figure 8. Planned aerial survey off West Greenland 26 March-15 April 2012.

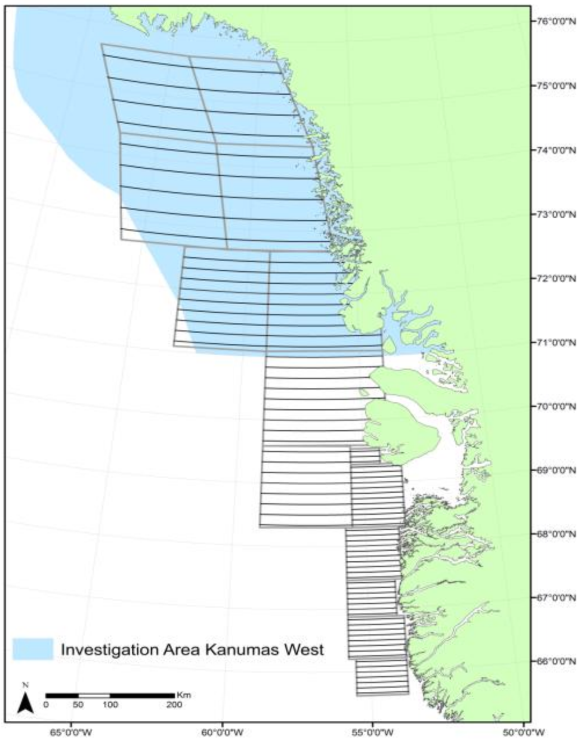

Figure 9. Planned aerial survey in Melville Bay 30 July-6 August 2012.

Ferguson reported on the requests of surveys to be carried out within the next 5 years: Cumberland Sound for beluga (most probably in 2012), and Jones Sound, Somerset Island, East Baffin Island for narwhal.

6.4.5 Recent changes in distribution in Canada

The Canadian delegation reported evidence of range extension towards the west and were hunted in 2011 in areas where hunting of narwhals is unusual (Cambridge Bay).

6.5 Assessment

6.5.1 Update of West Greenland assessment

Assessment West Greenland

Document NAMMCO/SC/19-JCNB/SWG/2012-JWG/10 used recent abundance estimates, historical catches starting from 1862, age-structure data from 2004 to 2010, and an age- and sex-structured population model with exponential or density regulated growth to perform Bayesian assessments of narwhals in West Greenland. The assessment included all areas in West Greenland except Uummannaq, and it was estimated that the catch selected against the take of animals younger than approximately 20 to 30 years of age (hunters likely prefer larger animals when possible). All applied models estimated a rather stable population which may have shown a small historical decline that, with the recent decline in the catch, proceeds into a stable or slightly increasing trend. The estimate of the current growth rate was rather stable, ranging from 1.4% (95% CI: 0.0–3.0) to 1.9% (95% CI: 0.3–3.2) across the seven different models. These were based on an average adult survival of 0.98 or 0.97, and included models that applied and did not apply the age structured data, as well as the winter surveys from the Disko Bay area.

Discussion

It was discussed that environmental variability was not included in the model, and that it did not assume a negative, or positive, effect of climate change on narwhal populations. The inclusion of such parameters could provide a worst case scenario and more conservative advice. However, it is unclear how a realistic level of environmental variability in life history parameters can be estimated from the available data, and the effect of climate change on narwhal populations are also largely unknown. The current approach, with feed-back from continuous population monitoring in assessments that look only 5 years ahead, is a pragmatic approach that, at least to some degree, incorporate major stochastic events and climate induced trends implicitly by re-estimating the dynamics on a regular basis. It was also discussed that some of the prior distributions might be overly optimistic, but no better alternatives were provided.

Assessment Uummannaq

Document NAMMCO/SC/19-JCNB/SWG/2012-JWG/11 used an age-structure from the 1993 catch of narwhals in Uummannaq to estimate the exponential growth rate of the stock that supplies this hunt. Contrary to the catch in other areas, there was no evidence that this catch selected against the take of smaller/younger individuals. The exponential growth rate in the absence of harvest was estimated to 1.3% (95% CI: −0.4–3.1%), if we assume an average adult survival of 0.98 in the prior, and the estimate declined to 0.4% (95% CI: −2.2–3.0%) with an assumed survival of 0.97. These estimates are comparable to the growth rate estimate for the other areas in West Greenland, suggesting that the growth of these stocks may be correlated, at least to some extent. The estimate was independent of assumptions on the abundance of the stock.

General discussion

The assessment models of NAMMCO/SC/19-JCNB/SWG/2012-JWG/10 and /2012-JWG/11 were restructured to a summer aggregation model for West Greenland. This implied separate models of the two summer aggregations (Inglefield Bredning and Melville Bay), as well as models of the fall hunt in Uummannaq and the winter hunt in Disko Bay.

The model for Inglefield Bredning was an isolated summer aggregation model assuming that these animals are not hunted elsewhere. It applied the summer estimates from the area, the spring count from 2009, and the 2007 age structure for West Greenland as a whole. It estimated a rather stable Inglefield Bredning aggregation since the 1960s, with an average abundance around 10,000 individuals, and a current exponential growth rate of about 1.2% in the absence of removals.

The JWG decided to model Melville Bay as a distinct summer aggregation that is distributed south along the west coast of Greenland during other seasons. The model assumed that of all the catches from Melville Bay, 14% of the catches were from fall and winter in Disko Bay (DB), and 12% of the catches were from winter in Uummannaq (Uu) and together are considered to be taken from the Melville Bay aggregation. These proportions were calculated on the assumption that Admiralty Inlet, Eclipse Sound and Melville Bay supply the hunt in Disko Bay in proportion to the stock sizes. Similarly Uummannaq is presumed to be supplied by whales from Somerset Island and Melville bay. Besides the catch history, the model was based on the 2007 abundance estimate (6,200; cv:0.85), and the 2007 age structure for West Greenland. Based on the information in the age structure, the narwhal abundance in Melville Bay was estimated to have increased slightly since the 1960s, with an exponential growth rate of one to two percent per year in the absence of removals.

The model for Uummannaq relates to the hunt on stock components that arrive in the area during fall and likely over winter in the Baffin Bay outside Uummannaq. This component was counted to 6,070 (cv: 0.37) individuals in 2006, and besides from this estimate the model includes also the age structure from animals caught in the area in 1993, and the Uummannaq catch history (of which 14% are allocated to the Melville Bay stock, with the rest assumed to be taken from Canadian stocks, primarily Somerset Island). This model estimates a rather stable population until the 1990s, where there were some decline due to very high catches, and a stabilisation into a stable or increasing population thereafter. The growth rate with no catches was estimated to approximately 2% per year.

The model for the Disko Bay area relates to the hunt on the stock components that over winter in the area. The model is based on the series of winter surveys in the area, the Disko Bay catch history, and the 2007 age structure for West Greenland as a whole. It is assumed that 14% of the Disko Bay catches are taken from the Melville Bay stock, and that the rest are taken from Canadian stocks, primarily from Eclipse Sound and Admiralty Inlet. Unlike the other areas, no absolute abundance estimates were available for this area, and it was not possible to construct a successful model.

By allocating catches from the fall and wintering grounds of Uummannaq and Disko Bay to the Melville Bay stock, it should be possible to use this model framework for advice on sustainable catches of narwhals in all areas in West Greenland and Canada.

Recommendations

The JWG agreed that age-structured models are the preferred assessment models for Greenland narwhal and beluga because they provide information on the survival and growth rate of the population and in some cases maybe even on abundance. However, the models presented require further refinement especially in relation to stock structure and the allocation of catches not taken during summer. Some further testing of assumptions regarding the prior distributions of growth rate, birth rate and survival rate, and consideration on the inclusion of stochastic elements, are also required.

West Greenland and Canada

The JWG agreed to reiterate its previous advice (Table 7 - ref. report from 2009 meeting). While the new assessment models look promising, and have the potential to better match the population structure as we understand it, the underlying data were considered inadequately explored at this meeting. In particular, the model for the allocation of summer, fall, winter, and spring hunts in Canada and Greenland to summering aggregations requires further development. The models explored at the current meeting, incorporating recent abundance estimates, updated age distribution data and new movement information from satellite tracking, confirmed that the current quotas in Greenland, for each stock area, are still sustainable.

Area	**Current situation**
Inglefield	85
Melville	81
Uummannaq	85
Disko	59
Total	**310**

Table 7. Current quotas for the take of narwhal in West Greenland

The JWG considered allocating the hunt in Canada and Greenland following the concept of a summer aggregation *(metapopulation)* model and inclusion of age structures. However, the JWG concluded that further work is required before these elements can be incorporated in the modelling approach for generating advice on sustainable removals in Canada and Greenland.

For the purpose of assessment the distribution of narwhals in West Greenland includes:

- two summer stocks (aggregations in footnote for Canada) in Inglefield Bredning and Melville Bay,
- fall and winter aggregations off Uummannaq,
- winter aggregations in and off the Disko Bay area.

Satellite tracking shows that these two fall and winter aggregations contain animals of Canadian origin, especially from Somerset Island, Admiralty Inlet and Eclipse Sound, as well as from Melville Bay.

Inglefield Bredning

A new assessment should include new information on abundance from a survey of Smith Sound and the possibility that the stock may be shared with Jones Sound. An exploratory Bayesian Analysis Model (BAM) including this new information resulted in a range of sustainable removals.

Melville Bay

The JWG acknowledged that, based on tagging data, the summering stock is also harvested in Disko Bay and Uummannaq during the winter. The wintering ground is also shared with stocks from Somerset Island, Admiralty Inlet and Eclipse Sound. Consequently the harvest from Disko Bay and Uummannaq was allocated on a preliminary basis from the proportional fraction of population sizes of the stocks and the tracking results between the stocks that share these wintering grounds. Tagging data from Admiralty Inlet and Eclipse Sound suggest that they contribute to the harvest in Disko Bay. Similarly, tagging data also suggest that animals from Somerset Island contribute to the harvest in Uummannaq. The fractions of Disko Bay and Uummannaq harvests assigned to the Melville Bay summer aggregation will be based on analyses of satellite tracking data.

The BAM would account for the fractions from these two other areas, Melville Bay and Uummannaq in the harvest data used in the model.

Uummannaq

The JWG acknowledged that the removals in Uummannaq are supplied by the fall and winter mixture of stocks wintering in Baffin Bay of which only a fraction periodically occurs inside Uummannaq and in winter remains near shore. Consequently the surveys executed in 2006 provided the basis for the population size estimates for this area as was done previously. The BAM should account for the fractions of different stocks in the model.

Disko Bay

The JWG acknowledged that removals in Disko Bay are supplied by a mixture of stocks wintering in Baffin Bay/Davis Strait of which only a fraction remains near shore. Consequently the surveys executed in 2006 provide the basis for the population size estimates for this area as was done previously. The BAM should account for the fractions from different stocks in the model.

6.5.2 Canadian summer stocks

Recommend the joint allocation model account for Canadian summer stocks as well.

6.5.3 East Greenland

Document NAMMCO/SC/19-JCNB/SWG/2012-JWG/12 analysed the dynamics of narwhals at the two hunting areas in East Greenland separately, *i.e.* the Ittoqqortormiit and Tasilaq/Kangerlussuaq areas. The 2008 age structure from Ittoqqortormiit was applied to both areas, and the harvest was found to be age selective, selecting against the take of animals younger than approximately 20 years of age. Assuming an average natural adult survival of either 0.97 or 0.98 in the prior, it is estimated that narwhals in the Ittoqqortormiit area have increased slightly, while narwhals in the Tasilaq/Kangerlussuaq area might be stable (increasing slightly with 0.98 survival, decreasing slightly with 0.97 survival). The current growth rate in the absence of harvest was estimated to lie between 1.2% (95% CI:0–3.5) and 3.7% (95% CI:1.6–5.9), depending upon model and area.

Based on the previous discussions (above) the JWG agreed that narwhals in Scoresby Sound (Ittoqqortormiit) and Kangerlussuaq-Sermilik (Tasiilaq) should be treated as two separate stocks. The age structure from animals collected between 2007 and 2010 in Ittoqqortormiit was applied to both areas, and the harvest was found to select older animals (Table 8). The BAM accounts for the fractions from these areas in the harvest data used in the model. A more conservative result was chosen for Tasiilaq because of the general lack of data for the area and the uncertainty on the growth of the population (Table 9).

P	Total Removals
95	17
90	35
85	45
80	50
75	60
70	70

Table 8. Narwhal East Greenland Ittoqqortormiit. The probability that total yearly removals from 2012 to 2016 will ensure an increasing stock. The estimates are average values between an exponential (with low survival) and a density regulated (with high survival) assessment model.

P	Total Removals
95	0
90	1
85	6
80	9
75	13
70	18

Table 9. Narwhal East Greenland TasiIlaq/Kangerlussuaq area. The probability that total yearly removals from 2012 to 2016 will ensure an increasing stock. The estimates are based on an exponential model with a low survival prior.

6.6 Future research requirements

Regular monitoring of population sizes (at least every 5-10 years) and further satellite tracking and dive behaviour work on the summering aggregations (20-50 animals per aggregation every 5 years) are key to developing the allocation model and providing accurate advice on allowable removals.

Development and testing of an allocation model for shared narwhal stocks and further development and testing of the assessment models using simulations where necessary to determine the impact of assumptions and identify potential biases.

7 IMPLEMENTATION OF EARLIER ADVICE

7.1 Beluga

At its last meeting this group presented a trade off table of risk factors and associated removals. The Scientific Committee of NAMMCO suggested choosing a factor of 70% or higher (corresponding to 310 removals for the total of West Greenland including the North Water). The NAMMCO Council adopted this advice and the quotas for 2011 were set to 290 removals for West Greenland, 20 for the North Water.

Canada

At its last meeting the Scientific Committee of JCNB suggested choosing a factor of 80% (corresponding to 265 removals for the total of West Greenland including the North Water). The NAMMCO Council adopted the 70% probability advice and the quotas for 2011 were set to 290 removals for West Greenland, 20 for the North Water.

7.2 Narwhal

East Greenland: Followed recommendations.

West Greenland: Followed recommendations.

Canada: Canada continues to assess Total Allowable Harvest Levels (TAHL) based on the Precautionary Approach that requires using Potential Biological Removals (PBR) since the five summer aggregations/stocks are considered Data Poor (*i.e.* limited time series of abundance surveys and limited age/sex structure and reproduction information).

8 TRADITIONAL KNOWLEDGE

8.1 Beluga

No new information.

8.2 Narwhal

Some information in the discussion above in NAMMCO/SC/19-JCNB/SWG /2012-JWG/07

9 IMPACT OF HUMAN-MADE-NOISE

9.1 Beluga

A recent paper demonstrated the reduction in stress hormones in the North Atlantic right whale during the hiatus in shipping through the Gulf of Maine during the week following September 11, 2001 (Rolland *et al.* 2012).

The US National Marine Mammal Laboratory plans to collect audiograms on belugas captured for tagging and health assessment in Bristol Bay. Audiograms will be collected with ambient background and with playback of typical anthropogenic noise to estimate the threshold shift resulting from noise exposure. Marcoux presented a study of passive acoustic monitoring of beluga presence and feeding in Cumberland Sound (NAMMCO/SC/19-JCNB/SWG/2012-JWG/O/21). In this study it was noted that passive acoustic methods are being increasingly used to monitor cetaceans because they are relatively inexpensive, operate under poor weather conditions as well as year round. Cumberland Sound is a diverse Arctic ecosystem and is home to a threatened population of belugas. Emerging fisheries for turbot and char, two potential prey species for belugas, are expanding in the Sound. There is a need for research examining the usage of Cumberland Sound by belugas and their relationship with turbot and char. Using passive acoustic methods, the authors attempted to detect the presence of belugas as well as their feeding events. They used a combination of a digital recorder (AURAL) and a click detector (C-POD) over 31 days in Clearwater Fjord, within Cumberland Sound, August 2010 and 2011. Belugas emit echolocation trains of clicks to navigate and locate their prey. They produce buzzes, a rapid train of clicks with inter-click intervals smaller than 20 ms that are believed to correspond to closing on a prey. The authors quantified the temporal pattern of click trains and buzzes as detected by the C-POD throughout the study period. Almost all the click trains detected by the C-POD were associated with beluga calls on the AURAL audio files (98% of random sample of 50 click trains). From the click series, belugas preferably visited the fjord at noon and at high tide. Future steps for this project include the validation of the C-POD as beluga click detector, assessment of false alarm rates, determination of the detection range of the instrument, and deployment of a network of C-PODs year-round in Cumberland Sound to monitor beluga time-space habitat usage pattern.

Discussion:
The JWG welcomed this study and suggested:

- Using satellite tagging to retrieve detailed information on the migration routes of the animals;
- Developing quantitative methods to estimate feeding from acoustics behaviour;
- Including other species in this investigation;
- Documenting the noise level of the area.

9.2 Narwhal

No new information on noise impact on narwhal.

The JWG notes that measurement of noise effects of seismic, drilling, shipping and other human activities on arctic marine mammals and the implications for population dynamics are not well understood for cetaceans in general and suggests that NAMMCO include this as a topic in an international symposium (see below item 10.3) on human impacts for all species of interest to NAMMCO.

10 OTHER BUSINESS

10.1 Implications of the inclusion of other species (*e.g.*walrus) in the work of the JWG

The inclusion of other species to the work of the JWG was discussed but it was not deemed desirable. For bowhead whales Greenland receives harvest quota advice from the IWC. Providing advice on other species would require additional expertise and increase the size of the present group to the point of jeopardizing efficiency. An alternative would be to convene a separate JWG to review pinniped science that would meet prior to or following the beluga and narwhal meeting to take advantage of the shared expertise while keeping the individual meetings manageable.

10.2 NAMMCO question regarding Ageing workshop

10.2.1 Beluga

Discussed above under item 5.2.1.

10.2.2 Narwhal

Discussed above under item 5.2.1.

10.3 Human Impact on habitat (NAMMCO request)

- Impacts of fish removal and fishing activity on beluga and narwhal.
- Impacts of changing sea ice conditions on beluga and narwhal.
- Impacts of feeding by beluga and narwhal on commercial fishing.

Discussion

The JWG discussed this topic briefly but noted that little new information was presented. However, in discussions on management advice it was noted that there is little information on the predicted response of marine mammal populations to changing arctic conditions including changes in sea ice, climate and forage species as well as increased human development activity in the arctic including seismic, shipping, drilling, and shore based development. Impacts may include changes in timing and distribution of prey and increased competition with fisheries, timing and distribution of sea ice, ensonification of the habitat, changes and increase of intensity and number of storms, and increased risk of toxic spills, all of which increase the uncertainty in the distribution and abundance of marine mammals of the arctic.

Recommendation

The JWG recommended holding an international symposium on the effect of seismic, drilling, shipping, increased fishing and other development activities on arctic marine mammals with a focus on beluga and narwhal.

10.4 Review of Rules of Procedure (ROP)

Regrettably the JWG did not have the time to examine the working proposal for a set of Rules of Procedure compiled by the NAMMCO Secretariat (NAMMCO/SC/19-JCNB/SWG/2012-JWG/05). However it was noted that for the future:

- Primary papers should be presented as working papers as opposed to published papers, and submitted in due time.

- New information should be reviewed.
- Abundance estimates and assessments should be rejected or adopted.

A small correspondence group will continue working on the matter.

11 ADOPTION OF REPORT

Approved in a preliminary form at the end of the meeting and by correspondence on 11 April 2012.

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Appendix 1

AGENDA

1. OPENING REMARKS

2. ADOPTION OF JOINT AGENDA

3. APPOINTMENT OF RAPPORTEURS

4. REVIEW OF AVAILABLE DOCUMENTS

5. BELUGA
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   - 5.2 Biological parameters
     - 5.2.1 Age estimation
     - 5.2.2 Reproductive rates
     - 5.2.3 Other information
   - 5.3 Recent catch statistics
   - 5.4 Abundance
     - 5.4.1 Recent and future estimates
   - 5.5 Assessment update
     - 5.5.1 West Greenland
     - 5.5.2 Other stocks
   - 5.6 Other information

6. NARWHALS
   - 6.1 Stock structure
     - 6.1.1 Genetic information
     - 6.1.2 Satellite tracking
     - 6.1.3 Other information
     - 6.1.4 Management units
   - 6.2 Biological parameters
     - 6.2.1 Age estimation
     - 6.2.2 Reproductive rates
     - 6.2.3 Population Dynamics
     - 6.2.4 Diving behavior
     - 6.2.5 Other information.
   - 6.3 Catch statistics
     - 6.3.1 Canadian and Greenlandic catch statistics
     - 6.3.1 Struck and lost
     - 6.3.2 Ice entrapments
   - 6.4 Abundance
     - 6.4.1 Recent estimates
     - 6.4.2 Estimates by management units
     - 6.4.3 Future survey plans
     - 6.4.5 Recent changes in distribution in Canada
   - 6.5 Assessment

6.5.1 Update of West Greenland assessment
6.5.2 Canadian summer stocks
6.5.3 East Greenland
6.6 Future research requirements

7. IMPLEMENTATION OF EARLIER ADVICE
7.1 Beluga
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8. TRADITIONAL KNOWLEDGE
8.1 Beluga
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9. IMPACT OF HUMAN-MADE-NOISE
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10. OTHER BUSINESS
10.1 Implications of the inclusion of other species (e.g.walrus) in the work of the JWG.
10.2 NAMMCO question regarding Ageing workshop
10.2.1 Beluga
10.2.2 Narwhal
10.3 Human Impact on habitat (NAMMCO request):
10.3.1 Beluga
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11. ADOPTION OF REPORT

Appendix 2

LIST OF DOCUMENTS

Document no	Title
NAMMCO/SC/19-JCNB/SWG/2012-JWG/01	List of participants.
NAMMCO/SC/19-JCNB/SWG/2012-JWG/02	Agenda.
NAMMCO/SC/19-JCNB/SWG/2012-JWG/03	List of documents.
NAMMCO/SC/19-JCNB/SWG/2012-JWG/04	Terms of Reference for this meeting
NAMMCO/SC/19-JCNB/SWG/2012-JWG/05	Draft Rules of Procedure for the Joint Working Group
NAMMCO/SC/19-JCNB/SWG/2012-JWG/06	Presentation Schedule
NAMMCO/SC/19-JCNB/SWG/2012-JWG/07	Westdal, K.H., Richard, P.R. and J.R. Orr. Availability bias in population survey of Northern Hudson Bay narwhal (*Monodon monoceros*)
NAMMCO/SC/19-JCNB/SWG/2012-JWG/08	Watt, C.A., Ferguson, S.H., Fisk, A. and M.P. Heide-Jørgensen. Using stable isotope analysis as a tool for narwhal (*Monodon monoceros*) stock delineation
NAMMCO/SC/19-JCNB/SWG/2012-JWG/09	Witting, L. Growth rate estimates from Bayesian assessments with age structured data.
NAMMCO/SC/19-JCNB/SWG/2012-JWG/10	Witting, L. and Heide-Jørgensen, M. P. Assessment of West Greenland narwhals.
NAMMCO/SC/19-JCNB/SWG/2012-JWG/11	Witting, L. and Heide-Jørgensen, M. P. Estimation of dynamics for narwhals in Uummannaq, West Greenland.
NAMMCO/SC/19-JCNB/SWG/2012-JWG/12	Witting, L. and Heide-Jørgensen, M. P. Assessment of East Greenland narwhals.
NAMMCO/SC/19-JCNB/SWG/2012-JWG/13	Witting, L. and Heide-Jørgensen, M. P. Assessment of West Greenland beluga.
NAMMCO/SC/19-JCNB/SWG/2012-JWG/14	Heide-Jørgensen, M.P. and Hansen, R.G. Catch statistics for belugas in Greenland 1862 to 2011.

NAMMCO/SC/19-JCNB/SWG/2012-JWG/15	Heide-Jørgensen, M.P. and Hansen, R.G. Reconstructing catch statistics for narwhal in Greenland 1862 to 2011.
NAMMCO/SC/19-JCNB/SWG/2012-JWG/16	Heide-Jørgensen, M.P., Hansen, R.G., Nielsen, R.H., Burt, M.L. Surveys of belugas and narwhals in the North Water 2009 and 2010.
NAMMCO/SC/19-JCNB/SWG/2012-JWG/17	Heide-Jørgensen, M.P., Richard, R.R., Dietz, R., Laidre. K.L. A metapopulation model of narwhals.
NAMMCO/SC/19-JCNB/SWG/2012-JWG/18	Heide-Jørgensen, M.P., Nielsen, N.H., Hansen R.G. Satellite tracking of narwhals in East Greenland.
NAMMCO/SC/19-JCNB/SWG/2012-JWG/19	Draft report from the Workshop on Age Estimation in Monodontids, Tampa, FL, 26-27 November 2011.
NAMMCO/SC/19-JCNB/SWG/2012-JWG/20	Executive Summary from the Workshop on Age Estimation in Monodontids, Beaufort, NC, 13-17 December 2011.
NAMMCO/SC/19-JCNB/SWG/2012-JWG/21	Watt *et al* Satellite tracking of narwhals (Monodon monoceros) from Admiralty Inlet (2009) and Eclipse Sound (2010-2011)
NAMMCO/SC/19-JCNB/SWG/2012-JWG/22	Hansén, J. and Harding, K.C. Some investigations on the minimum initial population size and possible growth rates of Narwhals in Greenland
NAMMCO/SC/19-JCNB/SWG/2012-JWG/23	Catch Statistics for narwhal and beluga in selected communities in Nunavut, Canada (2006-2010)

DOCUMENTS FOR INFORMATION

Document no	**Title**
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Appendix 3

Catch Statistics for narwhal and beluga in selected communities in Nunavut, Canada (2006-2010).

Introduction

Canadian narwhal and beluga fisheries are regulated by the Fisheries Act (R.S., 1985, c. F-14) and regulations made pursuant to it, including the *Fishery (General) Regulations* and the *Marine Mammal Regulations*. In the Nunavut Settlement Area, these fisheries are co-managed by Fisheries and Oceans Canada (DFO), the Nunavut Wildlife Management Board (NWMB), Regional Wildlife Organizations (RWOs), and Hunter and Trapper Organizations (HTOs), and Nunavut Tunngavik Inc. (NTI) in accordance with the Nunavut Land Claims Agreement (NLCA), and the Fisheries Act. Where an inconsistency exists between federal statutes and the NLCA, the Agreement shall prevail to the extent of the inconsistency. The NWMB is the main instrument of wildlife management in the Nunavut Settlement Area; however the DFO Minister retains ultimate responsibility for wildlife management.

This document presents updated landed catch information for subsistence narwhal and beluga fisheries in selected Nunavut communities for the period 2006–2010. Some communities have yet to report their narwhal and beluga catches for 2011. Preliminary information is included where available, but the values are subject to change.

For narwhal, regulatory quotas and harvest limits[10] are administered using numbered Marine Mammal Tags (MMT, or 'tag'), which are issued only to Inuit. DFO Fishery Officers monitor narwhal hunting activities when possible, to ensure compliance with the Marine Mammal Regulations. In some Nunavut communities, established narwhal hunting by-laws govern local hunting practices.

The harvest year extends from 01 April to 31 March. At the beginning of the harvest year, DFO distributes a set of MMTs to each Hunters and Trappers Organization equal to the community's quota or harvest limit. The HTO distributes these MMTs amongst its members, who report the outcome of their hunts to the HTO. Hunters are required to complete and attach a numbered MMT to each landed narwhal, *i.e.* to the tusk if present or to the carcass if not. Detachable tag returns are completed and returned to the HTO. At the close of the hunting season, each HTO returns its harvest summary to DFO, together with any unused MMTs and the completed tag returns from harvested narwhal. DFO compiles annual catch summaries using information from completed MMT returns and local summaries provided by individual HTOs.

Table 1 presents landed catches of narwhal in High Arctic communities from 2006-2010. Marine Mammal Tag returns for these years have recently been re-assessed; in some cases previously reported catches are slightly changed. The cumulative landed catch in these communities slightly exceeded 500 narwhals in 2006. In 2007-2009 landed catches stabilized at just under 400 narwhals (387-391), and then rose to 435

[10] Under Community Based Management, NWMB harvest limits replaced the original regulatory quotas in the participating communities.

narwhals in 2010. The average landed catch for this period was 422 narwhals, equivalent to the 2003-2007 average of 423 reported for these communities by Baker (2009). A breakdown of catches by seasons by years is provided in the original document (NAMMCO/SC/19-JCNB/SWG/2012-JWG/23).

Tables 2-4 summarize the seasonal distribution of narwhal harvests by community, using cut-off dates developed by Romberg and Richard (2005). Spring (floe edge/ice crack) hunts occurred on/before calendar day 205, summer (open water) hunts occurred between calendar days 205 and 274, and fall hunts occurred on/after calendar day 275. Igloolik and Hall Beach hunters have access to both the Somerset and Northern Hudson Bay stocks; the ratio of each stock present in the landed catch from these communities is not known.

Table 5 excludes narwhal catches that originated within the summer range of the Northern Hudson Bay population and provides information on seasonal proportions and the overall catch composition of community harvests for 2006-2010. Intervals are coded by calendar day (see Romberg and Richard 2005), where spring (ice-edge) hunts occurred before day 205, summer (open water) hunts occurred between days 205 and 274, and fall hunts occurred after day 274.

Table 6 provides data on landed catches of belugas in selected Nunavut communities from 2006 – 2010. Catch information for 2011 has not been received from some locations. Preliminary reports are included where available, but these values may be subject to change.

Literature Cited

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Table 1. Narwhal landed catches reported from selected communities in Nunavut, Canada from 2006 – 2010. For each year, the aggregate catch is compared to the quota available to these communities. Catch information from 2011 has not been received from some communities. Preliminary information is included where available, but the values are subject to change.

Community	2006		2007		2008		2009		2010		Cumulative (5-yrs)		*2011 Preliminary*	
	Quota / Harvest Limit	Landed Catch	Quota / Harvest Limit	Landed Catch	Quota / Harvest Limit	Landed Catch	Quota / Harvest Limit	Landed Catch	Quota / Harvest Limit	Landed Catch	Total Catch	Average Catch	Quota / Harvest Limit	*Landed Catch*
Arctic Bay [CBM]	130	130	130	124	130	132	130	129	130	128	643	129	130	*130*
Cambridge Bay	NRQ	-	NRQ	-	2 [1]	0	NRQ	-	NRQ	-	0	0	NRQ	*10*
Clyde River	50	43	50	42	50	17	50	13	50	50	165	33	50	*36*
Gjoa Haven	10 Ŧ	0	10 Ŧ	1	8 Ŧ	0	10 Ŧ	1	10 Ŧ	1	3	1	10 Ŧ	*pending*
Grise Fiord	20	21	20	20	20	23*	20	5	20	21 BA	90	18	20	*pending*
Hall Beach	10	1	10	0	10	0	10	0	10	2 [NHB]	1	0	10	*pending*
Igloolik	25	25	25	1	25	0	25	1	25	0	27	5	25	*pending*
Kugaaruk [CBM]	25 Ŧ	48 [2]	25 Ŧ	40	25 Ŧ	35	25 Ŧ	42	25 Ŧ	45	210	42	25 Ŧ	*50*
Pangnirtung	40	1	40	1	40	21	40	41	40	28	92	18	40	*pending*
Pond Inlet [CBM]	130	88	130	65	130	73 [3]	130	44	130	62	332	66	130	*112*
Qikiqtarjuaq [CBM]	90	85	90	88	90	80	90	90	90	89	432	86	90	*90*
Resolute Bay & Creswell Bay	32	28	32	9	32	10	32	16	32	9	72	14	32	*pending*

Taloyoak	10 Ŧ	34 *	10 Ŧ	0	10 Ŧ	3	10 Ŧ	5	10 Ŧ	2	44	9	10 Ŧ	*1*
Total	572	504	572	391	572	394	572	387	572	435	2111	422	572	*pending*
Harvest/Quota		0.88		0.68		0.69		0.68		0.76		0.74		

CBM Community Based Management harvest limit
NRQ No Regulatory Quota
BA Borrowed Against the following year's quota to reconcile overharvest, approved by NWMB & DFO
* Overharvest was reconciled with a transfer/borrowing of tags from another community
Ŧ In 2006, a combined harvest of 75 narwhals was approved for Gjoa Haven, Kugaaruk and Taloyoak. Of these, 45 are community specific and 30 are held in reserve by the Kitikmeot Regional Wildlife Board.
1 Cambridge Bay acquired 2 Marine Mammal Tags from Gjoa Haven, these were unused and returned
2 Allocation from Kitikmeot Regional Wildlife Board, plus 3 tags carried over from 2005.
3 An additional authorized harvest of 624 narwhals entrapped by ice is considered natural mortality and not included in the yearly total.
4 Catch is attributed to the Northern Hudson Bay population and not included in the yearly total.

Table 2. Catch composition of seasonal narwhal harvests in selected Nunavut communities in 2006-2007. For each community and year, darkened cells indicate seasons where no narwhals were landed.

Community	Quota / Limit	2006										2007									
		Number Landed	Spring			Summer			Fall			Number Landed	Spring			Summer			Fall		
			F	M	U	F	M	U	F	M	U		F	M	U	F	M	U	F	M	U
Arctic Bay CBM	130	130	30	96	0	3	1	0	0	0	0	124	15	53	0	3	53	0	0	0	0
			23.8 %	76.2 %	--	75.0 %	25.0 %	--	--	--	--		22.1 %	77.9 %	--	5.4 %	94.6 %	--	--	--	--
Clyde River	50	43	1	2	0	18	12	0	2	8	0	42	5	3	0	11	11	0	10	2	
			33.3 %	66.7 %	--	60.0 %	40.0 %	--	20.0 %	80.0 %	--		62.5 %	37.5 %	--	50.0 %	50.0 %	--	83.3 %	16.7 %	--
Gjoa Haven	10 Ŧ	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
			--	--	--	--	--	--	--	--	--		--	--	--	100 %	--	--	--	--	--
Grise Fiord	20	21	0	0	0	0	21	0	0	0	0	20	1	15	0	2	9	0	0	0	0
			--	--	--	--	100.0%	--	--	--	--		6.3 %	93.8 %	--	18.2 %	81.8 %	--	--	--	--
Hall Beach	10	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			--	--	--	100.0 %	--	--	--	--	--		--	--	--	--	--	--	--	--	--

Igloolik	25	25	0	0	0	10	15	0	0	0	0	1	0	0	0	0	1	0	0	0	0
			--	--	--	40.0 %	60.0 %	--	--	--	--		--	--	--	0.0 %	100.0 %	--	--	--	--
Kugaaruk CBM	25 Ŧ	48 [2]	0	0	0	9	39	0	0	0	0	40	0	0	0	4	36	0	0	0	0
			--	--	--	18.8 %	81.3 %	--	--	--	--		--	--	--	10.0 %	90.0 %	--	--	--	--
Pangnirtung	40	1	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0
			--	--	--	--	--	--	--	100. 0%	--			100.0 %							
Pond Inlet CBM	130	88	10	12	0	19	43	0	1	1	0	65	3	3	0	25	32	0	0	2	0
			45.5 %	54.5 %	--	30.6 %	69.4 %	--	50.0 %	50.0 %	--		50.0 %	50.0 %	--	43.9 %	56.1 %	--	--	100. 0%	--
Qikiqtarjuaq CBM	90	85	26	0	0	0	58	0	1	0	0	88	0	0	0	25	54		1	8	0
			100. 0%	--	--	0.0%	100. 0%	--	100. 0%	--	--		--	--	--	31.6 %	68.4 %	--	11.1 %	88.9 %	--
Resolute Bay & Creswell Bay	32	28	1	0	0	3	24	0	0	0	0	9	0	0	0	3	6	0	0	0	0
			100. 0%	--	--	11.1 %	88.9 %	--	--	--	--		--	--	--	33.3 %	66.7 %	--	--	--	--
Taloyoak	10 Ŧ	34 *	0	0	0	7	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			--	--	--	20.6 %	79.4 %	--	--	--	--		--	--	--	--	--	--	--	--	--

Table 3. Catchcomposition of seasonal narwhal harvests in selected Nunavut communities in 2008-2009. For each community and year, darkened cells indicate seasons where no narwhals were landed**.**

Community	Quota / Limit	2008										2009									
		Number Landed	Sprin			Summer			Fall			Number Landed	Spring			Summer			Fall		
			F	M	U	F	M	U	F	M	U		F	M	U	F	M	U	F	M	U
Arctic Bay CBM	130	132	29	19	0	9	75	0	0	0	0	129	8	9	0	7	10 5	0	0	0	0
			60.4 %	39.6 %	--	10. 7%	89.3 %	--	--	--	--		47.1 %	52. 9%	--	6.3 %	93. 8%	--	--	--	--
Clyde River	50	17	0	2	0	6	6	0	0	3	0	13	1	6	0	0	1	0	1	4	0
			0.0%	100.0 %	--	50. 0%	50.0 %	--	--	--	--		14.3 %	85. 7%	--	--	10 0.0 %	--	20. 0 %	80. 0%	--
Gjoa Haven	10 Ŧ	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
			--	--	--	--	--	--	--	--	--		--	--	--	10 0.0 %	0	0	--	--	--
Grise Fiord	20	23*	0	0	0	3	20	0	0			5	1	3	0	0	1	0	0	0	0
			--	--	--	13. 0%	87.0 %	--	--	--	--		25.0 %	75. 0%	--	--	10 0.0	--	--	--	--

																	%				
Hall Beach	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			--	--	--	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--
Igloolik	25	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
			--	--	--	--	--	--	--	--	--		--	100%	--	--	--	--	--	--	--
Kugaaruk CBM	25 Ŧ	35	0	0	0	5	30	0	0	0	0	42	0	0	0	16	26	0	0	0	0
			--	--	--	14.3%	85.7%	--	--				--	--	--	38.1%	61.9%	--	--	--	--
Pangnirtung	40	21	0	0	0	4	17	0	0	0	0	41	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
			--	--	--	19.0%	81.0%	--	--												
Pond Inlet CBM	130	73 [3]	10	4	1	23	34	0	1	0	0	44	11	10	0	12	8	0	1	2	0
			66.7%	26.7%	6.7%	40.4%	59.6%	--	100.0%	--	--		52.4%	47.6%	--	60.0%	40.0%	--	33.3%	66.7%	--
Qikiqtarjuaq CBM	90	80	0	0	0	5	28	0	8	39	0	90	0	0	0	3	77	0	6	4	0
			--	--	--	15.2%	84.8%	--	--	83.0%	--		--	--	--	3.8%	96.3%	--	60.0%	40.0%	--
Resolute	32	10	0	0	0	3	7	0	0	0	0	16	0	1	0	0	15	0	0	0	0

Bay & Creswell Bay																					
			--	--	--	30.0%	70.0%	--	--	--	--		--	100.0%	--	--	100.0%	--	--	--	--
Taloyoak	10 Ŧ	3	0	0	0	0	0	3	0	0	0	5	0	0	0	4	0	1	0	0	0
			--	--	--	--	--	100.0%	--	--	--		--	--	--	80.0%	0.0%	20.0%	--	--	--

Table 4. Catch composition of seasonal narwhal harvests in selected Nunavut communities in 2010. For each community and year, darkened cells indicate seasons where no narwhals were landed.

Community	Quota / Harvest Limit	2010									
		Number Landed	Spring			Summer			Fall		
			F	M	U	F	M	U	F	M	U
Arctic Bay [CBM]	130	128	10	28	0	10	80	0	0	0	0
			26.3%	73.7%	--	11.1%	88.9%	--	--	--	--
Clyde River	50	50	4	10	0	9	27	0	0	0	0
			28.6%	71.4%	--	25.0%	75.0%	--	--	--	--
Gjoa Haven	10 Ŧ	1	0	0	0	0	1	0	0	0	0
			--	--	--		100.0%		--	--	--
Grise Fiord	20	21 [BA]	5	3	0	5	7	1	0	0	0
			62.5%	37.5%	--	38.5%	53.8%	7.7%	--	--	--
Hall Beach	10	2 [NHB]	1 [NHB]	0	0	1 [NHB]	0	0	0	0	0
				--	--		--	--	--	--	--
Igloolik	25	0	0	0	0	0	0	0	0	0	0
			--	--	--	--	--	--	--	--	--
Kugaaruk [CBM]	25 Ŧ	45	0	1	0	0	44	0	0	0	0
			--	100.0%	--		100.0%		--	--	--
Pangnirtung	40	28	6	5	0	1	0	0	4	12	0
			54.5%	83.3%	--	100.0%	--	--	25.0%	75.0%	--

Pond Inlet CBM	130	62	8	9	0	16	20	0	6	2	0
			47.1%	36.0%	--	44.4%	55.6%	--	75.0%	25.0%	--
Qikiqtarjuaq CBM	90	89	0	0	0	18	52	1	3	15	0
			--	--	--	25.7%	73.2%	1.4%	16.7%	83.3%	--
Resolute Bay &	32	9	0	0	0	1	8	0	0	0	0
Creswell Bay			--	--	--	11.1%	88.9%	--	--	--	--
Taloyoak	10 Ŧ	2	0	0	0	0	1	1	0	0	0
			--	--	--	0.0%	50.0%	50.0%	--	--	--

Table 5. Catch distribution of narwhal harvests by community for 2006-2010. For each community, the total reported landed catch and seasonal proportions are followed by the overall catch composition and the proportion of the total catch taken in each of the spring, summer and fall hunting seasons. Seasons are coded by calendar day (Romberg & Richard 2005), where spring (ice-edge) hunts occurred before day 205 (July 23rd), summer (open water) hunts occurred between days 205 and 274 (July 24th-Sept 31st), and fall hunts occurred after day 274 (Oct 1st).

Community	Quota/ Harvest Limit	Landed (F:M:U)	2006				2007				2008				2009				2010		
			Spring	Summer	Fall	Landed (F:M:U)	Spring	Summer	Fall	Landed (F:M:U)	Spring	Summer	Fall	Landed (F:M:U)	Spring	Summer	Fall	Landed (F:M:U)	Spring	Summer	Fall
Arctic Bay CBM	130	130	126	4	0	124	69	55	0	132	48	84	0	129	17	112	0	128	38	90	0
		(33:97:0)	0.97	0.03	--	(18:106:0)	0.55	0.45	--	(38:94:0)	0.36	0.64	--	(15:114:0)	0.13	0.87	0	(19:109:0)	0.30	0.70	--
Clyde River	50	43	4	29	11	42	8	22	12	17	2	12	3	13	7	1	5	50	14	36	0
		(21:22:0)	0.093	0.67	0.22	(26:16:0)	0.19	0.52	0.29	(6:11:0)	0.12	0.71	0.18	(2:11:0)	0.54	0.08	0.38	(13:36:0)	0.29	0.73	--
Gjoa Haven	10 Ŧ	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0	1	0	1	0
		(0:0:0)	--	--	--	(1:0:0)	--	1	--	(0:0:0)	--	--	--	(1:0:0)	--	1	--	(0:1:0)	--	1.00	--
Grise Fiord	20	21	0	21	0	20	3	17	0	23*	0	23	0	5	4	1	0	21 [BA]	8	13	0
		(0:21:0)	--	1.00	--	(3:17:0)	0.15	0.85	--	(3:20:0)	--	1	--	(1:4:0)	0.8	0.2	--	(10:10:1)	0.38	0.57	--

Hall Beach	10	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2 [NHB]	1 [NHB]	1 [NHB]	0
		(1:0:0)	--	1.00	--	(0:0:0)	--	--	--	(0:0:0)	--	--	--	(0:0:0)	--	--	--	(1:1:0)	--	--	--
Igloolik	25	25	0	25	0	1	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0
		(10:15:0)	--	1	--	(0:1:0)	0	1	--	(0:0:0)	--	--	--	(0:1:0)	1	0	--	(0:0:0)	--	--	--
Kugaaruk CBM	25 Ŧ	48 [2]	0	48	0	40	0	40	0	35	0	35	0	42	0	42	0	45	1	44	0
		(9:39:0)	--	1	--	(4:36:0)	0	1	--	(5:30:0)	--	1	--	(16:26:0)	--	1	--	(1:44:0)	0.02	0.98	--
Pangnirtung	40	1	0	0	1	1	1	0	0	21	0	21	0	41	--	--	--	28	11	1	20
		(0:1:0)	--	--	1.00	(0:1:0)	1	0	--	(4:17:0)	--	0.9	--	(0:0:41)	--	--	--	(11:17:0)	0.39	0.04	0.57
Pond Inlet CBM	130	88	22	64	2	65	7	56	2	73 [3]	14	58	1	44	21	20	3	62	17	37	8
		(30:56:0)	--	0.73	0.02	(28:37:0)	0.11	0.86	0.03	(34:38:0)	0.19	0.79	0.01	(24:20:0)	0.48	0.45	0.07	(30:32:0)	0.27	0.60	0.13
Qikiqtarjuaq CBM	90	85	0	85	0	88	0	79	9	80	0	33	47	90	0	82	8	89	0	71	49
		(27:58:0)	--	0.99	0.01	(26:62:0)	0	0.9	0.1	(13:67:0)	--	0.41	0.59	(9:81:0)	--	0.92	0.08	(21:67:1)	--	0.80	0.20
Resolute Bay &	32	28	1	27	0	9	0	9	0	10	0	10	0	16	2	14	0	9	0	9	5

Creswell Bay																					
		(4:24:0)	0.04	0.96	--	(3:6:0)	0	1	--	(3:7:0)	--	1.00	--	(0:16:0)	0.125	0.88	--	(1:8:0)	--	1.00	0.00
Taloyoak	10 Ŧ	34 *	0	34	0	0	0	0	0	3	0	1	2	5	0	5	0	2	0	2	0
		(7:27:0)	--	1.00	--	(0:0:0)	--	--	--	(0:0:3)	--	1.00	0.00	(4:0:1)	--	1	--	(0:1:1)	--	1.00	--

Table 6. Landed catch of beluga in selected Nunavut communities from 2006 – 2010. Catch information for 2011 has not been received from some locations. Preliminary reports are included where available, but these values may be subject to change.

Community	Landed Catch						
	Quota	2006	2007	2008	2009	2010	2011 (preliminary)
Arctic Bay	NRQ	5	14	0	0	0	0
Clyde River	NRQ	0	0	0	0	0	0
Gjoa Haven	NRQ	26	6	0		nr	10
Grise Fiord	NRQ	6	2	10	1	1	*pending*
Hall Beach	NRQ	0	10	3		15 [1]	*pending*
Igloolik	NRQ	27	18	17	18	74	*pending*
Kugaaruk	NRQ	0	0	0		nr	0
Kugluktuk	NRQ	0	0	0	0	0	21
Pond Inlet	NRQ	2	0	0		0	0
Qikiqtarjuaq	NRQ	0	0	0		2	0
Resolute Bay	NRQ	31	5		6	6	*pending*
Taloyoak	NRQ	30	100	0		45	0
Total		127	155	30	25	146	*pending*

NRQ No Regulatory Quota
nr no record received
1 Hall Beach subsistence harvest in 2010 was originally reported as a range (15-20), the value was replaced with an average (15)

ANNEX 2

NAMMCO SCIENTIFIC COMMITTEE WORKING GROUP ON PLANNING THE SECOND TRANS NORTH ATLANTIC SIGHTINGS SURVEY

Marine Research Institute, Reykjavík, 10-12 January 2012

REPORT

1. CHAIRMAN'S WELCOME AND OPENING REMARKS

Chair Gunnlaugsson welcomed the participants (Section 5.7) to the meeting, the purpose of which was to plan the next large-scale, internationally coordinated cetacean survey in the North Atlantic. The Group likewise welcomed the newly-appointed Chair Gunnlaugsson and T-NASS Co-ordinator Desportes. Documents submitted for use in this meeting are listed in Appendix 1.

2. ADOPTION OF AGENDA

The adopted agenda is given in Appendix 2.

3. APPOINTMENT OF RAPPORTEURS

Acquarone was appointed as rapporteur, with the help of the participants, where needed.

4. BACKGROUND FOR AND RATIONALE BEHIND A NEW T-NASS

Due to national and international requirements, management decisions on cetacean harvests necessitate scientific advice based on updated abundance estimates. For this reason a series of national, management-oriented surveys are planned in the North Atlantic for the years 2013-2017.

At previous meetings, this Group (*e.g.* NAMMCO 2008, 2011) agreed that a better basis for the management of cetacean species in the area would be obtained through effort coordination aiming at a synoptic and contiguous survey across the whole North Atlantic. In particular it had noted that:

- coordination at least at the level of the 2007 T-NASS was desirable and should be pursued for the next round of surveys.
- the surveys should be coordinated to the maximum extent possible, while recognising differing national priorities.

The coordination of what would otherwise be ongoing national and international (European) survey efforts into a single coordinated survey conducted in July-September in the same year, using compatible methodology and covering the maximum possible area will provide a much better view of the overall distribution of cetaceans in the North Atlantic, compared to that realized with uncoordinated surveys.

This is particularly important in light of changes in distribution that have been observed for several species in the more recent surveys (SC/19/TNASS2/06, SC/18/AESP/07, SC/18/AESP/05, SC/17/AE/4, SC/19/TNASS2/O/07).

The data gathered in such coordinated surveys could permit the detection of trends in distribution and abundance of species for ecosystem monitoring. This requires a very large survey area and a series of surveys spread over time to be successful. This is an important added value that can only be realized with the continuation of a coordinated survey.

A coordinated planning of the survey will ensure that national survey areas are contiguous, and every effort will be made to cover any gaps with additional effort to form a contiguous survey area from the shores of Europe across the North Atlantic to Greenland and North America.

Such an enlargement of the coverage would reduce the probability of missing significant cetacean aggregations - thus countering a potentially negative effect of migrations and unpredictable variations in the seasonal distribution of animals on the precision of the abundance estimates. Additional objectives of the surveys will be updated distribution maps and associated basic environmental data to enhance our understanding of the relationships between animals and their environment.

Other practical advantages of a coordinated approach include the joint development of methodological protocols and equipment that can be used in future surveys, sharing of vessels and equipment, centralized purchasing which can result in cost savings, and more efficient joint data compilation, analysis, and dissemination.

5. OVERVIEW OF PLANS AND AVAILABLE RESOURCES BY JURISDICTION

5.1 Canada

Timing:	An aerial line transect census of cetaceans in eastern Canada in the late summer, from the northern tip of Labrador to the U.S. border, is planned to be conducted after 2015 (ideally 2017); with one Twin Otter in the north and another Otter and/or Partenavia P-68 Observer in the south, double-platform, and video camera coverage of the trackline.
Target species:	Cetaceans, sea turtles, basking sharks, sunfish.
Coverage:	The area covered will be the same as in the 2007 T-NASS (but see below).
Funding:	Department of Fisheries and Oceans (DFO) funding has been identified (900K CAD) for this scale of survey on a 10-yr rotation (hence the next DFO cetacean survey in the Atlantic is expected to occur in 2017); however there may be some flexibility in this schedule if an international survey is planned for an earlier period, although the 2015 time frame coincides with the fiscal support of the planned Atlantic harp seal survey.

Other issues: Funding is an issue that needs to be resolved well ahead of planning for a new survey. The eastern Arctic portion of Canadian waters may also be surveyed given the large-scale industrial developments proposed recently for northern Canada.

5.2 Greenland

Timing: An aerial line transect with a Twin Otter, double-platform and camera ideally for 2015; probably late August-September for weather reasons.

Target species: Primarily minke whales, but including all other species of marine mammals.

Coverage: Traditional west and southwest Greenland survey area with a possible extension of the area farthest north because of recent catches of minke whales in Siorapaluk. The survey will not extend to include areas for other species (e.g., westwards for pilot whales).

Funding: National

Other issues: Relatively large numbers of humpback whales and fin whales, in feeding grounds outside of Ammassalik/Tasiilaq have been sighted in August and the area has not been covered by the previous NASS. There is no hunting of these species in the area and the administration is not willing to fund surveys in that area as the management requirements for the minke whales harvest in East Greenland is covered by the abundance estimates from Iceland and Norway. Research in progress aims at providing measures for reducing the abundance CV and obtaining a new bias correction factor (surface time correction factor by satellite telemetry).

5.3 Iceland

Timing: A shipboard line transect survey in offshore waters and an aerial line transect survey in coastal waters around Iceland is expected to be conducted between 2013 and 2015. Iceland's policy is to conduct surveys every six years to meet the requirements of the RMP.

Target species: Fin, minke, sei, and sperm whales.

Timing: Not earlier than 20 June. Although surveying later in the summer would exclude the possibility of using a redfish survey platform, it would increase the chances of gathering high-quality data on sei and pilot whales, especially if an extension of the survey area to the south were included in the design.

Platforms: One aircraft, 2-3 dedicated vessels.

Coverage: The area covered in the aerial survey will be the same as in previous years, with a consideration to extend/shift coverage north/northwest to the ice edge. Shipboard survey area will be within the area covered in earlier surveys. The primary area will

	be Icelandic waters (200 nmi EEZ), with extensions to East Greenland and south to 55°N.
Funding:	No funding has been allocated for the survey. There are no indications of a change in the general policy of large scale surveys approximately every six years, although Iceland will be flexible on the timing, if this facilitates a coordinated survey.
Other issues:	Acoustic equipment is available. Biopsy collection from fin whales and tagging might be considered during the survey. It is not planned to repeat the modifications of the 2007 aerial survey for including harbour porpoises as target species.

5.4 Faroes

Timing:	A shipboard line transect survey in inshore and offshore waters is to be conducted between 2013 and 2015.
Target species:	Pilot whales (seasonal and spatial issue).
Timing:	Late June, but flexible for a later start if the pilot whale is the overall target species (seasonal and spatial issues).
Platforms:	One dedicated vessel.
Coverage:	Primarily Faroese EEZ, with potential extension to adjacent waters.
Funding:	National funding.
Other issues:	Acoustic equipment is available. Biopsy collection and tagging during the survey might be considered.

5.5 Norway

Timing:	Intention is to follow the RMP requirements for minke whales. This implies 6-year cycles (2008-2013, 2014-2019). Due to changes in resource allocation there is not going to be a survey in 2012. There are indications that survey effort in the future will be lower.
Target species:	Minke whales.
Season:	July.
Methods:	Two platforms, two dedicated vessels.

5.6 EU Waters

North Atlantic and North Sea

Timing:	A "SCANS-III" survey of European Atlantic waters is in the very early planning phase for centrally coordinated synoptic estimation of abundance and distribution mapping of cetaceans. The requirements are driven primarily by the demands of the Habitats Directive. Timing is considered an approximately decadal scale, meaning that the next survey should be between 2014 and 2017. The ideal year is considered to be 2015. It is currently unclear whether or not shelf and offshore waters can be surveyed in the same year.
Target species:	All cetacean species. Minke whales, common and bottlenose dolphins occur widely on and off the shelf.

Other: EU member states seem to be receptive to the idea of a new survey. Results will also inform management issues related to the rapidly increasing deployment of wind, tidal, and wave energy developments.

Mediterranean: A whole-basin survey with coverage of the whole Mediterranean Sea and Black Sea is being planned. The current plan is for most of the effort to be carried out by aerial survey. Small vessels will use towed acoustics to survey sperm whales.

The Group also took note of the French programmes submitted as documents SC/19/TNASS2/O/05 and SC/19/TNASS2/O/06.

5.7 Russian Federation

The availability of Russian resources for the next survey will be the same as for the previous T-NASS (one observer on a Russian Redfish survey vessel and two additional observers), with the possible inclusion of an Antonov AN-26 survey aircraft.

5.8 USA

Timing: At the time of writing the planned activities with secured funding are: aerial surveys (with Twin Otter) in March-April 2012 and Oct-Nov 2012. Other planned activities requiring funding are an aerial survey during Jan-Feb 2013, a shipboard and aerial survey in June-Aug 2013, an aerial survey in March-April 2014, and an aerial survey in Oct-Nov 2014. The 2013 summer shipboard and aerial survey may be pushed back a year or so, the non-summer surveys are of higher priority since the US has almost no survey effort in non-summer seasons.

Target: For all surveys, the target species are cetaceans, seals, sea turtles, basking sharks, and sunfish. Seabirds are also a target species during the shipboard surveys.

Coverage: All of the aerial surveys will cover "coastal" waters (from the coastline to about the 1000 m depth contour) from Florida to Bay of Fundy and the US and Canadian parts of the Gulf of Maine. The summer shipboard survey cover waters from the offshore edge of where the plane survey covers to the 4,000 m depth contour (which is usually near or beyond the US EEZ).

Funding: See timing.

Other issues: On the shipboard surveys passive and active acoustic equipment are also used. Funding has not been confirmed for 2013 and beyond. Depending on when the NAMMCO surveys are, the US might be able to also conduct a summer shipboard and aerial survey at the same time and not do the tentatively proposed 2013 summer shipboard and aerial surveys.

6. REVIEW OF METHODOLOGY FROM PREVIOUS SURVEYS

6.1 Aerial surveys

Pike presented (Appendix 3 – SC/19/TNASS2/04) a review of the recent (2001 and later) literature pertaining to aerial surveys for cetaceans, compiling a database of 48 surveys, including factors relating to survey type, target species, survey design, field methods, equipment, photography and/or video, and analyses. This was used to assess the present state of the art in aerial survey, and to provide examples that might be applicable in the T-NASS study area and situation. Most surveys used visual line transect methodology, and only a small proportion used cue counting or incorporated still and/or video photography. Aerial survey was used for all types and sizes of cetaceans, except deep divers such as sperm and beaked whales. Survey designs used in the 2007 T-NASS were generally adequate but the trackline layout in the Icelandic inner strata did not have an even coverage distribution. The majority of surveys (58%) used a single-platform configuration with one observer on each side; the remainder used either a full or partial double-platform. The correction of perception bias requires either a double-platform configuration or the circleback technique. In the latter, portions of a transect where animals have been sighted are re-flown some minutes later, and sightings from the first and second segment are then used to estimate the value of $g(0)$, incorporating both perception and availability biases. Circleback is applicable for species which have relatively short diving intervals and do not form large groups. In other surveys, availability bias is corrected using either cue counting or by incorporating data on time in view during the survey with data on availability based on surfacing frequency and dive profiles from external studies. For the latter method it is important to explicitly gather data on time in view during the survey. Improvements in declination and bearing measurement methodology, as well as increased precision and automation of data acquisition, are required. While few surveys use still or video photographic methods, this has great potential as camera and data storage technology has improved greatly in recent years. The potential of using photography as a second platform on smaller aircraft is particularly promising. Finally, unmanned aerial vehicles (UAVs) are undergoing rapid development and becoming commercially viable, but are presently either unsuitable for marine surveys or too expensive for most potential users. It is likely that this technology will become important for aerial surveys in the near future.

Some general recommendations were provided and endorsed by the Group:

Survey design

1. The stratification of the Icelandic aerial survey is generally effective for minke whales. However distribution does change between surveys and an adaptive approach, wherein the survey area is first covered at low effort and then additional effort is applied to areas of high density, should be considered.
2. A systematic design using parallel equally-spaced transects is best for most surveys as it always results in even coverage. Zig-zag designs may be preferable for very large, low-coverage strata where ferrying time is an issue, or rectangular strata.
3. The transect layout used in the Icelandic aerial survey resulted in uneven coverage in the inner strata, although this has not been quantified. Modification of this design will depend on the competing priorities of survey comparability and unbiased abundance estimation.

4. The designs of the Canadian T-NASS and Faroese 2009 surveys are adequate. Future changes in stratification could be based on observed animal density or changes in funded effort.

Platforms

1. Visual platforms should use bubble windows.
2. The secondary platform used in the Icelandic aerial surveys does not give a good view close to the aircraft. A larger aircraft and/or the use of a photographic secondary platform (see below) should be considered.
3. The circle-back method is successful for harbour porpoise surveys but has not been adequately tested for other species.

Data acquisition

1. Vocal recordings are the most efficient and reliable means of recording observer observations, and should be used on all surveys, even in cases where a dedicated data recorder is employed.
2. A system to record declination measurements immediately, perhaps using an electronic inclinometer, should be developed.
3. A means of more accurately determining when a sighting comes abeam of the aircraft should be developed.
4. The recording system used in the Icelandic aerial survey is dated, becoming unreliable, and must be improved.

Video and still photography

1. HD video and/or still photographic equipment is of moderate cost and excellent quality and should be considered for all surveys. Video might be particularly useful as a second platform on smaller aircraft.

Bias correction

1. Perception bias cannot be corrected without double-platform data; to accomplish this, double platforms would be required on all surveys (except those using circle-back).
2. Forward sighting distance and time in view (TIV) is required for the correction of availability bias using dive cycle information. Therefore TIV should be collected for every sighting. This again requires the use of observer recordings and accurate timing of observations.
3. The possibility of analyzing Icelandic survey data using a correction for availability based on TIV and dive cycle data, for comparison with estimates based on cue counts, should be investigated.
4. Ideally dive cycle information, including cue rates, should be collected from the survey area at the same time of year the survey is carried out.

Unmanned Aerial Vehicles (UAVs)

1. Civilian UAVs suitable for marine aerial survey are currently too costly and/or not adequately tested, and it is difficult to obtain operational permits in some survey areas. The use of HD video and/or still photograph in conjunction with

visual aerial surveys will facilitate the transition to UAVs should they become available.

In discussion it was emphasized that a double-platform configuration was essential to quantify perception bias for all species. This usually takes the form of two independent teams of observers, but photographic platforms might also be feasible and should be developed further. It was recognized that additional and more detailed data on dive profiles of target species were required from all areas to facilitate the application of corrections for availability bias. These detailed data could feasibly be collected using satellite-linked tags, but more appropriately using short-term recoverable tag applications. The Group strongly recommended that efforts be made to obtain these data in Iceland, Greenland, and Canada.

Recognizing the difficulties in training observers for species identification on aerial survey, the Group recommended the compilation of a photographic identification guide for observers.

The Group was informed that a large scale aerial survey was being planned in the Mediterranean (with *Caterina Fortuna (Chair), Greg Donovan, Ana Cañadas and Alexei Birkunin (Chair of the ACCOBAMS Scientific Committee) constituting the Steering Group).* This presents an important opportunity for cooperation on the joint development of equipment and techniques. In addition a workshop on aerial surveys at the upcoming European Cetacean Society Conference might provide a venue for collaboration.

The Group charged the T-NASS coordinator, Desportes, with establishing a Technical Working Group, led by Pike and proposed to include Lawson, Heide-Jørgensen, Donovan, Palka, and Gilles, to develop further the protocols and equipment requirements for aerial surveys, with specific terms of reference compiled from the recommendations above. The Technical WG will provide this Group with an initial progress report including a timeline and budgetary implications in time for the 2012 meeting of the NAMMCO SC in April.

6.2 Ship surveys

A double-platform mode, allowing for the correction of biases inherent to the collection of data for distance sampling in cetacean sightings surveys, has been used in the T-NASS shipboard survey and has been recommended by the WG to be used again in future surveys. Desportes presented a review (Appendix 4 – SC/19/TNASS2/07) of the logistic implementation of double-platform mode in shipboard sighting surveys based on a review of the over 50 surveys which have used such a mode. She also reviewed data recording methods and the recent improvements that have been implemented in data collection. The current most-used methods are (1) the Independent Observer configuration (IO mode), with two-way independence between symmetrical teams of primary observers, and (2) the Trial Observer configuration (BT mode), with one-way independence between a primary team and a tracker team. Both methods rely on the identification of duplicate sightings, based on timing and position, between the two platforms, which can be done *in situ*, requiring an observer dedicated to the task, or later during the analysis.

The complexity of the overall field logistics is a combination of the mode itself, data logging and data collection operations. Distance data (distance and bearing to sightings) are key data items in distance sampling. Bias in these has the potential to introduce large bias in abundance estimates and therefore they need to be recorded with the greatest accuracy possible. In recent vessel-based surveys (SCANS-II; NMFS), devices have been introduced for trackers using binoculars for achieving greater accuracy in the measurement of distance data. These are the photogrammetric methods first implemented in SCANS-II as well as the use of electronic range finders implemented in the NEFSC surveys. The tendency has been towards real-time data entry and automatic data logging, with the introduction in SCANS-II of an integrated data collection system, enabling observers to validate and cross check data collected during the cruise. In the context of the T-NASS (Iceland and Faroes) target species mix of fin, minke, and pilot whale, the BT method (correcting both for $g(0)<1$ and potential responsive movement) seems the most appropriate (the Group did not exclude the possibility of improvements or employment of alternative methods).. The *in situ* identification of duplicate sightings, which requires a dedicated person and very good communication system between platforms, is resource intensive, but adds unique knowledge of the situation which can provide an independent check for errors in the sighting information recorded by the observers (*e.g.*, in the distance estimate to sightings). The successful use of Big Eye binoculars by the trackers is very ship-, platform-, and observer-dependent and therefore they are not recommended *a priori*.
The measurement of distance data using precision instruments was considered to represent considerable progress for this type of platform, and should be pursued, although the way this was implemented in the field should be improved and simplified, taking into account the newest software and hardware developments. The technical logistical requirements underlying shipboard sighting surveys have become increasingly complex. Such planning must include increased and thorough testing of the equipment both on land and *in situ*, and a thorough training regime for the both the cruise leaders and the observers.

Some general recommendations were provided and endorsed by the Group:

1. The use of the BT method, which allows correction both for $g(0)<1$ and responsive movement, seems the most appropriate in the context of the T-NASS mix of target species.
2. A good separation of the search areas and the requirement of detecting the animals before they have reacted to the vessels imply using binoculars which are more powerful than 7×50 binoculars. However, because the successful use of Big Eye binoculars is very ship/platform/observer dependent, the use of mid-range binoculars (which require less room and should be easier to use on less stable platforms) should be investigated.
3. The measurement of distance data with more accurate tools than traditional reticule binoculars and angle boards was considered a significant advance and should definitely be implemented in future surveys.

   a. The way this was implemented for the tracker in SCANS-II, CODA and T-NASS should be improved and simplified, taking into account the newest software and hardware developments. Photogrammetric methods as implemented in SCANS-II require that both the horizon and the sighting are visible on the pictures taken, which is not always the case for several reasons including the occasional presence of fog. The use of electronic range finders, which do not require the horizon in the field of view, should be investigated and developed further.
   b. Distance and angle measurement methods should also be developed for primary observers searching with unaided vision.
4. The use of real-time data entry and automatic data logging, with the introduction of an integrated data collection system offers potentially valuable possibilities for *in situ* data validation and for checking whether sightings procedures and protocols are followed by the observers. Their utilization should be pursued. The data collection system as implemented in SCANS-II should be improved and made more user-friendly and more robust, taking into account the latest hardware and software developments.
5. The logistics of shipboard surveys, including preparation, have become increasingly complex and time-consuming. At the same time, their successful implementation requires intensive and dedicated training of both cruise leaders and observers. Both should be taken into account when planning future T-NASS surveys.
6. Measurement by the Tracker of distances to the Primary’s sightings should be implemented to improve the accuracy of Primary estimates of distance.

The proposed SCANS-III survey presents an important opportunity for cooperation on the joint development of equipment and techniques.

The Group charged the T-NASS coordinator, Desportes, of establishing a Technical Working Group, under her leadership and proposed to include Gunnlaugsson, Hammond, Gillespie, Leaper, and Palka to develop further the protocols and equipment requirements for shipboard surveys, with specific terms of reference compiled from the recommendations above. The Technical WG will provide this Group with an initial progress report including a timeline and budgetary implications in time for the 2012 meeting of the NAMMCO SC in April.

6.3 Acoustic surveys

T-NASS 2007 acoustic data have not yet been fully analysed because of technical problems. Considering both the interest in the potential abundance estimates of sperm whales and the investment already made in acquiring the acoustic data (including purchasing the equipment), the WG and the SC had recommended at their last meetings that the analysis of these data be carried out again and the abundance estimate finalised. They urged NAMMCO Secretariat to find a suitable agreement with the Sea Mammal Research Unit (SMRU), so the analysis could be redone in a timely manner. Contact with the relevant person at SMRU has been made during this meeting and an initial agreement has been reached.

The work needed to progress with the analyses comprises one day for resetting the hydrophone separation parameters (by Swift). This will be completed before April 2012. Additionally, approximately one month is needed to analyse the data and the budget for this work should be presented to the SC meeting in April 2012.
There are four sets of acoustic equipment from the 2007 T-NASS currently stored in Iceland and the Faroe Islands. The Group recommends employing these in the context of the next T-NASS.

7. COORDINATION ISSUES

7.1 Timing

The year 2015 seemed to fit best with the national constraints as outlined in 5.1-5.8. Furthermore choosing 2015 as the survey year would allow:

1) Sufficient preparation time,
2) Highest chance of having all the national surveys happening concurrently,
3) Concurrency with ICES redfish surveys for Iceland and Russia (likely with possibility of having observers on board the vessels as in T-NASS 2007),
4) Concurrent with the likely year of the proposed SCANS-III survey,
5) Good overlap within the Norwegian survey cycle.

The group acknowledged that a large-scale harp seal survey is planned in Canada for the DFO fiscal year 2015-2016. The magnitude of the funding for the harp seal and T-NASS surveys make it unlikely that both will be funded in the same fiscal year. Lawson will investigate the possibility to hold the Canadian component of T-NASS in 2015.

Gunnlaugsson presented document IWC-SC/56/O5 where systemic information on seasonal distribution of cetaceans around Iceland, and in some instances over to Greenland, was collected by placing one or in most cases two observers on platforms of opportunity in some spring (May) and autumn (August) surveys in the period 1980-1995, and analyzed accordingly. Sighting rates of all main species are considerably lower during the spring. Sighting rates are higher during the mid-summer NASS surveys, but effort in these surveys was higher. In addition the NASS 1989 survey was a fortnight later than the other surveys. Sei whale densities were highest in 1989 at the southern survey area boundary 52°N during the latter half of the survey and are also relatively highest during the autumn surveys as also indicated from the catch information. For fin whales the catches have indicated a peak in June-July on the grounds west of Iceland, but the survey data can not preclude a later peak for the area in general. The same applies to minke and pilot whales. Partial aerial surveys in coastal Icelandic waters were conducted during 2003-2005 in the spring (April-May) and autumn (September), and are compared to the midsummer surveys in document SC/19/TNASS2/06 and IWC-SC/57/O8. Large variation between years and an apparent northward shift in distribution observed in the midsummer surveys (June-July) complicate the comparison, but a peak in minke whale presence later than July but before September can not be ruled out.

In general seasonal timing will be agreed upon at a later meeting. The general agreement was that surveys should be conducted as close as possible in time to avoid problems associated with any systematic directional movement of animals. In the meantime, the Group recommended that a series of short aerial surveys be conducted in Icelandic waters in July-August to investigate seasonal distribution in the coming years to identify the optimal seasonal timing for a survey. This could also be investigated through satellite tag applications but this seemed to have less prospect of success at present. The possibility of using existing data from bottom moored acoustic recorders should also be investigated.

7.2 Coverage

Aggregations of humpback and fin whales have been observed off East Greenland as far as 74°N (Heide-Jørgensen *pers. comm.*). This indicates that these species are found close to the coast and much further north than previous surveys have covered. Most previous surveys do not approach the East Greenland coast because of ice and fog. The Group considered that an aerial survey covering the East Greenland shelf from Kap Farvel to Northeast Greenland could be effective in this area. Due to recent catches of minke whales in Siorapaluk the west and southwest Greenland, the T-NASS survey area should be extended further north to Kane Basin. The Group highlighted the importance of ensuring the largest possible contiguous survey area. In this context the Group recommended that:

- The Norwegian planning group take this principle into account when allocating which area to survey in the year of the next T-NASS.
- The allocation of supplementary survey effort be considered in the coastal areas of eastern Baffin Island, Davis Strait, and southwest Greenland, given the possibility of impact and/or displacement of cetacean populations by proposed industrial activities (ice-breaking, shipping, seismic oil exploration) in Arctic Canada, and data indicating that cetaceans utilize these areas.
- The coastal area of East Greenland be included in the aerial effort.

7.3 Coordination with associated surveys

7.3.1 USA

Palka is a member of this Working Group which will enhance co-ordination with the dedicated US cetacean abundance surveys.

More information should be gathered on platforms of opportunity such as any north Atlantic research cruises of the Woods Hole Oceanographic Institute and other North American research institutions.

7.3.2 Other (SCANS-III, Mediterranean, SPM)

It was noted that T-NASS should co-ordinate the development of the project with activities in the SCANS-III, the ACCOBAMS-Mediterranean, and Saint-Pierre and Miquelon areas.

7.3.3. Coordination with "opportunistic" shipboard surveys (*ICES Redfish, Ecosystem Surveys, Others*)

In general opportunistic platforms could help in covering areas that would otherwise not be surveyed (Figure 10). However, experience from the 2007 T-NASS suggests that further care needs to be taken in collection of these data, particularly with regard to selection of observers and adherence to observer protocols. At least two observers should be present on the same platform, and must cooperate in collecting data. It cannot be expected that such surveys will produce unbiased estimates of abundance; they are however useful in determining cetacean distribution and relative abundance outside of the core survey area.

The value of such data is enhanced by the associated detailed environmental data often gathered by these surveys. Therefore, given the above conditions are met, the use of opportunistic platforms for the collection of both marine mammal and other data is encouraged concurrently to the next T-NASS. The areas covered by these platforms should be located in such a way (peripheral) so that the coverage of the core survey area would not be compromised if the data collected by the opportunistic platforms should not meet the quality requirements of the dedicated survey.

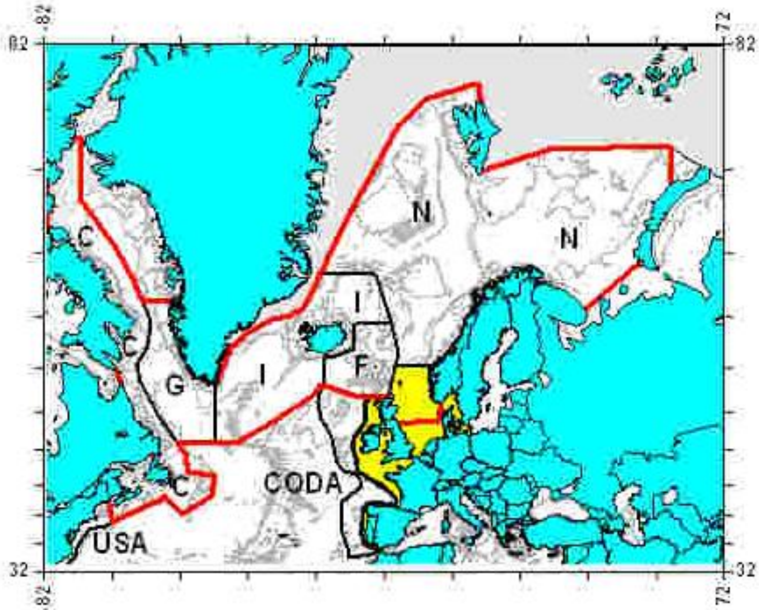


Figure 10. NAMMCO National Surveys with black boundaries and additional areas from additional synoptic surveys with red boundaries as in T-NASS 2007.

8. BUDGET

Nation	Area	Presumably covered by existing funding	Extra Funding required
Canada		Uncertain funding for 2015	
Greenland	West Greenland shelf	×	
	East Greenland shelf		×
	Southern Davis strait		×
	East Greenland north of Scoresby Sound		×
Iceland-Faroes	Irminger sea down to 55°N	×	
	Irminger sea south of 55°N		×
	South of Iceland-Faroe Islands to 55°N	×	
	South of 55°N		× (sei and pilot whales)
	East Iceland to Norway		× (important for pilot whales)
	Icelandic continental shelf	× (aerial)	
	Southern Norwegian Sea	×	
Norway	Jan Mayen block	Covered by Norway?	× probably
	Norwegian Sea (62-73°N)	most probable area Norway	
	Northern Greenland sea		× (could be possible)
	Spitsbergen/Barents		×

8.1 Integrated budget

The total budget for the 2007 T-NASS was 24,300 kDKK, including all expenses (also staff salaries) for preparation of the survey and the survey as such, but excluding data analysis. With an annual inflation at 3%, a similar level funding for the next T-NASS gives a budget of over 30,000 kDKK. The table above reflects the prospective budgetary commitment of the member countries and highlights the yet unfunded components. In addition there is a need for further funding for protocol development, equipment improvement and development and inclusion of platforms of opportunity. The Technical groups formed at this meeting will provide the necessary information.

8.2 External funding proposals

A project description and a proposal for funding should be developed by the T-NASS coordinator.

9. TASKS TO BE COMPLETED

9.1 Practical recommendations:

Under the leadership of the T-NASS Coordinator:

- Technical Working Group Aerial (6.1),
- Technical Working Group Shipboard (6.2),
- Project description to use for proposals.

Under the leadership of the NAMMCO secretariat (6.3):

- Feasibility of acoustic analyses from T-NASS 2007 data.

9.2 Publications/Deliverables

At its last meeting the AEWG considered necessary to appoint someone to take charge of coordinating this effort, and the Group recommended that this be done by Scientific Committee in cooperation with the NAMMCO Secretariat. In the absence of an appointment by the SC to date, this Group proposed Lawson as the Editorial Coordinator.

The following table, adapted from the report of the previous AEWG meeting, lists prospective items from T-NASS and earlier surveys to be prepared for a coordinated publication. The identified "Lead" is responsible for ensuring that all deadlines are met in completing the papers.

SUBJECT	SURVEY	LEAD
Introduction, general distribution	All	Lawson
Fin, sei, hump, blue	Ship+air	Víkingsson
Minke	Ship+air	Víkingsson
Pilot whales, Trends	Retrospective ship	Mikkelsen
Small toothed whales	Ship+air	Mikkelsen
Baleen whales	Can-air	Lawson
Harbour porpoises	Can-air	Lawson
Belugas	Can-air	Gosselin
Circleback/Correction factors (contact Palka)	SNESSA	Palka
Sperm whales	Ship acoustic	Gunnlaugsson
Baleen	Nils surveys 2002-7	Øien
Odontocetes	Nils surveys 2002-7	Øien
Large whales retrospective	Ship+air	Víkingsson

10. NEXT MEETING

This Group did not envisage the need to have a meeting before 2013.

11. ADOPTION OF REPORT

The report was adopted in a preliminary form at the end of the meeting. The final report was adopted by correspondence 10 March 2012.

Appendix 1

LIST OF DOCUMENTS

Document no	Title
SC/19/TNASS2/00	Practical Information
SC/19/TNASS2/01	List of Participants
SC/19/TNASS2/02	Draft Agenda
SC/19/TNASS2/03	List of Documents (this document)
SC/19/TNASS2/04	Daniel Pike, Aerial survey: state of the art and recommendations for the next T-NASS.
SC/19/TNASS2/05	Plans by jurisdiction
SC/19/TNASS2/06	Thorvaldur Gunnlaugsson. Aerial surveys off Iceland and minke whale distribution changes by season and over time.
SC/19/TNASS2/07	Desportes, Review of double platform implementation in shipboard sightings surveys.

BACKGROUND DOCUMENTS

Document no	Title
NAMMCO SC/18/07	NAMMCO Scientific Committee Working Group on Survey Planning (SPWG). Trans? North Atlantic Sighting Survey 2, First Planning Meeting. March 09-11, 2011 – Copenhagen
SC/18/AESP/05	Pike, Desportes, Gunnlaugsson, Mikkelsen and Bloch. Estimates of the relative abundance of pilot whales (*Globicephala melas*) from North Atlantic Sightings Surveys, 1987 to 2007.
SC/18/AESP/07	Pike, Gunnlaugsson, Vikingsson and Mikkelsen. Estimates of the abundance of sei whales (*Balaenoptera borealis*) from the NASS Icelandic and Faroese.
SC/17/AE /04	Pike et al. Estimates of the abundance of humpback whales (*Megaptera novaengliae*) from the T-NASS Icelandic and Faroese ship surveys conducted in 2007
IWC-SC/56/O5	T. Gunnlaugsson, G. A. Víkingsson and D.G. Pike. Comparison of sighting rates from NASS and other dedicated cetacean vessel effort around Iceland during 1982 to 2003
SC/19/TNASS2/O/01	C.R. Joiris. 2011. A major feeding ground for cetaceans and seabirds in the south-western Greenland Sea. *Polar Biol.* 34:1590-1607.
SC/19/TNASS2/O/02	Gillespie *et al.* 2010. An integrated data collection system for line transect surveys.
SC/19/TNASS2/O/03	Leaper *et al.* 2010. Comparisons of measured and estimated distances and angles from sightings surveys
SC/19/TNASS2/O/04	SCANS-II Shipboard Estimation Method Review
SC/19/TNASS2/O/05	Aerial surveys for observation of seabirds and marine mammals within the maritime domain of mainland France and its adjacent

	waters.
SC/19/TNASS2/O/06	Projets oiseaux et mammiferes marins en france metropolitaine
SC/19/TNASS2/O/07	Víkingsson, G., Pike, D., Lawson, J.W., Heide-Jørgensen, M.-P., Øien, N., Desportes, G., Gunnlaugsson, T., Gosselin, J.-F., Mikkelsen, B., Hansen, R., Wtting, L., Zabavnikov, V., and Acquarone, M. 2011. Changes in distribution and abundance of cetaceans detected using 20 years of North Atlantic Sightings Surveys. ESSAS Open Science Meeting, Seattle, WA.
IWC-SC/57/O8	T. Gunnlaugsson. Density by season in aerial sightings surveys around Iceland in 2003 and 2004. Preliminary report.

Appendix 2

AGENDA

1. CHAIRMAN'S WELCOME AND OPENING REMARKS
2. ADOPTION OF AGENDA
3. APPOINTMENT OF RAPPORTEURS
4. BACKGROUND FOR AND RATIONALE BEHIND A NEW NASS
5. OVERVIEW OF PLANS AND AVAILABLE RESOURCES BY JURISDICTION
   - 5.1 Canada
   - 5.2 Greenland
   - 5.3 Iceland
   - 5.4 Faroes
   - 5.5 Norway
   - 5.6 EU Waters
   - 5.7 Russian Federation
   - 5.8 USA
6. REVIEW OF METHODOLOGY FROM PREVIOUS SURVEYS
   - 6.1 Aerial surveys
   - 6.2 Ship surveys
   - 6.3 Acoustic surveys?
7. COORDINATION ISSUES
   - 7.1 Timing
   - 7.2 Coverage
   - 7.3 Coordination with associated surveys
     - *7.3.1 USA*
     - *7.3.2 Other (SCANS-III, Mediterranean, SPM)*
   - 7.4 Coordination with "opportunistic" shipboard surveys (*ICES Redfish, Ecosystem Surveys, Others*)
8. BUDGET
   - 8.1 Integrated budget
   - 8.2 External funding proposals
9. TASKS TO BE COMPLETED
10. NEXT MEETING
11. ADOPTION OF REPORT

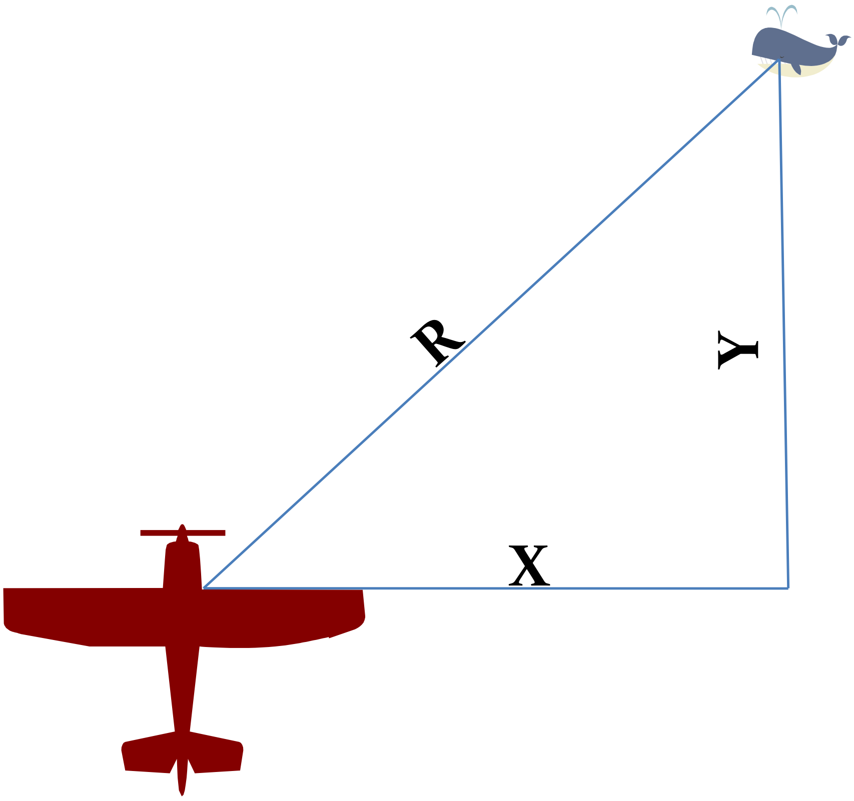
Appendix 3

AERIAL SURVEY:

STATE OF THE ART AND RECOMMENDATIONS FOR THE NEXT T-NASS

by

Daniel Pike



AERIAL SURVEY: STATE OF THE ART AND RECOMMENDATIONS FOR THE NEXT T-NASS

by

Daniel Pike, ESOX Associates, Ontario, Canada

INTRODUCTION

Aerial survey has been used in the NASS and T-NASS surveys since the first one carried out in 1987 (Pike *et al.* 2009, Hiby *et al.* 1989), primarily in coastal Icelandic and West Greenland waters. More recently the T-NASS 2007 survey included a large scale aerial survey off Atlantic Canada (Lawson and Gosselin 2008). In addition aerial survey is used off the US east coast (Palka 2005) and was used in a recent survey around the Faroe Islands (Gilles *et al.* 2011).

Aircraft can cover a large area in a short time. Aerial surveys are therefore generally preferred under one or more of the following circumstances: 1) areas with very geographically complex coastlines; 2) areas with short windows of acceptable weather; and 3) during animal migrations when the survey must be completed quickly. In addition, the altitude of the viewing platform allows simple and accurate measurement of distances using declination angles. Finally, aerial surveys are usually less expensive to conduct than ship surveys, as aircraft are less expensive to charter.

Most survey aircraft lack the range and speed to operate in the far offshore. In addition their relatively high speed means that a sometimes large proportion of whales are submerged during the passage of the aircraft, which can bias abundance estimates. Finally, there are significant safety issues with using aircraft offshore, although this is certainly true of ships as well.

Field methods, especially in the Icelandic aerial survey, have changed little since the survey was initiated in 1987. In 2011, the NAMMCO Scientific Committee Working Group on Survey Planning decided to commission a study to compare and contrast survey methodologies presently in use, and consider their advantages and disadvantages for use with the NASS species mix. I decided to approach this task by first reviewing the recent literature on aerial surveys to determine the state of the art, then using this information to provide recommendations for the improvement of aerial surveys in the NAMMCO area of interest.

MATERIALS AND METHODS

A non-exhaustive review of the recent (2001 and later) literature pertaining to aerial surveys for cetaceans was conducted. Searches were carried out using the *ProQuest* system searching the *Biological Sciences* database, primarily using the search terms “aerial survey”, “cetaceans” and “whales or dolphins or porpoises” ((“aerial survey”) AND (cetaceans OR whales OR dolphins OR porpoises)). As this sources primarily the published literature, additional searches were carried out on IWC documents (http://iwcoffice.org/publications/doclist.htm), and lists of unpublished documents held by DFO (http://www.meds-sdmm.dfo-mpo.gc.ca/csas-sccs/applications/publications/index-eng.asp) and NOAA (http://www.lib.noaa.gov/noaainfo/pubsource.html). The search was selective and only those documents that explicitly described surveys conducted in the past 10 years were chosen.

A database of surveys conducted in the past 10 years was compiled, including factors relating to survey type, target species, survey design, field methods, equipment, photography and/or video, and analysis. This database was used to assess the present state of the art in aerial survey, and to provide examples that might be applicable in the NASS study area and situation.

RESULTS AND DISCUSSION

A database including 48 surveys, most but not all conducted since 2001, was compiled (Appendix 1). The surveys were concentrated in the northern and western hemispheres, and appeared to be most common in the far north (Fig. 1). All surveys were conducted in nearshore (<100 nmi from shore), with the exception of a single-flight survey conducted in mid-Baffin Bay (Laidre and Heide-Jørgensen 2011).

Survey type

Surveys were classified into 4 general types. The majority (75%) were visual line transect surveys. Cue counting surveys accounted for 13% of the total, and these were carried out by only 2 groups with the author involved in both groups. Cue counting was applied to minke whales (common and Antarctic) only. Two surveys (4%) used a combination of line transect methodology and still photography to census large concentrations of whales; this methodology was applied to narwhal and beluga only. Finally 4 surveys (8%) used still photo strip sampling methods. Three of these were for beluga in Canada while one had minke whales as the target species (Witting and Kingsley 2005). No surveys used video exclusively and only one survey (Heide-Jørgensen and Acquarone 2002) used video to count animals.

Target species

In cases where target species were given, they were divided into 3 categories: Small, including small dolphins and porpoises; Medium, including large dolphins (narwhal, beluga and killer whales) and minke whales; and Large, including whales larger than minke whales. Large and medium sized whales were the targets of a similar proportion of the surveys (29% and 35%), while small whales were explicitly targeted in 23%. Twelve percent of the surveys targeted a mixture of species and sizes. These results suggest that aerial survey is suitable for nearly all types of whales, with the possible exception of deep-diving species such as sperm and beaked whales, which were not targeted by any surveys.

Stratification

The main purpose of stratification is to improve the precision of abundance estimates by concentrating survey effort in areas where high density is expected. Almost all of the surveys used some form of stratification, some based on prior knowledge of animal distribution, and some based on operational factors such as coastline shape.

Clearly stratification is advisable in cases where distribution is predictably concentrated in certain parts of the survey area.

The stratification of the Icelandic aerial survey was based on the observed distribution from a previous survey (Donovan and Gunnlaugsson 1989). This stratification appears to be rather effective, based on the observed number of sightings relative to survey effort (Fig. 2). However minke whale distribution has changed substantially since 2001. For example Block 8, which up to 2001 had high densities of minke whales, had low density in 2007 and 2009 and is therefore oversampled in these surveys. Such changes in distribution are not readily predictable and may reverse, so it is debatable whether the survey stratification should be changed to accommodate them.

Transect layout

Two types of transect layout were used in aerial surveys: Parallel lines, equal spaced (P-ES) accounted for 54% of the sample, while Zig-Zag, equal spaced (Z-ES) accounted for 29%. A further 15% used a mixture of both types. In almost all cases the transects were oriented across the prevailing depth gradient, generally from shore out to sea.

The P-ES layout is often preferred because it by definition results in equal coverage probability across the stratum, no matter how the stratum is shaped. However it does require ferrying between transects which can increase off-effort flying time. The Z-ES layout produces even coverage probability only for rectangular strata, although this issue can be reduced by stratifying complex areas and designing the transects using a convex hull or bounding rectangle (Thomas *et al.* 2010). Ferrying between transects is reduced but not eliminated altogether as the use of a convex hull or bounding rectangle to design the transects results in the transect ends being cut off in strata with concavities.

Other designs are at least potentially suitable for some circumstances. Randomly spaced parallel lines could work in circumstances where a systematic design might result in bias. An equal angle zig-zag (Z-EA) design has features similar to the Z-ES design. An adjusted angle zig-zag is also available in Distance (Thomas *et al.* 2010), but it does not appear to have been implemented in practice.

Ferrying time is not usually as large an issue for aerial surveys as it is for ship surveys. Unless coverage is low and transect spacing is very large, ferrying lasts only a few minutes and provides a welcome rest between transects for the observers. As equal coverage probability is an assumption for design-based analyses, the P-ES design should be preferred under most circumstances. Exceptions might include very large strata with low coverage, or rectangular strata in which the Z-ES or Z-EA designs will result in even coverage.

The Icelandic aerial survey appears to use a type of Z-ES design although a convex hull or bounding rectangle was apparently not used to define the transects as all transects intersect. Essentially the same design, with very minor modifications, has been used in every survey since the first in 1987 (Pike *et al.* 2009). Since the design was developed before survey simulation software was available (*e.g*. Distance), the coverage probability distribution of this design has not been assessed. Certainly the outer strata are not problematic as they are rectangular. However the Icelandic coast is highly indented in some areas so it is likely that coverage density is not evenly distributed in some inner strata; visual inspection suggests this is true. This could potentially bias abundance estimation if coverage density is correlated with animal density. If estimating absolute abundance is the main goal of the survey, the characteristics of this design should be assessed or changed to a P-ES design. However, if assessing trends in abundance is a major goal, maintaining the same design, as has been done over 6 surveys since 1987, is advantageous as any bias inherent in the design is maintained over surveys.

The Canadian T-NASS survey used P-ES in the Gulf of St Lawrence and Southern Nova Scotia areas, and Z-ES in the Newfoundland and Labrador area. The latter portions of the survey were designed and tested using Distance software and found to produce acceptable coverage distribution. The Faroese aerial survey conducted in 2009 used a P-ES design (Gilles *et al.* 2011), as did the 2007 Greenlandic survey (Heide-Jørgensen *et al.* 2010).

Platforms

All visual aerial surveys but one (98%) used fixed high-wing aircraft. One visual survey used a helicopter. Only photo surveys without observers used low-wing aircraft. The most common aircraft used was the Cessna 337 Skymaster followed by the Partenavia P-68 Observer. Both of these aircraft are among the smallest twin engine aircraft available. Twin engine aircraft are considered safer for offshore surveys. However neither of these aircraft is large enough to accommodate a full double platform configuration (see below), for which a larger plane such as a DeHavilland Twin Otter or Aerocommander is required.

Operating altitude varied from 500 to 1500 ft for visual surveys, and was most commonly (61%) between 500 and 750 feet. Surveys conducted at higher altitudes tended to be for large whales and, surprisingly, beluga whales. An altitude of 600 ft is standard for harbour porpoise surveys.

The majority of surveys (58%) used a single platform configuration with 1 observer on each side. A further 21% used a full double platform configuration (2 platforms, 2 observers per platform) while 16% used a partial double platform configuration (2 platforms, one of which has only one observer). However the frequency of the latter 2 categories is somewhat misleading as most cases were by a single survey group. In all cases where double platforms were used, the platforms were visually and acoustically isolated from one another. Single platform surveys can use smaller aircraft and require fewer observers and are therefore less costly than other configurations. However assessing perception bias, which is substantial for some target species, is impossible using a single platform configuration unless specialized methodologies, such as “circle-back” (see below), are used.

Of the single platform surveys, 80 % used bubble windows 47% of the double platform surveys used bubble windows on both platforms while 35% used a flat window on the secondary platform. A further 18% used flat windows on both platforms. Bubble windows are clearly advantageous because they allow a better view of the trackline and forward of the aircraft. However they are expensive and are not available for all aircraft types. The effective use of a bubble window also requires a seating position that is fatiguing for observers.

Circle-back

The circle-back or "racetrack" type of survey provides an alternative to double platforms that can be implemented in a small aircraft (Hiby 1998, Hiby and Lovell 1998). In brief, a suitable sighting triggers a protocol wherein the aircraft breaks off transect, circles and rejoins the transect some distance back from the sighting that initiated the circle-back. This segment is then re-surveyed. The second coverage of a portion of the transect ("trailing leg") can be seen as a second platform. The entire process before the location of the initial sighting is re-surveyed must take longer than the average dive cycle length of the target species, but not so long that the initially sighted pod would be likely to have moved off. For harbour porpoise surveys a single circle-back takes about 3 minutes. Sightings from the first and second segment are assigned a duplicate probability based on an objective model. These data are then used to estimate the value of $g(0)$, in this case incorporating both perception and availability biases.

This method was used by 4 (8%) of the surveys, and only for harbour porpoises (but see Palka 2005). Presumably the duplicate probability model would have to be modified for other species, and larger circles would be required for species with longer dive cycles. A longer circle-back would make it less probable that a pod would be available for resighting (*i.e.* it could move away from the trackline). Therefore this method appears to be most useful for slow-moving species with a short dive cycle, such as the harbour porpoise or perhaps the minke whale, and less so for faster species with longer dive cycles, such as the fin whale.

The main advantages of the methodology are: 1) no necessity for double platforms, thus enabling the use of a smaller aircraft and fewer observers; and 2) estimation of $g(0)$ incorporating both perception and availability biases (although these cannot be discriminated by the method). The main disadvantage would be the extra flying time required to perform the circle-backs, which can be considerable to obtain acceptable precision (Palka 2005, Scheidat *et al.* 2005, Berggren *et al.* 2004). Exact timing of sightings, careful flying and precise navigation are critical to making the method work. It has also proven best to gather data outside of high-density areas, as additional sightings on the resighting leg make it difficult to assign duplicates (Scheidat *et al.* 2005).

Evaluation

At present the "gold standard" configuration is a 2+2 double platform, both platforms with bubble windows. Using this configuration perception bias can be estimated through sight-resight methods (Laake and Borchers 2004). A double platform on only one side of the plane is also acceptable if sufficient sightings and sight-resight trials

Can be generated in this way. The circle-back method appears to be successful for harbour porpoise surveys but has not been proven for other species.

The Icelandic aerial survey has used a double platform with the “secondary” platform surveying on one side only. However the secondary platform does not have a bubble window and therefore does not have a clear view of the trackline beneath the aircraft. In practice this means the secondary observer almost never has sightings closer than 150 m from the aircraft. As *g*(0) is the proportion of sightings that are detected at distance 0, nearby sightings are the most important for its estimation, and if there are no trials at very low distance its estimation depends on extrapolation (*e.g.* Borchers *et al.* 2009). Clearly a second bubble window platform would be preferable but is not possible using the Partenavia P-68. A second video or photographic platform might be an alternative (see below).

The Canadian component of T-NASS 2007 used two platform types: a single platform configuration with bubble windows in the Gulf and Southern Nova Scotia areas, and a double platform on one side, with bubble windows at all stations in the Newfoundland and Labrador areas (Lawson and Gosselin 2008). The latter configuration allows estimation of perception bias while the former does not. The Faroese survey conducted in 2009 used a single platform (Gilles *et al.* 2011). However this survey had harbour porpoise as a target species and the observers were well-characterized in previous surveys which used the circle-back method. Therefore a *g*(0) correction from previous surveys was applied.

Data acquisition

All visual surveys recorded radial distances using a hand-held, mechanical inclinometer. Electronic inclinometers are available but the ones I have investigated are difficult or impossible to use quickly. This would appear to be an area ripe for technological innovation. Many mobile phones and game controllers have accelerometers and it would certainly be possible to devise a system that would record angle measurements in real time.

Almost all visual surveys recorded radial distance when the sighting was directly abeam of the aircraft. Only some cue-counting surveys recorded lateral angles before the sighting came abeam, using a simple angle board. No studies reported specifically how the observers determined when the sighting was abeam: this is usually left to the judgement of the observer.

Data recording systems came in two basic types: those with a dedicated data recorder (DR), and those in which observers recorded their own observations (OR). DR-type surveys, in which one crew member acted as a dedicated data recorder, comprised 40% of the visual surveys. The data recorder is in constant contact with the observers and usually uses a data entry program and laptop. A popular data recording software package for this purpose, VOR (Hammond *et al.* 1995), records and maps navigational output from the GPS while allowing the data recorder/navigator to record sightings and environmental information in real time. Other surveys used other data entry programs or even pen-and-paper to record data. Minimal requirements for such a system are: 1) a record of time and location, generally provided by the GPS data stream, and 2) a time stamp with every observation, which can be related to location.

In the remainder of the visual surveys (60%), the observers recorded their own observations, generally through time-stamped vocal recordings. These recordings can be georeferenced through merging with the GPS data stream. Such systems can be very simple, with observers simply recording their observations into digital voice recorders. Other systems integrate the GPS data stream directly with the voice recordings. Of course a separate recording channel is required for each observer.

DR systems have the advantage that data are entered in the "field", eliminating post-flight data transcription. This enables the survey leader to keep close track of observer performance in real time and correct any problems as they arise. A DR system is required for a circle-back type survey as circle-backs are triggered by observations in real time and careful navigation is required. An additional advantage is that the observers can rotate between the observation and data recording positions, allowing them some rest. A major disadvantage can be that one space on a very expensive platform is used for a task that could be done on the ground. However this is not an issue if the space used by the data recorder could not be otherwise utilized. It is possible that the data recorder can become overwhelmed in areas with a high density of sightings. For this reason a DR system is not usually feasible for double platform configurations, when multiple observations coincident in time can be expected. Finally, there is often a slight time lag between making an observation and having it recorded. While this is not necessarily an issue for conventional line transect surveys, it is for cue-counting and circle-back surveys which rely an accurate timing to estimate radial distances and duplicate probability respectively.

All surveys using a double platform configuration used an OR system, as did 38% of those using a single platform. The advantages of the system mainly reflect the disadvantages of a DR system: possible better utilization of aircraft space, more accurate timing and the creation of a permanent record that can be analyzed repeatedly. The main disadvantage is the necessity for post-flight transcription. This latter issue can be serious if there is no opportunity for data transcription during the survey, because observers should be monitored consistently. In a worst case this can lead to data loss through an undetected malfunction, as happened in the 2009 Icelandic aerial survey (Pike *et al.* 2009).

Evaluation

The Icelandic aerial survey has used an OR system since its inception. As mentioned an OR system with accurate and identical timing on all channels is an absolute requirement for cue counting. In this survey the flight leader recorded environmental conditions navigational information in addition to his own sightings. This information was transcribed post-flight, in 2009 with the assistance of ground personnel. The recording system is now somewhat dated technically and recommendations for its improvement are provided in Appendix 1.

The Canadian component of T-NASS used a modified DR system in which observers recorded the time of their observations using a keyboard and were then queried by the data recorder for the details of the sighting. This latter innovation improves the accuracy of sighting times which are important for duplicate matching. In addition each observer was equipped with a notepad to record details of sightings in cases where the data recorder was engaged. The data recorder used VOR software to record sightings and environmental conditions. The reliability of this system might be improved if the observers recorded their observations vocally instead of using notepads, as memory can be faulty and note taking diverts observer attention.

The Faroese 2009 survey used a DR system with VOR software. The survey was modelled after harbour porpoise surveys conducted using circle-back in Germany and elsewhere (Gilles *et al.* 2011), even though the survey itself did not use circle-back.

There are advantages to recording observations vocally, especially accurate timing of observations and creation of a permanent record. Some observers (including me) have difficulty remembering the details (*e.g.* angles and headings) of a sighting within moments of making it. Therefore, I recommend that observers record their observations vocally even in cases where a data recorder is used. In addition an OR system is probably essential for any double platform configuration.

Some form of DR, wherein the data recorder also acts as navigator, is probably essential for a circle-back survey, as adaptive decision making and careful navigation are required for this survey type. Even in surveys of this type, however, recording observations vocally is recommended for the reasons noted above.

Video and still photography

Of the 48 surveys assessed, 4 (8%) were classified as primarily photographic. Three of these targeted beluga and/or narwhal. The remaining one (Witting and Kingsley 2005) had minke, fin and humpback whales as the primary target species. This latter survey is generally considered to have been unsuccessful because so few whales were detected on the photos and abundance estimates were hence much lower than comparable visual surveys in the same area (West Greenland).

Of the 44 visual surveys, 6 incorporated video, 11 used still photography and 5 used both. Of the latter 4 were done by the same survey group (Heide-Jørgensen *et al.*).

Although 6 surveys used video, only 1 (Heide-Jørgensen *et al.* 2002) actually used the system to count whales. In this West Greenland survey a single video camera was used to monitor the trackline. Video monitoring was essentially used as a second platform and video detections were used as trials for the visual observers in a sight-resight analysis. The remainder of the surveys that used video used it for habitat monitoring, mainly for ice cover (Heide-Jørgensen *et al.* 2002, 2007, 2009, 2010, Laidre *et al.* 2011). Other surveys did not report any use of the collected video.

Only 2 of the primarily visual surveys that incorporated still photography used it for counting whales. One narwhal survey (Asselin *et al.* 2011) used an adaptive survey design wherein a photographic strip survey was triggered when large concentrations of narwhal were encountered. Similarly Richard (2005) reported a beluga survey that used photo-strip methodology to census estuarian concentrations. Others used photography for habitat classification, confirmation of group sizes, photogrammetry and adult/calf classification but these results were generally not reported in detail and were secondary to the visual survey results.

Evaluation

The use of video and still photography in aerial surveys is now much less expensive due to the progress made in digital photography and especially data storage. The latter used to be a significant barrier as hours of video or thousands of photographs required a substantial amount of space; however very large capacity hard drives are now inexpensive, compact and readily available.

The use of still photography as a census method has been largely limited to highly visible species that aggregate in large numbers, most often narwhal and especially beluga. It has been less successful for more cryptic species that do not aggregate, such as minke and fin whales. In the latter case the main barrier is certainly detecting whales on the photos, when the vast majority of sometimes 10's of thousands of photos will not contain whales. This can be very difficult as a surfacing whale, photographed instantaneously, can be very difficult to distinguish from a wave or other disturbance. Even if it does appear to be a cetacean it may be impossible to identify to species from a single photo. So far, software to detect whales on vertical photographs has not been developed.

Video may offer an advantage here as the human eye more readily detects movement against a background. My own experience with the use of video in Antarctica (Kelly *et al.* 2010) suggests that medium size species such as killer and minke whales can be readily detected, however these data have not been formally analyzed (N. Kelly pers. comm.). Mellor and Maher (2008) found that marine birds were readily detected and identified to species using an HD video system flown at 600 m, which would certainly imply that cetaceans could be detected as well.

Both types of photography provide a permanent record of the survey that can be analyzed post-survey. For surveys that use both visual observers and photography, the camera is clearly independent from the observers and can provide a second "platform" for estimating perception bias through mark-recapture. Even if not used for this purpose, the photographic or video record can be used as an adjunct to the visual observations to more accurately estimate perpendicular distances, confirm species identity and group size and composition, measure animal size and perhaps individually identify animals.

The Greenlandic aerial survey portion of T-NASS 2007 used both video and still photographic surveillance of the trackline. Neither was used in any subsequent data analysis (Heide-Jørgensen *et al.* 2010). The Greenlandic system is interesting however as it is a fully integrated data collection system for spatially related video, still photos and multichannel observer recordings. Video and photos collected using the same system have been used for habitat classification in other analyses (Heide-Jørgensen *et* *al.* 2002, 2007, 2009, Laidre *et al.* 2011). No other T-NASS aerial survey used video or still photography.

The cost of a video and/or still camera system is moderate, especially when compared to other costs (such as aircraft time) of a survey. The systems are lightweight, compact and generally do not take up space that could be otherwise used. Therefore such a system can be used even with a small aircraft such as a Partenavia. In fact a video system would seem particularly valuable in small aircraft that do not have space for 2 sets of observers. Even if the collected data is not immediately used in estimating abundance, it can be stored and analyzed at any time in the future. Therefore there seems little reason not to include a camera system in future aerial surveys.

Analysis type
While data analysis is not a primary focus of this review, I present it briefly here because the type of analysis that is possible is generally dictated by the type of data that is collected. Classified broadly by analysis type, 35% used mark-recapture distance sampling (MRDS). Of these 10% were cue counting surveys while the remainder used line transect methodology. All of these by necessity used a double platform configuration to generate the sight-resight data required for this technique.

Conventional distance sampling (CDS) techniques were used by 19% of the surveys, while 10% used multiple covariates distance sampling (MCDS). The remainder of the surveys used more specialized techniques such as CDS combined with circle-back (6%) and encounter rate mapping (21%). Photographic surveys used a strip transect approach (8%).

Bias correction
Estimation of the proportion of visible pods that are missed by observers (perception bias) requires sight-resight data generated by a double platform configuration, either within a single aircraft or through the circle-back technique. Perception bias was estimated and corrected in 46% of the surveys; of these 35% used MRDS while the remainder used circle-back. The remainder (54%) of the surveys did not estimate this bias.

The proportion of whale pods that are submerged during the passage of the aircraft and therefore not available to be seen (availability bias) presents a different problem for aerial surveys as it usually cannot be estimated using data from the survey alone. An exception here is the circle-back technique, used in 8% of the surveys, which provides data to estimate perception and availability bias simultaneously; however the two biases cannot be discriminated in this type of analysis (Hiby 1998, Hiby and Lovell 1998). The cue-counting technique, used by 10% of the surveys, estimates the density of whale behaviours or cues, usually dives or blows, in the survey area. The rate at which the animals cue must be estimated separately outside of the actual survey, generally through observational studies and/or tagging experiments. The combination of cue rate and cue density provides an estimate of abundance that is not biased by availability (Hiby and Hammond 1989). The remainder of the surveys that did correct for availability bias (33%) incorporated an estimate of near-surface availability, generated from observational or tagging studies, to estimate the bias.

In the latter methodology the proportion of whales at or near the surface is used as a multiplier to correct for availability bias. The depth range at which whales are considered visible depends on water clarity and other factors, and is sometimes assessed using artificial targets (*e.g.* Heide-Jørgensen *et al.* 2009, 2010). For example, if half of all whales are, on average, within the visible depth range, the survey estimate might be doubled. However, as this is an "instantaneous" rate or proportion, this is only true if the sighting process is also instantaneous, as for example is a photograph. If the instantaneous availability proportion is used to correct a survey in which the sighting process is not instantaneous, the estimate may be "overcorrected" and therefore positively biased. The length of time that a sighting is potentially in view of an observer (Time in View, TIV) depends on the observer's field of view and the speed of the aircraft. If TIV is known or can be estimated, this can be combined with information on the dive cycle of the target species to estimate availability bias (McClaren 1961, Laake *et al.* 1997).

Unfortunately, few aerial surveys actually record the exact time at which an animal is sighted: most only record the time at which the sighting passes abeam of the aircraft. Both times must be recorded to estimate the length of time the sighting was in view of the observer. Perhaps as a result, 27% of the surveys, or 81% of those that used this method of estimating availability, applied the instantaneous availability proportion without accounting for TIV. Only 3 surveys (6%) explicitly incorporated TIV in estimating availability bias, and one of these (Lawson and Gosselin 2011) did not record TIV but estimated it from platform speed, altitude and sighting distances.

The TIV depends on a number of factors including aircraft speed and altitude, observer searching pattern, the availability of bubble windows, and the visibility of the target. The latter depends on target size and cue type, as well as environmental conditions. Generally speaking TIV will be longer for large conspicuous species such as humpback whales and shorter for small cryptic species such as harbour porpoises. Heide-Jørgensen *et al.* (2010) estimated that minke whales were in view of observers for an average of 2.6 seconds (CV 0.29) during an aerial survey off West Greenland. This can be very dependent on the searching pattern of the observers: the mean TIV for minke whales from a cue counting survey around Iceland in 2009 was 8.3 seconds (CV 0.90) (D. Pike unpublished data).

Evaluation

The Icelandic cue counting surveys should theoretically provide unbiased estimates of minke whale abundance because they incorporate a double platform configuration to estimate perception bias and cue counting is not biased by availability (see above). The double platform configuration used is however not fully satisfactory as the secondary platform has a poor view below the aircraft. Perception bias may therefore be poorly estimated in some cases. The incorporation of a video and/or photographic platform, or the use of a larger aircraft with 2 sets of bubble windows, should be seriously considered for this survey.

The collection of radial distances to cues forms the basis of cue counting. Unlike in some line transect surveys, forward detection distances, and therefore TIV's, are collected for every sighting. To provide an alternative estimate of abundance, these data could be analyzed as a line transect using MRDS methods, then corrected for availability using the TIV distribution and available data on minke whale dive cycles (summarized by Lawson and Gosselin 2011). Such an analysis would be useful for comparison with the extant cue counting estimates and is strongly recommended.

The Canadian component of T-NASS 2007 used MRDS to estimate perception bias for the Newfoundland and Labrador portions of the survey (Lawson and Gosselin 2011). The Southern Nova Scotia and Gulf of St Lawrence did not incorporate a double platform. As perception bias nearly always exists and can be very substantial, the use of a double platform configuration in all areas is strongly recommended.

Lawson and Gosselin (2011) used published dive cycle information and estimated TIV to provide a correction for availability bias for some species. TIV was estimated using the largest perpendicular distance for a given species and assuming that observers searched in a semi-circular pattern. Forward distances and therefore TIV's were estimated trigonometrically. This rests on assumptions about observer behaviour, so the direct recording of forward distances would provide a more certain estimate of TIV. This is not feasible using the data collection system as was implemented in 2007 (Lawson and Gosselin 2008), so the development of a system that would facilitate this is recommended.

All surveys that use dive cycle information and TIV to estimate availability bias are of course dependent on the quality of the dive cycle information available. As diving behaviour may change with location, season or time of day, ideally the dive cycle data should come from the survey area, coincident in time with the survey. However, these are rarely achieved; (but see Innes *et al.* 2002).

The Faroese survey conducted in 2009 used MCDS analysis combined with an availability/perception bias correction derived from other surveys using the circle-back technique (Gilles *et al.* 2011). While the methodology and observers used in the survey were the same as those for which the availability/perception correction was derived, a survey-specific estimate would clearly be better. If this survey is conducted again, circle-back or other techniques to estimate availability and perception bias should be incorporated.

Use of unmanned aerial vehicles (UAV)

Unmanned aerial vehicles (UAV) are pilotless aircraft that are either remotely controlled from the ground, autonomous to some degree, or both. The most highly developed UAVs are available for military applications but civilian UAVs are also available. In fact the development of UAVs is a burgeoning field: Koski *et al.* (2010) estimated that more than 200 UAVs available or under development in the USA alone.

Koski *et al.* (2010) provide a thorough evaluation of the available UAVs and their application to surveys of marine mammals, and I will not replicate that here. Koski *et* *al.* (2010) concluded that most available civilian systems did not meet the minimum requirements for a marine aerial survey, but that several candidate systems might do so in the near future. Regulatory hurdles that preclude the operation of UAVs without special dispensation remain a serious issue in some jurisdictions. The best UAVs are presently too costly for most survey groups, but costs will likely come down as UAVs are further developed.

As UAVs applied to whale surveys will use HD video and/or still photography, the adoption of these technologies in manned survey platforms will simplify the transition to UAVs when they become more readily available.

CONCLUSIONS AND RECOMMENDATIONS

A review of aerial surveys conducted over the past 10 years suggests a general lack of innovation in field methodologies. Most surveys used 2 observers only and either did not correct for any biases, or did so using a simple (and erroneously applied) instantaneous availability rate. All observers continue to use mechanical inclinometers designed for forestry to measure angles, in a time when the simplest mobile phone or game controller incorporates a GPS and accelerometer. That said, the review provided several ideas for improvement of the T-NASS aerial surveys, especially in the areas of data acquisition, bias correction and the use of video or still photography.

Certainly the most exciting areas of development in aerial survey are in the use of photography, especially HD Video. The advantages of having a permanent record of a survey, rather than relying solely on inherently unreliable human observers, are obvious. Another area of rapid development is in the use of UAVs, but these are not yet ready for wide application to marine surveys. Certainly we can expect rapid development of aerial survey techniques in the next decade.

General recommendations are outlined below.

Survey design

1. The stratification of the Icelandic aerial survey is generally effective for minke whales. However distribution does change between surveys and an adaptive approach, wherein the survey area is first covered at low effort and then additional effort is applied to areas of high density, should be considered.
2. A systematic design using parallel equally spaced transects is best for most surveys as it always results in even coverage. Zig-zag designs may be preferable for very large, low coverage strata where ferrying time is an issue, or rectangular strata.
3. The transect layout used in the Icelandic aerial survey results in uneven coverage in the inner strata, although this has not been quantified. Modification of this design will depend on the competing priorities of survey comparability and unbiased abundance estimation
4. The designs of the Canadian T-NASS and Faroese 2009 surveys are adequate. Future changes in stratification could be based on observed animal density.

Platforms

1. All surveys should use double platforms, both platforms with bubble windows
2. The secondary platform used in the Icelandic aerial surveys is inadequate as it does give a good view close to the aircraft. A larger aircraft and/or the use of a photographic secondary platform (see below) should be considered.
3. One of the aircraft used in the Canadian T-NASS did not have a double platform configuration. Future surveys should have double platforms on all aircraft.
4. The circle-back method appears to be successful for harbour porpoise surveys but has not been adequately tested for other species.

Data acquisition

1. Vocal recordings are the most efficient and reliable means of recording observer observations, and should be used on all surveys, even in cases where a dedicated data recorder is employed.
2. A system to record angle measurements directly, perhaps using an electronic inclinometer, should be developed.
3. A means of more accurately determining when a sighting comes abeam of the aircraft should be developed.
4. The recording system used in the Icelandic aerial survey is dated, becoming unreliable and must be improved.

Video and still photography

1. HD video and/or still photographic equipment is of moderate cost and excellent quality and should be considered for all surveys.
2. The use of HD video as a secondary platform for the Icelandic aerial survey should be considered.

Bias correction

1. Perception bias cannot be corrected without double platform data; therefore double platforms are required on all surveys (except those using circle-back).
2. Forward sighting distance and time in view (TIV) is required for the correction of availability bias using dive cycle information. Therefore TIV should be collected for every sighting. This again requires the use of observer recordings and accurate timing of observations.
3. Cue counting requires the collection of TIV data. The Icelandic survey data should be analyzed using a correction for availability based on TIV and dive cycle data, for comparison with estimates based on cue counts.
4. Ideally dive cycle information, including cue rates, should be collected from the survey area at the same time of year the survey is carried out.

UAVs

1. Civilian UAVs suitable for marine aerial survey are currently too costly and/or not adequately tested. The use of HD Video and/or still photograph in conjunction with visual aerial surveys will facilitate the transition to UAVs should they become available.

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Yazvenko, S.B., McDonald, T.L., Blokhin, S.A., Johnson, S.R., Meier, S.K., Melton, H.R., Newcomer, M.W., Nielson, R.M., Vladimirov, V.L. and Wainwright, P.W. 2006. Distribution and abundance of western gray whales during a seismic survey near Sakhalin Island, Russia. *Environ. Monit. Assess.* 134:45-73.

Zerbini, A.N., Danilewicz, D., Secchie, E.R., Andriolo, A., Cremer, M., Flores, P.A.C., Ferreira, E., S. Alves, L.C.P., Sucunza, F., Castro, F.R., Pretto, D., Sartori, C.M., Schulze, B., Denuncio, P. and Laake, J. 2011. assessing bias in abundance estimates from aerial surveys to improve conservation of threatened franciscana dolphins: preliminary results from a survey conducted in southern Brazil. IWC SC/63/SM9.

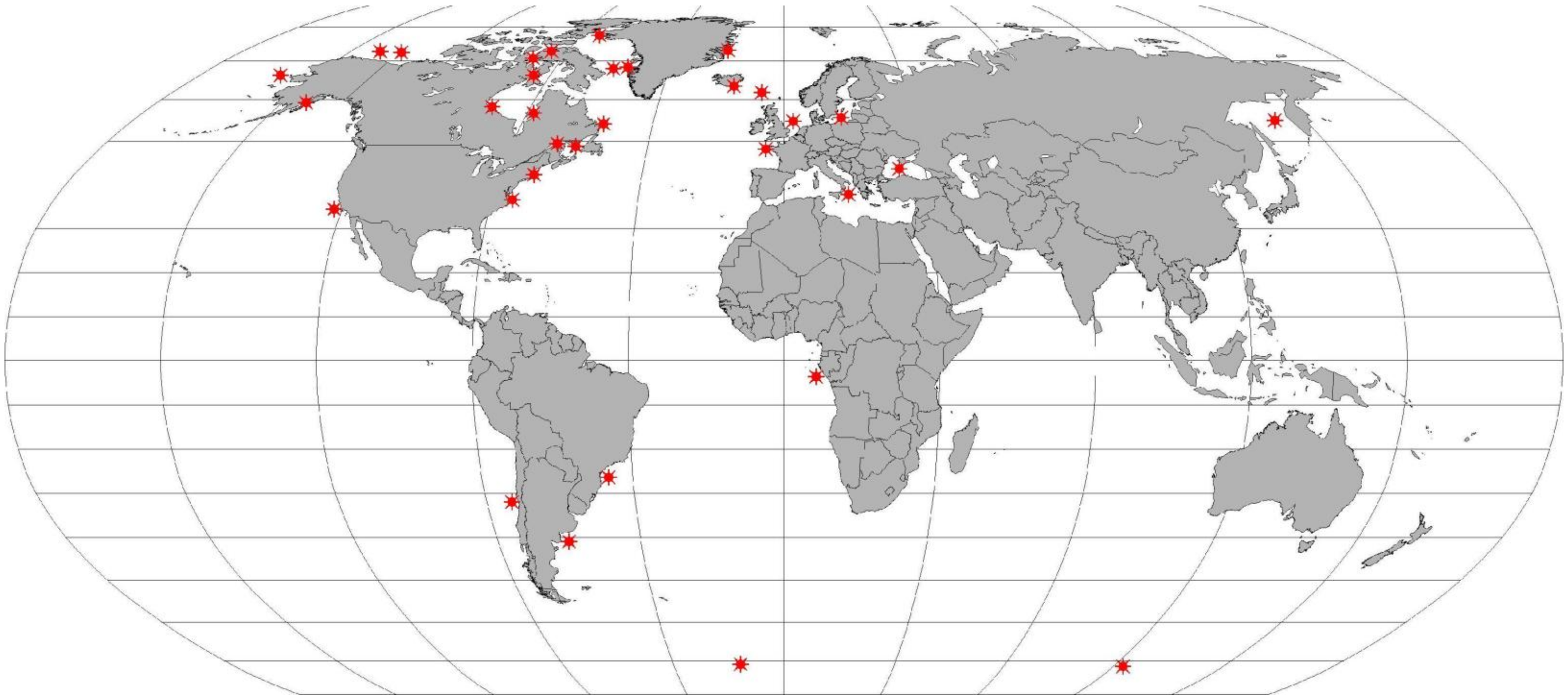


Figure 1. Locations of aerial surveys used in the assessment.

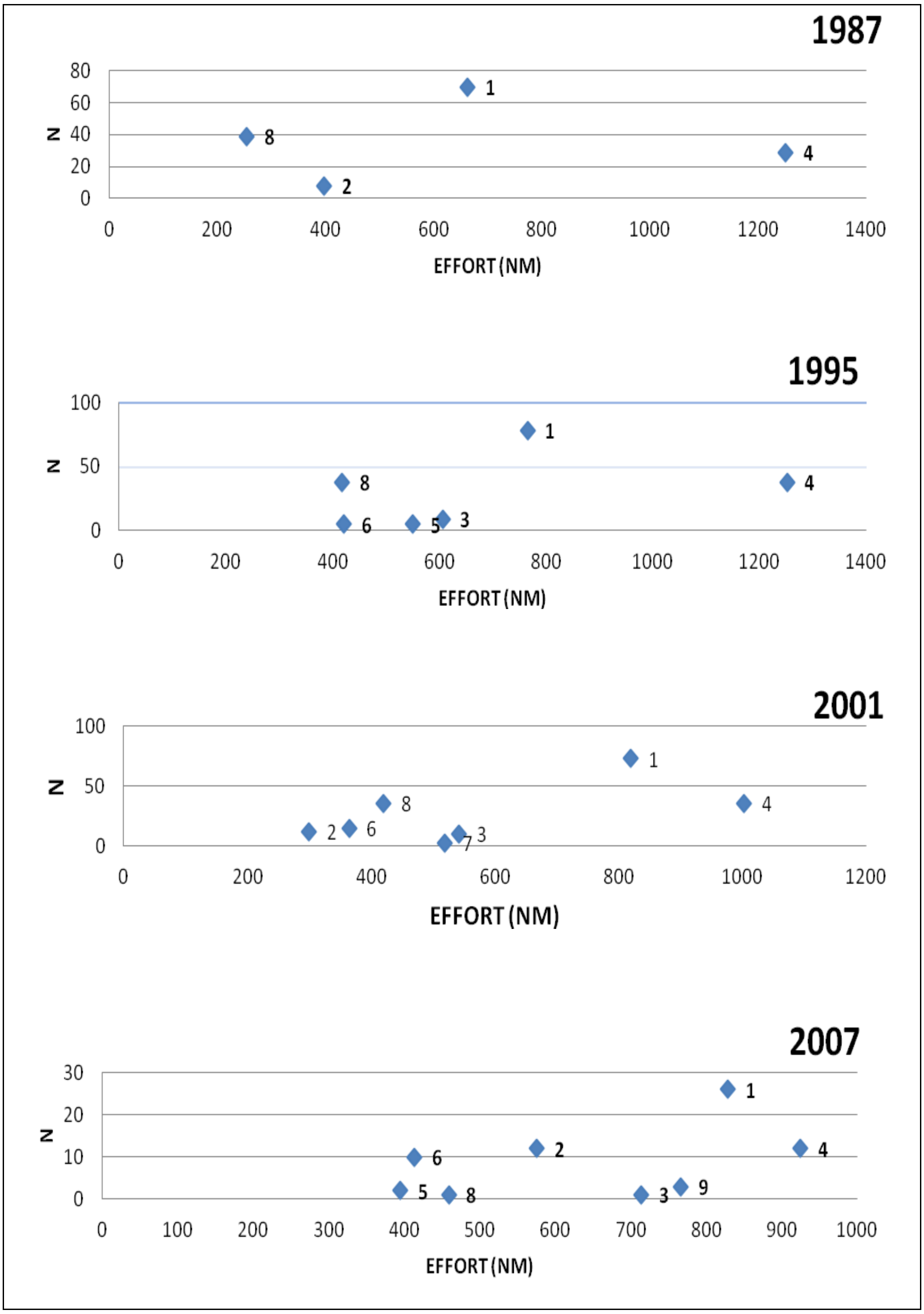


Figure 2. Numbers of sightings (N) by stratum in Icelandic aerial surveys. Strata labelled in the graphs.

Appendix 1

List of surveys assessed

V/P – visual or photographic; SUR – Survey type, LT=line transect, CC=cue counting, P=photo, A=adaptive; PER_B – Perception Bias correction, MR=mark recapture, CB=circle back, N=none; AVA_B – Availability Bias Correction, SD=surfacing data, CB=circle back, CC=cue counting, N=none; DES – Design, P-ES=parallel equal spaced, Z-ES=Zigzag equal spaced; TARG – Target species; Size – target species size; Aircraft – Aircraft type, FH=fixed high wing; FL=fixed low wing; RH=rotary; P/S – Platforms/Stations; WIN_P/S – Windows, Primary/Secondary, B=bubble, F=flat; DREC – Data recording, OR=observer recordings, DR=data recorder; VID – Video, Y or N; STIL – Still photography, Y or N; ANLYS – Analysis Type, MRDS=Mark Recapture Distance Sampling, CDS=Conventional Distance Sampling, MCDS=Multiple Covariates Distance Sampling, CB=Circle back, CC=cue counting, ER=encounter rate; AVAIL – Availability bias correction methodology, TIV=Time in view, CB=circle back, CC=cue count, I=instantaneous, N=none.

REF	**V/P**	**SUR**	**PER_B**	**AVA_B**	**DES**	**TARG**	**SIZE**	**AIRC**	**P/S**	**WIN_ P/S**	**DREC**	**VID**	**STIL**	**ANALYS**	**AVAIL**	**SOFTW**
Asselin and Richard 2011	V	LT-P-A	MR	SD	P-ES, Z-ES	MM	S	FH	2/4	B/B	OR	N	Y	MRDS	TIV-FR	D
Berggren et al. 2004	V	LT	CB	CB	Z-ES	PP	S	FH	1/2	B/	DR	N	N	CDS-CB	CB	PR
Birkun et al. 2003	V	LT	N	N	P-ES	PP, TT	S	FH	1/2	B/	OR	N	N	CDS	N	D
Blokhin et al.2004	V	LT	N	N	P-ES	ER	L	FH	1/2	F/	OR	N	N	ER	N	PR
Borchers et al. 2009	V	CC	MR	CC	Z-ES	BA	M	FH	2/3	B/F	OR	N	N	MRDS-CC	CC	D
Burt et al. 2008	V	LT	CB	CB	Z-ES	PP	S	FH	1/2	B/	DR	N	N	CDS-CB	CB	PR
Clarke et al.	V	LT	N	N	VAR	Bmy	L	FH	1/2	B/	DR	N	N	ER	N	NA

REF	V/P	SUR	PER_B	AVA_B	DES	TARG	SIZE	AIRC	P/S	WIN_ P/S	DREC	VID	STIL	ANALYS	AVAIL	SOFTW
2010																
Clarke and Ferguson 2010	V	LT	N	N	P-ES	EG	L	FH	1/2	B/	DR	N	Y	ER	N	NA
Cosens et al. 2006	V	LT	MR	SD	P-ES	BMy	L	FH	2/4	F/F	OR	N	N	MRDS	I	D
Crespo et al.2004	V	LT	N	SD	Z-ES	PB	S	FH	1/2	F/	DR	N	N	MCDS	TIV-ALT	D
Gilles et al. 2011	V	LT	CB	CB	P-ES, Z-ES	PP	S	FH	1/2	B/	DR	N	N	MCDS	CB	D
Gosselin 2005	V	LT	N	N	P-ES	DL	M	FH	1/2	B/	OR	N	N	CDS	N	D
Gosselin et al. 2007	V	LT	N	N	P-ES	DL	M	FH	1/2	B/	OR	N	N	CDS	N	PR
Gosselin et al. 2007	V	LT	N	SD	P-ES	DL	M	FH	1/2	B/	OR	N	N	CDS	I	D
Gosselin et al. 2009	P	P	N	SD	P-ES	DL	M	FL	1/2	NA	P	N	Y	S	I	PR
Gosselin et al. 2001	V	LT	N	N	P-ES	DL	M	FH	1/2	B/	OR	N	N	CDS	N	D
Gosselin et al.2002	P	p	N	SD	P-ES	DL	M	FL	1/2	NA	P	N	Y	S	I	PR
Hammond et al. 2002	V	LT	CB	CB	Z-ES	PP	S	FH	1/2	B/	OR	N	N	CDS-CB	CB	PR
Heide-Jorgensen and Acquarone	V	LT	MR	SD	P-ES	DL, MM, Bmy	M,L	FH	1/2	B/	OR	Y	N	MRDS	I	D

REF	V/P	SUR	PER_B	AVA_B	DES	TARG	SIZE	AIRC	P/S	WIN_ P/S	DREC	VID	STIL	ANALYS	AVAIL	SOFTW
2002																
Heide-Jorgensen et al 2007	V	CC	MR	CC	P-ES	BA, BP, MN	M,L	FH	2/3	B/F	OR	N	N	MRDS	CC	D
Heide-Jorgensen et al 2009	V	LT	MR	SD	P-ES	BMy	L	FH	2/4	B/B	OR	N	N	MRDS	I	D
Heide-Jorgensen et al 2007	V	LT	MR	SD	P-ES	DL	M	FH	2/4	B/B	OR	Y	Y	MRDS	I	D
Heide-Jorgensen et al. 2010a	V	LT	MR	SD	P-ES, Z-ES	MM	M	FH	2/4	B/B	OR	Y	Y	MRDS	I	D
Heide-Jorgensen et al. 2010b	V	LT	MR	SD	P-ES	BA, BP, MN	M,L	FH	2/4	B/B	OR	Y	Y	MRDS	TIV-AVG	D
Hobbs et al. 2010	V	LT	MR	SD	Z-ES	PP	S	FH	2/3	B/Belly	DR	N	N	MRDS	I	D
Innes et al.2002	V	LT	MR	SD	P-ES	DL, MM	M	FH	2/4	F/F	OR	N	Y	MRDS	I	D
Jung et al. 2009	V	LT	N	N	Z-ES	PP	S	FH	1/2	B/	DR	N	N	ER	N	NA
Kelly et al. 2010	V	CC	MR	N	P-ES, Z-ES	BB	M	FH	2/4	F/F	OR	Y	Y	MRDS-CC	N	D
Laidre and Heide-	V	LT	MR	SD	Z-ES	MM	M	FH	2/4	B/B	OR	Y	Y	MRDS	I	D

REF	V/P	SUR	PER_B	AVA_B	DES	TARG	SIZE	AIRC	P/S	WIN_ P/S	DREC	VID	STIL	ANALYS	AVAIL	SOFTW
Jorgensen 2011																
Lauriano et al. 2011	V	LT	N	N	P-ES	BP, SC, TT	S,L	FH	1/2	B/	DR	N	N	MCDS	N	D
Lawson and Gosselin 2008	V	LT	MR	N	Z-ES	UW	S,M,L	FH	2/3	B/B	DR	N	N	MRDS	N	D
Martins et al.2004	V	LT	N	N	P-ES, Z-ES	MN	L	FH	1/2	B/	DR	N	N	ER	N	NA
Moore et al.2010	V	LT	N	N	P-ES, Z-ES	ER	L	FH	1/1	na	DR	N	N	ER	N	NA
Moore et al.2003	V	LT	N	N	P-ES	BMy	L	FH	1/2	B/	NA	N	Y	ER	N	NA
Pike and Gunnlaugsson 2008	V	CC	MR	CC	Z-ES	BA	M	FH	2/3	B/F	OR	N	N	MRDS-CC	CC	D
Pike 2009	V	CC	MR	CC	Z-ES	BA	M	FH	2/3	B/F	OR	N	N	MRDS-CC	CC	D
Pike et al. 2011	V	CC	MR	CC	Z-ES	BA	M	FH	2/3	B/F	OR	N	N	MRDS-CC	CC	D
Richard 2005	V	LT-P	N	SD	P-ES	DL	M	FH	2/3	B/F	OR	N	Y	CDS	I	D
Richard 2010	P	P	N	N	P-ES	MM	M	NA	1/1	NA	P	N	Y	S	N	PR
Rosenbaum et al.2004	V	LT	N	N	Z-ES	MN	L	FH	1/2	F/	DR	N	N	CDS	N	NA
Scheidat et al. 2007	V	LT	N	N	P-ES	UW	L	RH	1/2	B/	ORDR	N	Y	ER	N	NA
Shelden and	V	LT	N	N	P-ES	ER	L	FH	1/2	B/	DR	N	N	ER	N	NA

REF	V/P	SUR	PER_B	AVA_B	DES	TARG	SIZE	AIRC	P/S	WIN_ P/S	DREC	VID	STIL	ANALYS	AVAIL	SOFTW
Laake 2002																
Torres et al.2005	V	LT	N	N	P-ES	TT	S	FH	1/2	B/	DR	N	N	ER	N	NA
Vernazzani et al. 2009	V	LT	N	N	Z-ES	BM	L	FH	1/2	F/	OR	N	N	CDS	N	D
Wedekin et al.2010	V	LT	N	N	P-ES, Z-ES	MN	L	FH	1/2	B/	DR	N	N	MCDS	N	D
Witting and Kingsley 2005	P	P	N	SD	P-ES	BA,BP	M,L	FL	1/2	NA	P	N	Y	S	I	PR
Yazvenko et al. 2006	V	LT	N	N	P-ES	ER	L	FH	1/2	F/	DR	N	N	CDS	N	D
Zerbini et al. 2011	V	LT	ALT	N	P-ES	PB	S	FH	2/4	B/F	OR	N	N	MCDS	N	D

Appendix 2

Recommendations for improvement of the recording system used in Icelandic aerial surveys, compiled after the 2009 survey.

Problems

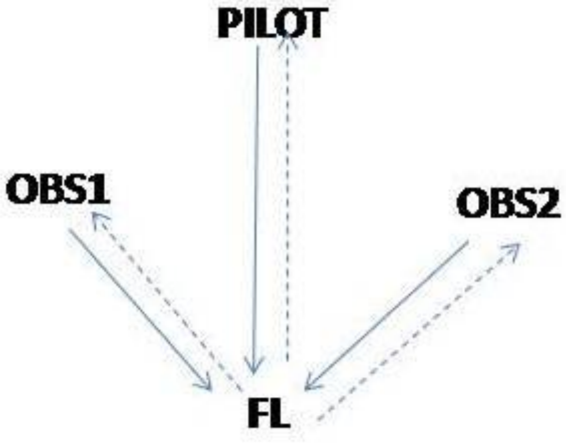
1. The software "HVAL2004" is intended for ship surveys and records time with at 1 second intervals. While this is adequate for a slow moving ship it is not for a plane, which moves over 50 m in 1 second. In addition the software can be adjusted to record positions at a minimum of 1 minute intervals, which is not precise enough for an aerial survey.
2. There is a slight (fraction of a second) time delay between pressing the microphone button and when the recording begins. Thus the first word of many records (usually "Dive") is often missed.
3. The present system requires 3 laptop PCs to be running at all times. They are difficult to secure adequately in the airplane and take up most of the cargo space. They are also doing nearly nothing, and 1 computer should be more than sufficient for the monitoring needs.
4. Use of the handheld microphone to make recordings is extremely cumbersome for the primary observers particularly, as they must use both hands to make observations in the rather small bubble windows.

Recommendations

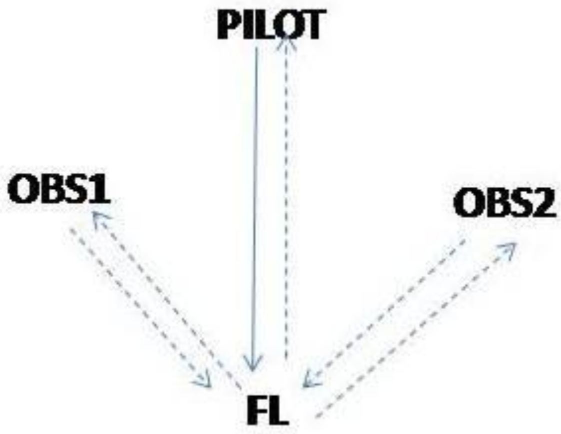
The system used is nearly 10 years old and was developed at a time when computer memory was much more expensive and bulky than it is now. Hence it was reasonable to have a system that minimized the consumption of memory by recording observations only. Now computer memory is inexpensive and compact, and there is no technical reason why vocal records of entire flights should not be recorded. This would free the observers from having to manually press a button and hold a microphone to make recordings. Instead the observer would use the headset microphone to make recordings.

The system envisioned would have to work in 3 operational modes. In the diagrams below the solid lines are open lines of communication, while the dashed lines require a manual switch (*e.g.* a button press):

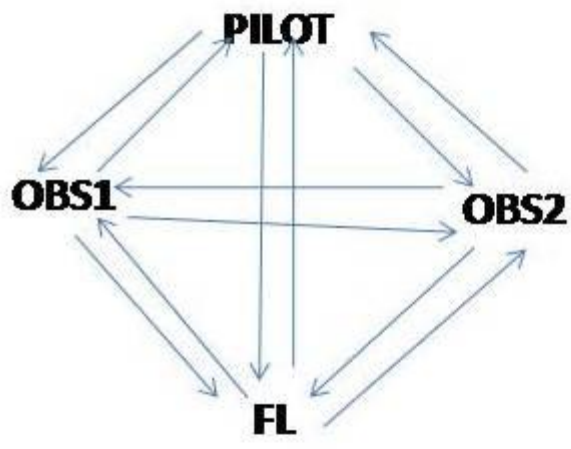
1. **Mode 1.** When FL is a non-independent observer. This would likely be used during training flights.



2. **Mode 2.** When FL is an independent observer.



3. **Mode 3.** (Chat mode) In non survey mode, *i.e.* ferrying or closing on a sighting.



System requirements

1. A recording channel for each observer. This could record onto a flash-memory card or to a computer hard-drive and would have a capacity of at least 10 hrs of continuous recording. The recordings would have a time signal from the computer, which would be synchronized to the GPS.
2. A switching device for each observer and the flight leader, to switch between modes.
3. A GPS that produces a log data file with date, time, lat and long, altitude, speed, etc., recorded at 1 second intervals throughout the flight.

There are likely many potential designs for such a system, and a technical expert should be consulted at the outset. But a very simple and inexpensive way of achieving this operational capability would be as follows:

1. All observers would record constantly through an open headset microphone to a single laptop computer equipped with a multi-channel sound card (minimum 3 channel) and the appropriate jacks. An alternative design would use individual voice recording devices at each station, but these should record onto a flash card or be easily down-loadable.
2. An adapter jack with an on/off switch or button and a splitter before the switch (i.e. the split would not be controlled by the switch) would plug into the aircraft intercom microphone jack, and the microphone jack from the headset would plug into this. The split would lead to the recording computer or dictaphone. Thus each station could easily shut down transmissions to the aircraft intercom system, but all voice at each station would be always recorded.
3. The survey modes would be controlled by switching on or off the intercom microphone switch. In Mode 1, the observer switch would be on, while the

FL switch would be off unless he/she wanted to speak to the observer. In Mode 2, the usual survey mode, all switches would be off. The FL could speak to the observers by switching on his/her microphone, and the observers could speak to the FL by doing the same. In Mode 3, all switches would be on.

The data output for each flight would be a single recording for each observer and the FL, and the GPS output. After the audio data are entered they can be easily merged by date and time with the GPS data. Data entry from single long recordings may seem daunting, but it is actually very simple using freely available software such as Audacity, as the voice records are easily found visually in the files.

Appendix 4

REVIEW OF DOUBLE PLATFORM IMPLEMENTATION IN SHIPBOARD SIGHTINGS SURVEYS.

by

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INTRODUCTION

Shipboard surveys have widely been used in the NASS and T-NASS surveys by all the countries involved since the first one was carried out in 1987 (Víkingsson *et al.* 2009), principally in offshore areas but also in coastal areas. They are, at present, the only platforms that can operate in the far offshore, where aerial surveys lack the range to operate.

Besides the design of representative and efficient surveys, there are several practical difficulties in meeting the key assumptions (*e.g.* Buckland et al. 1993, 2001) of conventional line-transect sampling when conducting shipboard cetacean surveys. Conventional line-transect methods for estimating abundance assume in particular that

1) all animals on the trackline line are detected with certainty ($g(0)$=1)
2) perpendicular sighting distances (*i.e.* radial distances and angles to animals) are measured without bias and error.
3) all animals are stationary, *i.e.*, they are detected before they may move in response to the survey platform.

Also school size should be estimated without error.

On most cetacean surveys, the assumption that $g(0)$=1 is questionable or known to be false (*e.g.* Hammond *et al.* 2002). Animals on the track line may be unavailable for detection a) because they are underwater (availability bias), or b) observers may fail to detect them even though they are available (perception bias). Responsive movement of animals to survey ships before they are detected may also lead to severe bias in line transect estimates of abundance - negative if animals avoid ships and positive if animals are attracted to ships. The most problematic bias in terms of conservation is the positive bias caused by strong attraction, such as has been demonstrated for example for common dolphins (Cañadas *et al.* 2004, Deboer *et al.* 2008).

Since the first NASS survey was conducted in 1987, there have been several key developments in field methods and analysis for shipboard surveys, in the hope of meeting the given assumptions or for allowing the estimation of the biases. For the latter, a variety of methods combining mark-recapture and distance sampling (MRDS) methods have been developed (see Laake and Borchers, 2004, for an overview), requiring double platform (DP) configurations to generate duplicate sightings data from which $g(0)$ can be estimated. Hammond *et al.* (2006, appendix A2.1) reviewed data collection and analysis methods for shipboard data to inform the development of methods to be used in SCANS II 2005.

Two main configurations have been used, an independent observer configuration (IO mode, two independent but symmetrical teams of observer, which survey the same area of the sea) and a trial-observer configuration (BT mode, a “Tracker” team search ahead of the area searched by an independent “Primary” team).

The IO method typically allows abundance estimates to be corrected for perception bias and double platform track line conditional independence procedures may be used for estimating abundance (*e.g.*, Palka 1995; Borchers *et al.* 2007).

The BT method (Buckland and Turnock, 1992), allows abundance estimates to be corrected both for animals missed on the transect line and for movement of animals in response to the survey ship.

Palka and Hammond (2001) developed a method for accounting for responsive movement using data recorded in any mode. They look whether responsive movement is occurring by using the recorded initial swim direction. If it does, they apply a modified BT two-team analysis method where the sighting data are post-stratified into regions “close” to the ship (between the ship and a critical radial distance) and “far” from the ship (beyond that distance) instead of the original BT stratification by observation team. The PH method simultaneously estimates *g(0)* and accounts for responsive movement, and cannot separate out the effect of responsive movement from the effect of *g(0).*

Laake (1997) describes methods for correcting abundance estimate for availability bias.

Both SCANS surveys (1995 and 2005) used DP shipboard surveys with a trial-observer configuration (Hammond *et al.* 1995, 2006). The logistic/technical implementation of the method was very much developed under/for SCANS II, the development focusing on achieving an automated data logging method and improving methods to measure distance and angle to sightings (Hammond et al. 2006, Gillespie et al. 2010). The SCANS II method was later implemented in the concurrent CODA and T-NASS surveys in 2007, with only few modifications.

The NAMMCO Working Group and Scientific Committee recommended the use of a DP configuration in the shipboard component of future NASS surveys (NAMMCO 2011ab), because it provided important data with which to correct biases. While these biases tended to be more important for smaller, cryptic species such as minke whales than for larger species such as fin whales, analyses have demonstrated that they exist even for the latter.

However, recognizing that there had been problems with the implementation of the BT method in 2007 in both surveys and particularly on the T-NASS vessels, and that other types of double platform survey methodology, such as I/O as used by Norway, or different ways of implementing the BT method, e.g. with post-survey duplicate identification as used in SNESSA, were available, the NAMMCO Scientific Committee decided to recommend a study “to consider and compare the advantages and disadvantages of these approaches in the context of the target species mix and other circumstances expected in the next NASS”.

Limited time was allocated to the review (40 hrs), which concentrated on reviewing the field implementation of the different DP methodologies and their technical and logistic requirements. In addition it looked how the problem with error in distance and angle estimation was tackled in both single platform and DP surveys.

MATERIALS AND METHODS

1) A non-exhaustive review of the recent literature (2000 and later) pertaining to shipboard surveys for cetaceans was conducted, as well as a wider specific search for shipboard surveys using a double platform methodology (since 1988). The focus was not on the analysis side but on the logistic implementation. Searches were carried out using the *ProQuest* system searching the *Biological Sciences* database, primarily using the search sentence (survey AND ship*) AND (whales* OR cetaceans* OR dolphins* OR porpoise*). Additional searches were carried out on the IWC documents (http://iwcoffice.org/documents/publications/SCSMWSDocs1970plus.pdf), the lists of unpublished documents held by NOAA (http://www.lib.noaa.gov/noaainfo/pubsource.html) and DFO (http://www.meds-sdmm.dfo-mpo.gc.ca/csas-sccs/applications/publications/index-eng.asp), the CREEM list of distance sampling related references (http://www.ruwpa.st-and.ac.uk/distancesamplingreferences/) and list of publications (http://www.ruwpa.st-and.ac.uk/Publications/index.htm). The logistic implementation of the method used is often not very detailed in the published literature, and we also had access to a number of survey guidelines, and cruise and survey reports.

2) A database of shipboard surveys using DP methodology, mostly conducted in the past 15 years, was compiled, including factors relating to survey type, target species, field methods, equipment, logging software, number of observers required and technical requirements.

3) Going beyond the strict scope of a review of double platform implementation, a review of the newest technical implementations for improving data recording (especially distance and angle estimate) and logging was also conducted.

4) Review of debriefing reports and CR from SCANS II, T-NASS and CODA to review problems encountered in the implementation of the BT method described in Gillespie et al (2010).

RESULTS AND DISCUSSION

1. REVIEW OF SURVEYS USING DP METHODOLOGY

A database including over 50 DP surveys conducted since 1984 was compiled (Appendix 1). Surveys performed by the same institute and using similar methodology and logistic implementation are grouped. Groups/institutes often keep to the same methodology, though developing methods for improving data collection.

Three types of double platforms mode have been used, with variants.

1.1 CIO mode, Conditionally Independent Observer mode: direct account of perception bias

A standard line transect is conducted but *occasionally* a "conditionally independent observer" search the same area as the primary observers and only announces sightings after they have passed abeam and have been clearly missed by the primary observation team (Barlow 1995)

- All cetaceans, several SWFSC surveys (Barlow 1995, Appler *et al.* 2004, Barlow *et al.* 2004, Calambokidis and Barlow 2004, Barlow and Forney 2007)
- Harbour porpoises, California 1995 (Caretta *et al.* 2000)
- All ceatceans, Gulf of Alaska AFSC surveys (GOALS), (Rone *et al.* 2010)

1.2 IO mode, Independent Observer mode: direct account of perception bias

Two independent (audibly and visually isolated) and symmetrical platforms search the same body of water. The two platforms act as two (independent) primary platforms, both providing a sighting rate. Three variants have been used.

<u>1.2.1 IO Mode – one-way independence or trial independence</u>*:*

A modified IO mode, where both platforms search the same body of water, but only one platform is independent for logistic reasons.

- Harbour porpoises, bottlenose dolphins and grey seals; Cardigan Bay (Reay 2005)

<u>1.2.2 IO Mode with cetacean schools as sighting unit:</u>

To facilitate the identification of duplicate sightings, some resightings are recorded, but no systematic tracking is performed.

- Harbour porpoises; California, Oregon and Washington 84-86 (Barlow 1988)
- Minke whales; Antarctic; IWC/IDCR-SOWER surveys (*e.g.* Butterworth and Borchers 1988, Matsuoka *et al.* 2003, Matsuoka *et al.* 2011);
- Minke whales and harbour porpoises; North Sea 90 (Øien 1992)
- Harbour porpoises; Gulf of Maine-Bay of Fundy 91 (Palka 1995)
- All cetaceans; Gulf of Maine-Bay of Fundy 98, 99, 04, AMAPPS-NE 11 (Palka 2005ab, 2006, AMAPPS 2011ab)
- White sided dolphins, fin & sei whales; Northwest Scotland 98 (MacLeod 2004, MacLeod *et al.* 2006)
- Minke whales; Western North Pacific (Miyashita 2006, 2007, 2008a,b, Miyashita and An 2010)

<u>1.2.3 IO Mode with tracks of cues as sighting unit:</u>

Specific tracking procedures are required for the target species: the observers shall concentrate on tracking the whale and report positional data (time, radial distance, angle) of all detected surfacings until the whale pass, or is assumed to have passed, behind abeam. The method is a *cue counting* variant. Analysis of these data requires estimate of cueing patterns or surfacing rates and generates abundance estimate corrected both for perception and availability biases.

- Minke whales; Northeast Atlantic; **NILS 1995-2011** (Øien 1995, Schweder *et al.* 1997, Skaug *et al.* 2004, NILS 2007, Øien and Bothun 2008, Bothun *et al.* 2009).

1.3 BT Mode, Buckland and Turnock mode: accounting for responsive movement, perception bias and some (a.o. species dependent) availability bias

Two asymmetrical platforms, where the higher, "tracker" platform search ahead of the area where the independent "primary" platform searches. The primary platform is independent of the tracker platform, but the reverse is not necessary. The primary platform (PP) provides the sighting rate, while the tracker platform generates trial for the PP.

- Small cetaceans; North Sea and adjacent waters – **SCANS 94** (Hammond *et al.* 1996, 2002, 2006, SCANS II, 2005a,b)
- Pilot and minke whales, dolphins; Northeast Atlantic; **Faroese NASS 95** (Desportes *et al.* 1996, Borchers *et al.* 1996, Burt and Borchers 1997, Cañadas *et al.* 2004, 2009)
- Common dolphins; Western approaches of the English Channel, WDCS 2005 (De Boer 2008)
- Minke whales and dolphins; Northeast Atlantic, **NASS 01** (Víkingsson *et al.* 2009)
- Small cetaceans in the North Sea and European Atlantic continental shelf waters – **SCANS II 05** (SCANS 2005, SCANS II 2006, MacLeod *et al.* 2009, Hammond *et al.* 2011)
- All cetaceans, European Atlantic offshore waters – **CODA 07** (CODA 2007, CODA 2009, MacLeod *et al.* 2009, Hammond *et al.* 2011)
- Fin, minke and pilot whales in the Northern North Atlantic – **TNASS 07** (TNASS 2007, Desportes 2011)
- Marine mammal and turtles, Gulf of Maine, **SNESSA 07** (Palka 2008)
- Minke whales, Antarctic **- SOWER experiment** (Burt and Borchers 2008)

2. LOGISTIC IMPLEMENTATION OF DOUBLE PLATFORMS ON SELECTED SURVEYS

We choose here to describe in more detailed the logistic of only the most recent surveys.

2.1 IO mode: 2 independent and symmetrical sighting platforms

Survey in IO mode are usually conducted in passing mode, although a delayed closure can be used as help to species identification and school size estimation.

The identification of duplicate sightings can be done on-line (real-time) or off-line (post survey).

Since both observer platforms must be independent, the on-line identification of duplicates requires that the duplicate identifier (DI) be placed on a separate platform, still allowing a good view over the search area and the sightings. A third "sighting" platform is therefore required. This 3-platform configuration is for example used in the IDCR/SOWER surveys (Butteworth and Borchers 1988, Matsuoka *et al.* 2003, Matsuoka *et al.* 2011) and some Japanese surveys Miyashita 2006, 2007, 2008a,b, Miyashita and An 2010). When this 3-platform configuration seams unlikely to happen in the framework of a T-NASS, we decided to not present further this type of configuration.

2.1.1 Schools as sighting unit

This methodology is used by the North West Atlantic NEFSC surveys, under the leadership of D. Palka. These surveys have a similar data collection methodology, although according to the target species the observers may be searching with naked eye (Palka 1995, 2000, 2006) or using Big Eyes (Palka 2005a,b, 2006, AMAPPS 2011a,b). Naked eye observers record their own data, while Big Eyes observers have a data recorder.

Example: AMAPPS 2011 (AMAPPS 2011a,b)

Target species: all marine mammals and turtles
Survey mode: delayed closing (abeam & <2nmi)
Identification of duplicate: off-line, using an automatic routine
Platform and observer configuration:

- Each team: 1 rest station and 3 work stations - a port big eye binocular (25x150 powered, BE), center observer/recorder (DR) (naked eye), and a starboard big eye binocular.
- Each BE search from 90º on side to about 10º on the other side.
- The recorder search (when not recording data) the entire area and should concentrate on distances close to the ship (from 30º port to 30º starboard and near the ship, from 0 to 1000m from the ship, where the high powered binoculars cannot see).
- **Periodic recording of resightings, but no systematic tracking**
- Each platform records its own data on its own independent ToughBook computer (+GPS).

Angles and radial distances.

- Angle: Angle ring at the base of each BE and mounted angle boards for the recorder.
- Distance: Reticle in the eye piece of the BE and E-Ranger (see under 4.4.1), naked eye or measuring stick estimation for the recorder.

Requirement in observers: 8 (2*3+1, with 2*2 dedicated observers)
Communication between platforms: no inter-platform communication needed
Data logging:

- Automatic data logging: date, time and position of ships, after sighting-input from data recorder
- No automatic sighting data transfer. All sighting data have to be announced to the recorder, incl. distance data from the E-Ranger.

Technical requirements:

- No communication system between platforms or between platforms and bridge.
- No cables connection between observer post and recorder computer.

2.1.2 Cues as sighting unit

This methodology has been used by the North East Atlantic NILS surveys, under the leadership of N. Øïen since 1995. The basic methodology is the same as that established in 1995 (Øïen 1995), but there has been much development in the technical logistics for data logging during the survey (*e.g.*, NILS 2007).
There is a single target species, the minke whale.

Example: NILS 2007 (NILS 2007, Bøthun *et al*. 2009)

Target species: minke whales
Survey mode: passing mode
Identification of duplicate: off-line, using an automatic routine
Platform and observer configuration:

- Each team consists of 2 on-effort observers searching using unaided eye and 2 off-effort observers. Observers rotate among the two positions within platform, but do not rotate between teams and platforms.
- 2 team leader alternate as data recorder in the bridge (as a back up to the audio recording).
- Search within 45° to 0° each on their side and within 1500 from vessel.
- **Specific tracking procedures for minke whales: the observers shall follow the whale and report the positional data (radial distance, angle) of all its surfacings until it passes, or is assumed to have passed, behind abeam.**
- Sightings data report is recorded as audio file directly to disc (central computer situated in the bridge) through a microphone with a push button. All microphones and buttons are connected to a central computer equipped with a GPS unit. Time delay due to software and hardware is expected to be less than one second for initial sightings and for resightings there is no time delay.
- Voice reporting to bridge through "intercom" of initial (minimal) sighting data after end of minke whale track or sighting of harbour porpoises and large whales.

Angles and radial distances.

- Mounted angle boards for the each observer
- Distance estimation by eye.

Requirement in observers: 10 (4 * 2 + 2)
Communication between platforms:

- No inter-platform communication needed, minimal reporting to bridge as a back up.

Data logging:

- Automatic data logging of vessel position and time, but not of sighting data.
- All sightings and resightings received a time and position stamp from the GPS unit in the audio files.

- Audio files translated to data form during the course of the survey when in off-effort mode.

Technical requirements:

- No communication system between observation platforms
- Each observation post is connected to bridge through communication cable to the DR and sound cable to central computer logging the voice files.

Remark

The method is very demanding and can only generate good data for one species at a time, the target species (in the Norwegian survey, the minke whale). Sightings of other species are recorded with lowest priority and in a normal way, as single sighting. The method is therefore not appropriate in multispecies target survey.

2.2 BT mode: 2 asymmetrical platforms with at least the primary platform independent

A BT mode implementation was first used in the SCANS 94 survey under the leadership of P. Hammond (Hammond *et al.* 1995). It was further developed for the SCANS II survey (SCANS II 2006), then used with little modification in the CODA (CODA 2007, 2009) and T-NASS (T-NASS 2007, Desportes 2011) surveys. The American NEFSC SNESSA survey used a simpler variant of the SCANS II implementation (Palka 2008).

The identification of duplicate sightings can be done on-line (real-time) or off-line (post survey).

<u>2.2.1 Two independent platforms and off-line identification of duplicates</u>

Example: SNESSA 2007 (Palka 2008)

Target species: all marine mammals and turtles
Survey mode: passing mode
Platform and observer configuration:

- Primary team (lower platform): 3 on-effort observers searching using naked eye + 2 off-effort observers. Search from 90° starboard to 90° port.
- Tracker team (upper platform): 4 on-effort observer, 2 searching with BE with each his own DR + 2 off-effort observers.
- The primary team determines the sighting rate of each species, i.e., record as many groups as possible, recording some resightings but no systematic tracking.
- The tracker team, both using BE, search from 60° starboard to 60° port, with an emphasis on the area 30° on either side of the track line, concentrate on tracking groups of animals from as far from the ship as possible to the time the group is abeam of the ship.
- Observers do not rotate between platforms.
- Systematic tracking by trackers: track groups of animals from as far from the ship as possible to the time the group was abeam of the ship.

- On either team, data logging of information on a computerized data entry device ("PingleNet"):

Angles and radial distances:

- Angle: Angle ring at the base of each big eye and mounted angle boards for the recorders and PO.
- Distance: Reticle in the eye piece of the BE, naked eye or measuring stick estimation for the recorder and PO.

Requirement in observers: 11 (3ne+2 // 2be+2dr+2)
Communication between platforms: no inter-platform communication needed
Data logging:

- Three separate data logging, one for each tracker, and one for the primary team.
- Automatic data logging: date, time and position, after input from data recorder.
- No automatic sighting data transfer. Sighting data have to be announced to the recorder.

Technical requirements

- No communication system between platforms or between platform and bridge.
- No cable connection between observer post and recorder computer.

<u>2.2.2 On-line identification of duplicates, one independent platform</u>

Example: SCANS II 2005 (SCANS II 2006), CODA 2007, T-NASS 2007

Target species: varies between the 3 surveys, from small to large cetaceans
Survey mode: passing mode
Platform and observer configuration:

- Primary platform (PP, lower platform) houses the independent observer team (PP), unaware of the activity and observations made on the other platform.
- Tracker platform (TP, upper platform) houses the trackers, the duplicate identifier (DI) and the data recorder (DR), all receiving all observation data and cooperating in assessing duplicates.
- PP: 2 on-effort observers searching with naked eye + 1 on-effort on TP as duplicate identifier (DI) or DR + 1 off-effort observer.
- TP: 2 on-effort observers tracking one with BE, the other with 7*50 binoculars, 1 on-effort observer serving as DI or DR + 1 off-effort observer.
- The primary team searched waters from 90° starboard to 90° port close to the ship (500m): determine the sighting rate of each species, i.e., record as many groups as possible.
- The tracker team searched beyond 500m, the BI from 60° starboard to 60° port, and the BE from 40° starboard to 40° port: concentrate on tracking groups of animals from as far from the ship as possible to the time the group was abeam of the ship or they have been assessed as duplicate of a primary sighting.

Angles and radial distances:

- PO and DI use mounted angle boards for recording bearing and estimate distance by eye or using a measuring stick.
- The tracker use angle ring (BE), angle board (7*50) and reticles to measure angles and distances, but these are also measured by photogrammetry (using two cameras attached to both binoculars)

Requirement in observers: 8 (2ne+1 // 2(be+bi)+1di+1dr+1)

Communication between platforms: very good inter-platform communication needed

Data logging:

- Common data logging on DR computer
- Automatic data logging: date, time and position, sighting number (and form) and for the tracker webcam image (angle) and video footage (distance) after touch of any sighting/resighting button.
- Integrated data collection system.

Technical requirements:

- Good communication system between platforms.
- Connection cables between all observer post, both primary and tracker, to the recorder computer.
- Connection between tracker post to video storage devices to DR computer.

Main problems encountered in SCANS II, CODA and T-NASS

In T-NASS, there were numerous technical problems with the audio and video equipment and the survey software that in some cases were never resolved. A particular problem was incompatible/ malfunctioning external sound cards which prevented the recording of audio. In addition communication between the platforms was very poor, which is problematic for the implementation of the BT method as planned. The media (external hard drives) meant to record the videos for distance estimate did not worked properly on any vessels.

Gillespie *et al.* (2010) review the problems encountered with the integrated data collection system used in the SCANS II and CODA. They note: “The data collection system worked effectively on all seven vessels taking part in the SCANS II survey, although the complexity of the system and the large number of interconnected components working in a harsh environment required a certain level of enthusiastic vigilance on the part of the operators to keep it running. The most commonly encountered problems were with the video capture system”.

It is interesting to note that less problems were encountered during the very well prepared SCANS II survey, where all cruise leaders had participated to 2-week pilot survey, than in CODA and T-NASS, where many things were only ready at the last minutes and several additions/transformations/changes made since SCANS II had not been fully tested. During the debriefing meetings of both CODA and T-NASS, it was recognized that a pilot survey/a period for testing/learning equipment would have been beneficial. Problems experienced at sea with the data collection system could have been minimised by rigorous testing in real condition before hand (CODA 2007b, NAMMCO 2008).

It was also clear from the SCANS survey, that the vessel experiencing the least technical problems were those having a “system technician” onboard or those where the integrated data collection system had been set-up and tested in survey condition by a “system technician”.

Clearly the combination of a more complex survey procedure with the complexity of an integrated data collection system requires a thorough preparation of the cruise leaders and observers, and not the least the equipment, which was not achieved for T-NASS and CODA for various and different reasons (CODA 2007b, NAMMCO 2008)

Shipboard surveys are becoming increasingly technical and the time needed for a thorough preparation has consequently increased, this needs to be acknowledged and kept in mind for future surveys.

3. GENERAL PROBLEMS ENCOUNTERED IN DATA COLLECTION

Gillespie *et al.* (2010) underline that the majority of surveys still rely entirely on human observers for *estimating* and collect key data items, with limited scope for identifying or rectifying errors, while in other fields of science and engineering the use of calibrated instruments to take and record measurements is considered the norm.

3.1 Distance data

A fundamental assumption underlying distance sampling is that the relative locations of animals can be determined without error (*e.g.*, Chen 1998, Buckland *et al.* 2001, Palka and Hammond 2001). Distance data are therefore critical data, although they rely on estimates from observers, which often are *occasional* observers lacking routine and training. They may be subject to considerable errors, which has been confirmed experimentally (*e.g.* Williams *et al.* 2007), thus having the potential to introduce large bias in abundance from transect sightings surveys (Williams *et al.* 2007). Measurements errors are widely considered to be a problem to most surveys (*e.g.*, Schweder 1997, Leaper *et al.* 1997, Williams *et al.* 2007). Leaper *et al.* (2010) found a consistent pattern of over-estimation of small radial distances and under-estimation of larger ones. The potential effects of measurement error on abundance estimation are reviewed by Leaper et al. (2010).

Measurement errors on distance data are difficult to evaluate, and thus accounted/corrected for, because the distance experiments using fixed buoys, usually intended to examine these errors are unlikely to yield much information about the errors that occur under real conditions (Williams *et al.* 2007, Leaper *et al.* 2010), see under 3.2 for further discussions.

The introduction of photogrammetric measurements of distance and angle allowed investigating estimation errors made in the course of the real sighting process and for sightings of surfacing cetaceans. For the trackers, the difference between estimated and measured angles and distances could be directly compared for the same sighting event, while angles and distances estimated by the naked eye observers could be compared to photogrammetric measurements from the TO for the simultaneous surfacing events (Leaper *et al.* 2010).

3.1.1 Distance to sightings

The introduction of reticles reading improved distance estimation, but do not remove the "human estimate" with the observer having to extrapolate between reticle lines. This is particularly difficult for larger distances, with a tendency of rounding to certain reticle values (Leaper *et al.* 2010). The ability in estimating distances varies according e.g. to sea state, with reticle estimate of distances being more precise in good sea state (Kinzey and Gerodette 2003).

Leaper *et al.* (2010) compared measured distance and distance estimated by reticle (both Big Eye and 7*50) and by naked eye for sightings of surfacing cetaceans in SCANS II, CODA and SOWER. The magnitude of the errors indicated by the CV_{RMSE} varied between 0.19 for the CODA Big Eyes to 0.33 for the SCANS II Big Eyes and was 0.39 for the naked eye. They found an evidence of a non-linear relationship between error in distance and distance, with a consistent pattern of over-estimation of small radial distances and under-estimation of larger ones. Same pattern was observed by Williams *et al.* (2007) By contrast, there was no evidence of a similar pattern in the errors to fixed buoy in distance experiments performed with the same observers.

3.1.2 Angle to sighting

Leaper *et al*. (2010) compared measured and estimated angles using the data collected during SCANS II and CODA. For the 7 × 50 binoculars, this resulted in 651 initial sightings where both estimated and measured bearings were available. Of these, 5% (34 sightings) showed gross errors of more than 20º which could not be resolved (by listening to commentaries) and were assumed to be either observer error or related to angle pointers becoming mis-aligned. For the remaining sightings, the root-mean-square error was 7.1º for SCANS II and 7.2º for CODA. For the Big Eyes there were 355 sightings with both estimated and measured bearings of which 6% of sightings showing errors of more than 20º. Excluding these sightings with large errors gave a RMS error of 6.0º for SCANS II and 5.7º for CODA. For the simultaneous sightings from naked eye observers during SCANS II where there was also a measured angle from the tracker, the RMS error was 5.9 º. However, this value may be influenced by the selection criteria used for simultaneous sightings; angles needed to be within +/– 10 º and hence, sightings with larger angle errors were eliminated before the comparison.

Errors in angle measurements appear less likely to cause bias than errors in distances, but will affect the variance of estimates. Although there was little evidence of angle error causing overall bias, the contribution to the variance will be dependent on the distribution of angles to sightings (Leaper *et al.* 2010).

3.2 Distance and angle experiment

Most shipboard sightings surveys devote/are supposed to devote substantial time to training observers in distance estimation, but also in testing them in distance and angle estimation, with the hope of yielding sufficient data for assessing variance and correcting for distance errors. Fixed artificial visual target are used as cetacean proxy, generally fixed buoys, although the last harbour porpoise surveys have been using a porpoise model (NEFSC surveys, SCANS II).

Williams *et al.* (2007) results suggested that an observer differed in the ability to judge distance to fixed, continuously-visible cues and ephemeral, cetacean cues, which calls into the question the common practice of using fixed cues like marker buoys as cetacean proxies in distance-estimation experiments. Leaper *et al.* (2010) showed from the SOWER data that, although it would be expected that estimated distances to a stationary object that remains at the surface are more accurate than those to whales, the extent of the difference was surprisingly large. Based on this and the pattern of distance errors found, Leaper *et al.* (2010) concluded that distance errors are difficult to predict or correct from typical distance experiments using fixed targets and ultimately there appears no substitute for measuring these at sea.

Also these experiments are usually conducted under relatively good weather conditions (a.o. for safety reasons) which may not represent the overall condition of the survey.

When also considering how time consuming these "experiments" are, that the time taken is usually from over average good survey conditions and that they easily develop in a logistical nightmare, it would be worth reconsidering their utility in future surveys.

This comment however does not concern the usefulness of *training* observers in distance estimation, which is certainly worth pursuing, especially in the case of observers not regularly participating in surveys.

If someone should anyway attempt a distance and angle experiment, Norway has introduced GPS recording as a standard tool for the distance experiments, using a GPS (***Garmin Fortrex 201)*** device mounted on the buoy.

3.3 Observer experience

Mori *et al.* (2003) estimated that the sighting rate for minke whale schools by Beginners observers (0-4 surveys previously) was 42% lower (95% CI = 22%-56%) than that by Expert observers (>4 surveys previously), from looking at the IWC/IDCR-SOWER surveys from 1993/94 to 1998/99. Motivation and aptitude of the observers was likely also an important factor that influences sighting abilities. They concluded that "The estimated abundance of minke whales has decreased by some 50% between the second circumpolar set of surveys and the third, according to the analysis of Branch and Butterworth (2001). It seems reasonable to postulate that the introduction of Beginner observers during the third set may be responsible for part of this decrease."

The difference among individual observers was one of two significant factors influencing perpendicular sighting distances for shipboard surveys in the Pacific in 1986-1996 (Barlow *et al.* 2001). Individual differences reflected visual acuity, experience, training, concentration, and state of rest/fatigue. Barlow *et al*. (2006)

found observer experience (grouped as first-time observers, observers with at least four months experience, observers with at least 12 months experience) to be a highly significant factor explaining differences in sighting rates for beaked whales off the coast of California, with sighting rates for experienced observers being approximately twice that of inexperienced observers.

Observer experience is particularly crucial in the case of cryptic species, including minke whales and porpoises as well as beaked whales.

4. ADVANTAGES AND DISADVANTAGES OF THE DIFFERENT METHODOLOGIES AND LOGISTIC IMPLEMENTATIONS

The need to use BT or IO as opposed to simpler methods, such as a single platform survey, is depending on the target species. The choice is more difficult in the case of a target species mix, as in T-NASS, and the specific biases that might be expected (response to the presence of the survey vessel, surfacing pattern, “detectability”, etc). For fin whales, for example, preliminary estimates of *g(0)* have been close to 1 and responsive movement is not expected. Therefore a single platform mode would be adequate for this species and more efficient in terms of use of observers. In the NILS surveys 1995-2001, Øïen and Bøthun (2006) found *g(0)* estimates ranging for the single primary platform from 0.71 (1995) and 0.74-0.75 (1996-2001) and for the combined platform 0.91-0.92 (1995) and 0.93-0.94 (1996-2001). Pike *et al.* (2001, 2008) report *g(0)* values of 0.81 for the 2001 survey and 0.87 for the 2007 survey, both conducted in BT mode. For species such as minke and pilot whales, *g(0)* is low and responsive movement is expected. Therefore a BT type mode is required if absolute abundance estimates are desired for these species.

The table below presents data on responsive movement for the target species of T-NASS 2 shipboard survey. Responsive movement could be a problem for several of the species and a methodology which will allow investigation of whether it is present or not will be an advantage.

TNASS 2	avoidance	attraction	neutral	NA	Reference
Target species					
Fin whale					
Sei whale					
Minke whale	+				Hammond *et al.* 1995, 2002, 2011, Palka & Hammond 2001, Hammond *et al.* Submitted
Pilot whale		+			Palka 2006

Non target species					
Humpback whale				0	
Bottlenose whale	+				
White sided dolphin	+				Palka & Hammond 2001
White beaked dolphin		+			Hammond *et al*. 1995, 2002; Palka & Hammond 2001
Lagenorhynchus sp		+			Hammond *et al.* 1995, 2002
Common dolphin		+			Cañadas *et al*., 2004, 2009, de Boer *et al.* 2008 Hammond *et al.* Submitted
Harbour porpoise	+		+		Barlow 1988, Hammond *et al*. 1995, 2002, Palka & Hammond 2001, Hammond *et al.* Submitted
Stenella	+				Au and Perryman 1982
Risso dolphin	+				Palka 2006

4.1 Logistic limitation

The most adequate method is also dependent, although it should ideally not be, on the available platform. Palka describes in the following way, why she chose back the IO method in 2011 after having been using the BT method in 2007:

"I changed back to the IO method for 2 reasons. Primarily the BT method did not work that well on the ship we were using. This is probably because the primary team was using naked eye (where the primary target species was harbor porpoises) on a platform that was plenty high (11m) but it was far from the bow and the naked eye observers had a difficult time seeing the harbor porpoises. Their sighting rate was lower than I expected. The tracker team had big eyes and so being so far from the bow did not affect them and their sighting rate was very high even with the tracking task added on. The harbor porpoise estimate was not horrible, but the level of uncertainty was very high. I have not published these data because I was not sure I liked the fact that the tracker sighting rate of harbor porpoises was higher than the primary team. Note the observers on the primary team were good and so that is not why the sighting rate was low".

4.2 On- *vs* off-line identification of duplicates

All double platform methods rely on the identification of duplicate sightings/cues. In method CIO and IO- trial independence the duplicates are, by definition, identified on-line. For the other IO variants and BT mode, the identification of duplicate can/has been done both on-line (requiring good communication between platforms) and off-line (no communication between platform required) later during the analysis. In all cases identification of duplicate is based on timing, bearing and distances of cues.

Identifying duplicate on-line requires a person dedicated to the task (duplicate identifier, DI), especially in medium and high whales densities. It may prove very difficult to keep the pace in high density areas. In more normal situation, because the DI is looking at the sightings and can follow the tracks in the BT method, he can compensate for error in distance estimates from the primary. But the judgment is some times very subjective. Post survey identification of duplicate, using an automatic routine, is by definition a more objective process.

The on-line identification of duplicates creates the need for very good communication between platforms, especially if the density of sightings is high and there is no time for a repetition of data and discussion between observer and DI, which has proved to be a problem in many surveys.

In IO mode, because of the independency of the two platforms, the DI must be positioned on a third platform, which has logistical implications. Among the surveys reviewed, this was only done on the large Japanese research vessels (*e.g.* IDCR/SOWER and Japanese cruises). In BT mode, only the primary platform needs to be independent and the DI can be positioned with the trackers and cooperate with them to identify duplicate.

A reliable identification of duplicates, and particularly off-line, requires that angles and radial distances are estimated or measured as accurately as possible and not rounded. It is also important to obtain exact times of sightings and re-sightings and record swim direction.

4.3 Possibility for improving data collection

To be able to collect good quality data, especially when tracking of animals is involved, the observers should be able to concentrate on the sighting and not on recording, worse writing down data. On the other hands all the data required should be recorded, without missing data and without errors. Filling in paper forms takes the attention of observers away from their sightings and prevent the use of automatic time stamp. Clearly automatic data logging of data such as time of the sighting, distance and angle, position of the vessel is a big advantage.

4.3.1 Time of sightings

Sighting and resighting time are important in determining the relative location of the animal, but are especially important in identifying duplicate sightings, and particularly off-line. This is best achieved by an automatic logging of the time as a response to the observer pressing a sighting/resighting button.

4.3.2 Distance to sightings

Photogrametric methods

In SCANS II, the introduction of a photogrammetric method based on the method of Leaper and Gordon (2001) permitted to "measure" the distances to tracker sighting (Gillespie *et al*. 2010), besides the reticle estimation. The method was later used, practically unmodified in CODA and - with less success - in TNASS, as well as on an experimental basis in the last SOWER surveys (Leaper 2007, Gillespie *et al*. 2010, Leaper *et al*. 2010). One of the main challenges to the system is capturing an image of the first surfacing reported by the observer of sufficient quality to allow measurements to be made.

Gillespie *et al.* (2010) evaluate as follows the use of the system: "Success rates for the 7 × 50 and 25 × 100 binoculars were similar but varied considerably among vessels as a result of different conditions experienced and some technical problems. The overall success rate for the CODA survey (66%) was higher than that for SCANS II (37%). This was probably due to the use of high definition video cameras that resulted in much better image quality meaning that fewer surfacings were missed due to camera resolution and the fact that harbour porpoises, which made up the vast majority of sightings during SCANS II but were absent on CODA, were particularly challenging subjects. The most common problems encountered were with control of the Firestore hard-disc recording units."

Electronic range finders

Palka (2011) experimented in the 2011 AMAP survey with electronic range finders (E-Ranger) that are mounted on top of the big eyes for estimating radial distances. In the AMAPPS-Information for NE Shipboard Observers the following explanations are given.

> "This device consists of the E-Ranger box that is mounted on top of the big eyes, a cable attached to an LCD display which hangs from the big eye stand, and a cable to a START/STOP hand held switch. The E-Ranger box has an electronic inclinometer which, when given the height the big eyes are above the water, will display on the LCD display the distance between the big eyes and the spot on the water. "

In the AMAP survey, the LCD display was not connected to the recorder computer, so there was no automatic logging of the distance and the observer/recorder had to read and record the distance himself. As it is, because of their size, volume and weight, E-rangers can only be used on big eyes.

Once the E-ranger is calibrated, it is not needed to have a clear horizon to get a distance estimate. The difficulty resides in keeping the center cross hairs on the spot of the water, where the whale appeared, while the chip constantly records the distance, a mean distance being recorded on the display.

Figure B1 from AMAPPS (2011): The E-ranger mounted on the big eyes. Palka (pers. commn.) evaluation of the system at this point is: "The E-rangers need a bit more work, particularly the battery. Also Folks are so used to doing with reticles, some were reluctant to use the E-ranger. But they basically worked fine. The next version should be better, I would not suggest anyone uses the current version."

4.3.2 Bearing to sightings

Estimated angles are presently usually obtained using angle boards. For the observer, using unaided eye or loose binoculars, the angle board is usually attached on the ship rail in front of each observer. In some case, however, a single angle board is used for a whole platform. Clearly every single observer position should be equipped with its own angle board and a single angle board per platform is not considered as adequate.

In SCANS II (CODA and T-NASS) photogrammetric measurements of bearing were introduced (Gillespie *et al.* 2010). It used a downward pointing camera (webcam) taking a still image of reference marks on the deck of the vessel.

On the SCANS II survey (Gillespie *et al.* 2010), the bearing cameras generally worked well, with an overall 94% success rate. On CODA (and T-NASS) there were more problems due to hardware conflicts related to the number of USB devices connected to the computer resulting in a lower success rate of 85%. Achieving a high success rate of bearing measurement using webcams should be possible, however recent developments in other angle measurement devices (e.g. magnetic sensors) may ultimately give better results (Gillespie *et al.* 2010).

4.4 Real-time data entry and possibility for on-board validation of the data

Automatic logging of data liberates for posterior data entry and minimizes the need of exchange of data and communication between data recorder and observers.

Real-time data entry into a computer by definition minimises off-line data entry, liberating time for a validation of the data, supported by data validation algorithms, while details of the sightings are still fresh. It also allows for an automatic check for missing key data items.

The validation software developed for SCANS II allowed cruise leaders to examine the type of error made during data acquisition for identifying problems such as rounding in estimated value, discrepancy in measured and estimated distance, scanning of an inappropriate angle sector, problems which might be corrected during the course of the survey.

4.5 Comparing methods

More problems were encountered in implementing BT in T-NASS and CODA than in SCANS II, which is primarily due to equipment problems, of which many would have been solved with better preparation and testing. Others were likely due to insufficient training and experience of both cruise leader and observers, particularly in T-NASS. The problems of implementing the method could be overcome in future surveys through improvements in equipment and better observer training.

Methods where duplicate identification is done during the analysis, *e.g.*, the BT method as implemented in SNESSA or the IO method implemented in AMAPPS with *a posteriori* identification of duplicate, are less technically complex and equipment dependant than an implementation like the SCANS II, with duplicate identification in real time and a centralised computerised data entry.

SNESSA implemented a BT setup without communication between the primary and tracker platforms, with duplicate determined *a posteriori*, thus requiring much simpler equipment. The two trackers each had their own data recorder (a Fujitsu Stylistic Tablet PC), which recorded data on a hand-held computerized data sheet (*in house* NMFS software) that used both touch pull-down menus and hand-writing recognition fields. The three primary observers recorded their data on the same type of computer. The procedure performed very well, with no technical problems.

The proper use of the Big-Eyes seemed to depend on the stability of the platform and the willingness and determination of the trackers to persevere in using them, besides the quality of the equipment as such. If Big-Eyes are to be used in future surveys, special attention should be given to the stability of the vessels and platforms.

On the other hand searching with naked eyes might be problem if it leads to very many unidentified whales or dolphins. Palka (pers. comm.) switched back to the IO mode in the 2011 survey, after having conducted the 2007 survey in BT mode, because it was conducted outside of harbor porpoise habitat, unlike the 2007 survey. She notes “Using naked eye to identify all the different species of dolphins and whales would have been very difficult and so resulted in lots of unidentified dolphins and whales, which would not have been very useful. So in 2011 we had two teams using big eyes searching independently.”

CONCLUSION AND RECOMMENDATION FOR FUTURE SURVEYS

The level of bias observed in the collection of distance data clearly points to the need for close attention to the measurement of these and the need of some form of more precise distance and angle measurements system, than reticle and angle board reading. Latest technical (*e.g.* high definition cameras) and software development has permitted the development of such systems and their use should be strongly considered. Williams et al. (2007) recommended that even if measurement could not be made to/obtained for all sightings, it was important to generate a sufficient and representative sample size to assess error distributions, examine evidence for non-linearity, and to consider inter-observer differences. As Leaper *et al.* (2010) point out, there still remain technological challenges in operating complex electronic systems at sea to measure distances and bearings, but compared to increase ship time, investment in these methods should be a cost effective way of reducing bias and improving precision of cetacean abundance estimates. Also Gillespie *et al.* (2010) note "As computer hardware capabilities develop it is likely that the optimum means of implementing a system like this may change more fundamentally. For example, some of the rather cumbersome cabled connections used here might be replaced by wireless links."

The SCANS II system attempted to precisely measure data wherever possible and to record data in ways that allowed errors to be identified (*e.g.*, cross validation). This effort should be pursued in future surveys.
The validation system also allowed the cruise leaders to control in the course of the survey the way each observer was collected the data, in turn allowing for improvement if necessary.

From experience gained in the NASS and T-NASS surveys and other regular surveys (Palka, pers. comm.), compared to occasional surveys such as SCANS and CODA, it has become evident that it is not always easy to implement new methodologies and that observers (and cruise leaders) can be very reluctant in using new techniques. They will do so, however, more easily if they have a good knowledge and understanding of the new methodology and if they have been prepared to use it, i.e., trained to use it, so they feel confident in using it.

This takes us back to the absolute necessity in prioritizing first the training of the cruise leaders, second that of the observers. Also, and particularly in the case of the implementation of a new methodology requiring new equipment, it is fundamental that this equipment has been tested *in situ* and works smoothly. Therefore it is critical that a technical backup is available in case of problems, so the problems can be solve before the training of observers id carried out and before departure.

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Appendix 1

List of double platform surveys reviewed

Survey year	Area	Target	Method	Duplicate Id	PO	TP/IOP	FB	DI	DR	Tot	Specification	Reference
1986	California, Oregon, Washington	HP	IO	off	3-5bi	3bi						Barlow 1988
1986/87 -now	Antarctica	MW	IO	on	2bi	1bi	2bi		3-4			Butterworth & Borchers 1988, Matsuoka *et al.* 2003; Matsuoka 2011
1990	North Sea	MW, HP	IO?	?	?	?			?			Øien 1992
1991, -93, -96, 2001, 2005	U.S. west coast.	all	CIO	on (IO)	2be	1bi			1ne			Barlow 1995, Appler *et al.* 2004, Calambokidis & Barlow 2004, Barlow & Forney 2007
1991	Gulf of Maine	HP	IO	off	3ne	3ne				8	Short tracking for Dup ID	Palka 1995
1994	**SCANS, North Sea and adjacent waters**	HP, MW, dol	BT	on (DI+Tracker)	3ne	2bi		1		8		Hammond *et al.* 1995, 2002
1995	NASS Faroes, NEA	PW, MW, BW, CD, WSD	BT (SCANS)	on (DI+Tracker)	2ne	2bi		1		10	WINCRUZ	Desportes *et al.* 1996, Cañadas *et al.* 2004, 2007, Víkingsson *et*

												al. 2007
1995	NILS 95, NEA	MW	IO cues	off	2ne	2ne	x			9/12	Tracking of MW, Tape recorder	Øïen 95, Schweder *et al.* 1997
1995	California	HP	CIO	on (IO)	4bi	1			1	9	PPCRUISE	Caretta *et al.* 2000
1996-2001	NILS, NEA	MW	IO cues	off	2ne	2ne			?	8	HVAL2000, Tracking of MW,	Skaug *et al.* 2004
1998	NW Scotland	Fin and sei, wsd	IO (Palka 95)	off	3ne	3ne				8	LOGGER, reticle reading	Macleod 2004, Macleod *et al.* 2006
1998, 2004	NW Atlantic	all (low density)	IO	off	2be	2be			2ne	8	Short tracking for Dup ID, hand-held data entry computers	Palka 2005a,b, 2006
1999	NW Atlantic	all (high density)	IO	off	3ne	3ne				8	*same as above*	Palka 2000, 2006
2000-2002	Antarctica	FW, HW, MW	BT exp.	on (DR)	1	2bi			1			Williams *et al.* 2006
2000-2009	W N Pacific (Japan, Korea)	MW	IO / DC	on	2ne	2ne	x			?		Miyashita & An 2010

2001	NASS, NEA	FW, HW, MW	BT	on	2ne	2bi		1		10	WINCRUZ	Víkingsson *et al.* 2007
2002	Hawaii	all	CIO	on (IO)	2be	1bi			1bi			Barlow *et al.* 2004
2002-2007	NILS, NEA	MW	IO cues	off	2ne	2ne	x			8	Hval2000, Hval 2004.	Øien 2007, Bøthun *et al.* 2009
2003-2005	Cardigan Bay	HP, BD, GS	IO trial	on(IO)	2ne	1ne				4-7		Reay 2005
2005	W.A. English Channel (winter)	CD	BT	off	2ne+1 DR	1bi					LOGGER, digital voice recorder, camera measuring angle	WDCS 2005, De Boer *et al.* 2008
2005	**SCANS- II, North Sea**	HP, BD, DD	BT	on (DI + Tracker)	2ne	2bi+be		1	1	8	LOGGER, reticles, camera for angle & distance	SCANS-II 2006, MacLeod *et al.* 2009, N37Hammond *et al.* 2011
2005/06 - 2008/09	Antarctica	MW	BT2	on (FB)	2ne	2bi	2		3-4			Burt & Borchers 2008, IWC 2008, Russel *et al.* 2011
2006	Northern Sea of Japan	MW	IO	on	2ne	2ne		2		?	Voice recording system	Miyashita 2007
2007	CODA/T-NASS North	diverse	BT (SCANS II)	on	2ne	2bi+be		1	1	8	LOGGER, camera for angle &	T-NASS 2007, CODA 2007, CODA 2009, MacLeod *et al.* 2009,

	Atlantic										distance	Desportes 2011, Hammond *et al.* 2011
2007	SNESSA	all	BT	off	3ne	2be			2ne	11	PingleNet computers	Palka, 2008
2008-2013	NILS, NEA	MW	IO cues	off	2ne	2ne	x			8	Hval 2004, audio files	Øien & Bøthun 2008
2009	Gulf of Alaska	all	CIO	on (IO)	2be	1bi			1bi		wincruz	Rone *et al.* 2010
2011	AMAPPS	all	IO	off	2be	2be			2*1ne	8	ToughBook, VisSurv_NE	AMAPPS 2011ab

ANNEX 3

WORKSHOP ON AGE ESTIMATION IN MONODONTIDS
26-27 November 2011, Tampa Convention Center, Florida, USA

EXECUTIVE SUMMARY

The workshop was a 2-day event organised immediately before the Society for Marine Mammalogy biennial conference in Tampa. NAMMCO funding enabled participation of 4 invited experts and also supported the organization and logistics associated with the workshop. The breadth and depth of the workshop presentations made it clear that most issues concerning monodontid age estimation are not unique. Many researchers investigating many taxa have considered a diversity of methods and tissues to reveal biological records of age. Aside from the biological materials, accuracy and precision of the counts or metric have been considered, as well as their interpretation.

Relative age can be estimated using biological or chemical changes if the rate of change is known. Attempts to use **genetic telomere length** to estimate relative age show telomere lengths provide a measure of individual body fitness and condition rather than age, as environment, migration, health and reproduction affect telomere length. The method has potential but is still under investigation. Reviews of **aspartic acid racemization (AAR) aging techniques** on eye lenses from harp seals, *Pagophilus groenlandicus*, fin whales, *Balaenoptera physalus*, harbour porpoises, *Phocoena phocoena*, and bowhead whales, *Balaena mysticetus*, indicated potential for producing relative ages but warned that the presence of cataracts in the eye lens could seriously bias the age estimation upward. In narwhal, *Monodon monoceros*, tusk growth layer groups (GLG) correlated well with AAR age. The AAR method is relatively accurate, but species-specific racemization rates are essential for accurate age estimation. Age models using **endogenous fatty acid (FA) ratios** have been successfully derived for killer whales, *Orcinus orca*, and humpback whales, *Megaptera novaeangliae*. Preliminary results using a single FA ratio for Cook Inlet belugas, *Delphinapterus leaucas*, correlated with age from tooth GLG for physically immature animals. Future work using two FA ratios in belugas is expected to provide more precision in relative age. It may be possible to use bone density as an indicator of relative age in beluga and narwhal flippers. The method would need to be calibrated with reference to GLG in beluga teeth and validated AAR ages in narwhal.

The recording of **historic hunting artifacts** recovered in bowhead whales in Alaska has presented an opportunistic and potentially remarkable insight into longevity of this species (which may exceed 100 yr if the interpretation of the artefact is correct).

Micro-CT scanning demonstrated potential for investigating internal structure of teeth and other hard tissue specimens. Because there is no destruction of the specimen and 3-D viewing is possible, this technique could be applied to specimens that are difficult to interpret from thin sections or rare, and therefore, not possible to section.
Counts of presumed annual markers provide a more accurate (absolute) estimate of age than other tissues which show gradual changes with age. Hard structures that show **regular episodic growth** are the most commonly used tissues to investigate for

records of age that can be estimated from **GLG.** Tissues include bones, otoliths, claws, and ear plugs although teeth are most widely used. Undamaged e**ar plugs in baleen whales** provide a permanent record of total age from GLG therein. Apart from longevity, life-history parameters of age at sexual maturation and possibly physical maturation can be identified from the GLG patterns. Such patterns might exist in some teeth, and should be investigated. Ear plug extraction from carcasses of minke whales, *Balaenoptera acutorostrata*, is facilitated by a new method of **using injected gelatin** which increases the possibility of extracting whole and undamaged ear plugs. This method should be evaluated for bowhead whales in which ear plugs are soft and fragile.

Teeth GLG are commonly used to age carnivorous mammals, including marine mammals. Techniques for preparing teeth vary. All are directed at obtaining the most complete record of clear laminae, key to which are tooth sections with correct orientation to display all the laminae. A review of aging in sirenians indicated there are many internal similarities between dugong, *Dugong dugon*, tusks and beluga teeth, and also perhaps narwhal tusks. The GLG deposition rate in dugong tusks is annual.
In belugas, counting **GLG in dentine,** as seen in medial longitudinal sections of teeth, is the standard method and consistent with methods used in other taxa. The most suitable material is a thin untreated section (ca 150-200 micron). Counting **GLG in cement**, using the same medial sections, may be useful for belugas where cement is thick and especially when the dentine is worn down at the tooth crown. Cement is not useful for most cetaceans. GLG patterns in sperm whales and belugas are very similar.

Precision and accuracy are essential in age estimation from GLG counts. The repeatability of the GLG counts (precision) and accuracy (whether or not the GLG counts indicate the correct age) are not the same. **Quality control** is essential for both and there must be regular monitoring of an aging programme. The best measures of age precision are coefficient of variation (CV), average percent error (APE) and index of dispersion (D), while the least reliable is percent agreement among readers which is usually the most commonly used assessment. A permanent reference collection of aging materials, *e.g.*, known-age beluga teeth, is the key to effective quality control. In an investigation of precision and bias in beluga tooth age data, it was concluded that errors arising in estimation of biological parameters can be both negatively and positively biassed with varying degrees of variance. In turn these translate to errors in estimation of growth rates. Efforts should be made to quantify bias and precision.
One of the most persistent debates in age estimation of the beluga has been about the accurate translation of GLG counts into time units (years). The **measurement of radiocarbon, ^{14}C,** in laminated hard structures of animals has been a precise and successful method for validating age in many species, including **belugas where GLG deposition rate was found to be unquestionably annual.** The most direct age estimation technique is that of following recognizable individuals through time. **Long-term photo-ID monitoring** and surveys of the Gulf of St Lawrence belugas resulted in an abundance of reliable data on life history, age, reproduction, growth and colour change. Teeth collected during necropsies on recovered known-age and known-history belugas have validated GLG deposition rate.

Investigation of the age from teeth of known-history captive belugas, together with data on **tetracycline time-marking of teeth** generally also supported an annual deposition rate of GLG. However, GLG definition was unclear in some specimens, particularly in the juvenile phase. Several other studies confirmed the value of long-term monitoring of known animals for validation of age. **Information on growth and reproduction** of Cumberland Sound belugas that was presented in support of a deposition rate of 2 GLG per year was criticized on a number of counts and was not accepted by participants.

Future research was identified in several areas to fine tune our understanding. One potential technique for estimating total age from worn beluga teeth using **the angle of the boundary layers relative to the pulp cavity edge** appeared promising and should be followed up. Of a broader nature is the potential to understand the ecological correlates to lamina formation. **Laser ablation (ICPMS) for trace elements** in beluga tooth GLG indicated some elements show periodic oscillations. Investigation of **stable isotope ratios** ^{13}C and ^{15}N in beluga teeth were also promising. The point of weaning can be identified from the ^{15}N depletion up to this point. Oscillations of elements in the teeth may be linked to ecology and movements associated with feeding and migration, although these may not be annual, and thus cannot be used as an age proxy presently.

A number of **specific recommendations for monodontids** were made at the workshop, including inter-method comparisons of alternative aging methods using data and samples from free-living known-age animals. The number of samples of known age captive beluga from which teeth can be collected should be augmented with comprehensive sampling of other materials useful for age estimation. A focus on the immature phase of growth in teeth in beluga with reference to captive animals to determine GLG patterns is desirable. Reference collections (hard parts) should be established and digital image exchange for calibration and training among labs be considered. Quality control routines should be established and should include periodic exchanges among laboratories and inter-laboratory calibration for all aging techniques. Comparison of tooth preparation methods among labs is desirable. A new study to estimate crown wear from angles of boundary layers into the dentin-cement junction in beluga teeth to estimate the maximum number of GLG that have disappeared should be initiated. Chemical time-marking for age calibration of hard parts and bomb radiocarbon validation of hard parts and eye lenses is encouraged. A study comparing GLG in teeth to GLG in ear bones for beluga, and if successful, evaluating ear bones as a method for obtaining direct estimates of age in narwhals is encouraged. A comparison of GLG structure among stocks (free-living and captive) is desirable.

In conclusion, the workshop members agreed on several aging methods which are or may be applicable to monodontids, including potential new methods which, depending on the type of tissue required for analysis, may be applicable both to living and dead animals.

Overall, tooth GLG are judged to be the best and most precise method. Presently, tooth GLG are only useable in belugas, but the AAR technique is very promising in narwhals. More work needs to be undertaken on embedded tusks of young narwhal to help calibrate the AAR rate in narwhals. GLG in ear bones should be compared to results from the other methods. The AAR method should also be applied to beluga eye lenses to provide a correlation with beluga tooth GLG. Such a study might provide more reliability on the narwhal AAR work presently done.

Currently, **bomb radiocarbon** is the method that is most accurate and that can be used for calibration of alternative aging methods**.** However, the main limitation is that at least some of the teeth or hard tissues must come from animals that were born before the fallout commenced, *i.e.*, pre-1958.

The workshop agreed that an annual deposition rate of tooth GLG was to be the accepted standard in belugas.

Finally, it was agreed to publish the proceedings from the workshop in a volume of the NAMMCO Scientific Publication Series, entitled *Age estimation in marine mammals with a focus on monodontids*. NAMMCO has approved the proposed volume with a probable publication date in 2013. The editors would comprise the members of the Steering Committee for this workshop in addition to the technical editor, Mario Acquarone.

MAIN REPORT

1. OPENING, WELCOME AND INTRODUCTION

The workshop opened with a welcome by Christina Lockyer, General Secretary of NAMMCO, who presented the other members of the steering committee responsible for planning and convening the workshop. The steering committee, appointed by the Joint Scientific Working Group (JWG) of the NAMMCO-JCNB (Joint Canada Greenland Commission on Narwhal and Beluga), was Aleta Hohn (NOAA, Beaufort, North Carolina, USA), Roderick Hobbs (NOAA, Seattle, Washington, USA), and Robert Stewart (DFO, Winnipeg, Manitoba, Canada) in addition to Christina Lockyer. Mario Acquarone, Scientific Secretary of NAMMCO, was appointed general rapporteur for the meeting.

Lockyer stated that the focus of the workshop was on monodontids although contributions on all marine mammals, and even other organisms, that had possible relevance to methods applicable for monodontids would be welcomed. Many contributions had already been offered and registered, and a booklet of abstracts of most presentations was available to participants at the workshop.

2. WORKSHOP BACKGROUND, BASIS AND OBJECTIVES

Approval for the workshop came from the JWG of the NAMMCO-JCNB, and subsequently was approved a budget by NAMMCO Council under the work of its Scientific Committee.

Initial publications on age estimation in odontocetes used tooth growth layer groups (GLG) which were codified and defined by Klevezal (1980) and Perrin and Myrick (1980). A GLG is a group of incremental layers which may be recognised by virtue of cyclical repetition. Spacing of GLG is usually constant or changes in a regular, systematic manner, usually diminishing with age, and a GLG must involve at least one change between light and dark incremental layers. Hohn (2009) provides a good overview of aging in marine mammals.

From a historical perspective, publications on age estimation in belugas, *Delphinapterus leucas*, date from the pre-1970s (Sergeant 1959, Brodie 1982) when 2 GLG per year were anticipated by comparison with the then supposed deposition rate in sperm whales, *Physeter macrocephalus*, (Gambell and Grzegorzewska 1967). When this assumption for sperm whales was subsequently amended to an annual deposition rate (IWC 1969; 1980; Best 1970; Gambell 1977), a more general assumption was made for all odontocetes, except for belugas (Heide-Jørgensen *et al.* 1994). The assumption of an annual GLG deposition rate in odontocetes was also supported by other publications on a variety species for which validation of age estimation was possible;, *e.g.*, Myrick *et al.(*1984, 1988), Hohn *et al.* (1989), and Lockyer (1993).

The question of GLG deposition rate was raised again for belugas at the 51st IWC SC (IWC 2000) by Hohn and Lockyer (1999) referring to the examination of two captive known-age, known-history belugas with tetracycline time-marking of teeth. Although no conclusions were reached at this time, there was sufficient evidence to sow doubt on the interpretation of 2 GLG per yr in belugas.

Subsequently, a workshop, supported by NAMMCO and the NOAA laboratory in Beaufort, USA, focusing on interpreting age from teeth of 10 known-age and known-history belugas was held in 2001 (Lockyer *et al*. 2007). Recommendations included further monitoring of known-age captive belugas, trials of other aging methods, *e.g.*, aspartic acid racemization (AAR), and, not least, - standardization of GLG counting among researchers.

At the meeting of the JWG held February 2009 in Winnipeg, Canada, participants expressed broad support for a workshop to address age estimation in monodontids (beluga and narwhal). They noted, for example, the value of cross-laboratory calibration, standardization of methods, and the use of AAR of eye lenses relative to growth layers in small, embedded tusks of narwhal. It was suggested that consideration should be given to how the insights on age estimation developed at the workshop(s) will be incorporated into model input. Better life-history data based on known-age animals will improve the reliability of population assessments. Finally, interest was expressed in having new methods of age estimation (*e.g.*, fatty acids) explored in a workshop context.

NAMMCO indicated a willingness to convene and organize the workshop(s) and that selection of the venue(s) would be critical. For the practical components, it would be necessary to hold the workshop(s) in an appropriately and adequately equipped laboratory.

Recognizing that there are a number of problems with age estimation for both the monodontid species, and that these need to be studied in more detail, the JWG recommended that a steering group (chaired by Lockyer and including Hobbs, Hohn, and Stewart) work inter-sessionally by e-mail to scope the problems and produce draft terms of reference for one or more workshops.

Terms of Reference (TOR) were developed by the steering group, and subsequently approved by NAMMCO, which also approved a budget for the workshop(s). The two TOR provide the following guidance:

1. To standardize tooth GLG reading methods for age estimation in beluga and narwhal where feasible, and calibrate against other techniques such as using AAR, and produce a manual as a guide to tooth reading in the above species.
2. To draw together traditional and new techniques for determining age in marine mammals, where these methods may be applicable to belugas and narwhals, by holding a workshop of experts in this field, and produce a report.

At this stage it became clear that there should be two different workshops: one where new ideas and techniques could be presented and discussed (TOR 2), and another which focused purely on laboratory preparation, examination, interpretation and validation of teeth, (TOR 1). Two workshops were planned in association with the biennial Society for Marine Mammalogy (SMM) conference in 2011 when there would be the opportunity to bring as many experts together as possible. TOR1 was addressed at a laboratory workshop at the NOAA Beaufort laboratory following the SMM Conference and results will be reported in a separate document.

For the current workshop, held in Tampa, the following TOR were derived from TOR 2 (above):

1. Review current methods of age estimation in marine mammals with a focus on monodontids.
2. Recommend the method(s) most suitable for monodontids; and trials of any new techniques that are as yet untried in monodontids.
3. Compile previously unpublished papers submitted to the workshop and relevant to age estimation in monodontids in a publication volume entitled “Age estimation in marine mammals” of the NAMMCO Scientific Publication Series.

Invited participants (Appendix 1) discussed a diversity of studies as noted in the workshop agenda (Appendix 2). The following sections present each author’s abstract, a summary of the presentation materials, and discussions that followed each presentation.

PRESENTATIONS

3. Age estimation methods applicable in mammals with special emphasis on marine mammals and especially monodontids – Fiona L. Read

ABSTRACT: *Accurate age estimates are fundamental for understanding and interpreting many aspects of mammalogy. Age has traditionally been used to understand the biology of a species at an individual and population level and further study the dynamics of the population and the need for accurate and precise ages has increased over time due to changes in research interests. Age estimation can be defined as absolute and relative age. Absolute ages are achieved by counting growth layer groups (GLG) in hard structures such as teeth, ear plugs, baleen, bones and claws. Relative age can be obtained by methods such as aspartic acid racemization of the eye lens, telomere length, bone mineral density, fatty acid signatures etc. The present work provides a review of methods for age estimation in marine mammals, including the pros and cons and accuracy of each method. Methods for validating age estimations will be discussed. Furthermore, the unresolved discrepancies of aging monodontids (narwhals and belugas) (mainly 1 or 2 GLG per annum) with special emphasis on recommendations for overcoming these problems and the application of newer methods,, e.g., telomere length, with be discussed. Finally, concluding with the main objectives that future age estimation studies should focus on.*

The presentation covered a variety of materials (Fig. 1) and methods used for estimating age in marine mammals, with an appraisal of each type. During her presentation the difference was noted between absolute and relative ages. The concept of a Growth Layer Group (GLG) was also explained as a repeating pattern that equates to a period of time. The structure of teeth was discussed in relation to the dentine originating from the pulp cavity and external cementum originating from the gum tissue, as well as the significance of the neonatal line at birth.

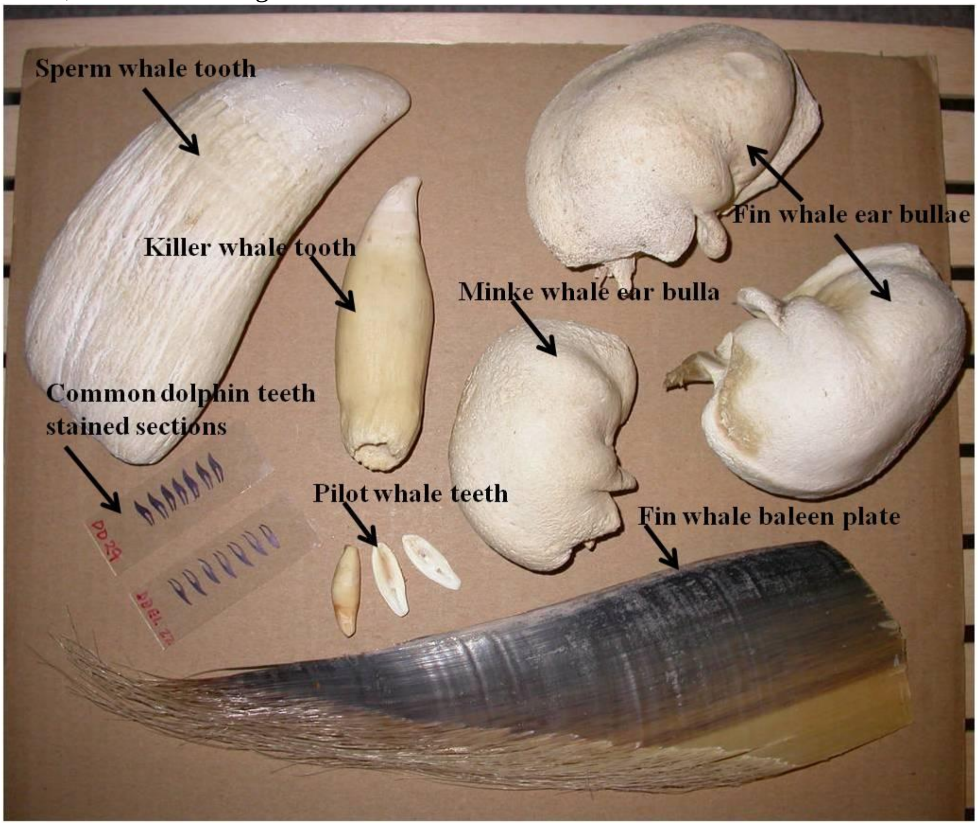

Figure 1. Hard parts including teeth, ear bones and baleen plates that can be used for age estimation (Photo: Christina Lockyer, Age Dynamics, Denmark.).

<u>Preparation methods:</u>

Direct methods

In summary, for teeth:

- Untreated sections: are often best for dentine, depending on species, and can be used for cementum. The method is time and cost effective. The method is less reliable for some species as GLG are not prominent and the pulp cavity becomes occluded with age.
- Stained sections: are best for small teeth, and are successful for several species but are time consuming to prepare and require additional specialized equipment.
- Acid etching of half teeth: is a simple and inexpensive method, but is not very satisfactory for teeth from small animals.
- Scanning electron microscopy (SEM): produces a 3D image with high clarity, which is very readable, but is not good for small species and is very expensive in time and resources.

- Microradiography: is a method that is non-destructive, unlike many others mentioned. For determining older GLG, high precision is needed.

Other materials than teeth employed for aging include:

- Claws: a method useable for seals, which is quick, easy and inexpensive. The method is only applicable for young animals with less worn claws.
- Baleen plates: this method is useable for baleen whales, but as with claws, only in young animals with unworn baleen.
- Ear plugs: this is a method useable in baleen whales. Total age and age at sexual maturity can be estimated, but the ear plugs are challenging to collect.
- Ear bones (tympanic bullae): thin untreated sections provide GLG counts lower than ear plugs, perhaps because of bone resorption with age. The method is limited to a few mysticete species.
- Periotic bones: this method is used in manatees where teeth (molars) are changed throughout life and cannot be used, but maybe be useful for other species, as well. Sections are decalcified and stained.
- Tusks: found in narwhals and walruses, as well as male dugongs, are often worn down and provide an incomplete age.
- Other bones, mainly mandibles and ribs, are sometimes useable but the methods are very species-specific, and to be used as a last resort when other means fail.

Mineralization anomalies in teeth can be used to identify environmental variations or unusual events (El Niño, life-history events – Manzanilla 1989). Presence of anomalies can be a source of potential misinterpretation of age. Misinterpretation of the GLG and poor preparation of the sections can lead to inaccuracy in counting. These issues may be overcome by some standard routines. There are also differences in GLG between young and old animals, which may lead to age inaccuracies. The former have accessory lines, while old animals may have tightly packed GLG that are hard to differentiate.

Indirect methods

Such methods provide relative age and are mostly unpublished and/or are unsuccessful.

- Bone density: a non-invasive, fast and relatively inexpensive method. However it requires basic age data for the model and specialized equipment. The method can be used from live to badly decomposed animals, all sexes.
- Genetic telomere: a method based on measurement of the average telomere length. Only two studies on marine mammals are currently published and are not unequivocally promising. Validation and calibration are necessary and the results may only produce age class information.
- Aspartic acid racemization (AAR): a method based on the D/L ratios of enantiomers, requiring stable temperatures. The method is better for old animals and species for which other methods are difficult, sensitive, and complicated, but it needs species-specific data for calibration and more precision.

- Fatty acid signatures (FA): the method can use the FA composition of the outer blubber layer. It has been successful with some species and is minimally invasive as biopsies can be taken. Presently the method can not to be used for estimating longevity and is not comparable across labs. The underlying biological factors are unclear.
- Ovarian corpora: a method that is easy and inexpensive, but requires dead animals and applies only to females. To calibrate age, life history data are needed to provide age at first parturition.
- Baleen plates in baleen whales can be analysed for isotopic patterns due to seasonal dietary changes. The method has been successful in bowhead whales (Schell and Saupe 1993, Lubetkin *et al*. 2008) but may only be useful in younger animals when other methods are more reliable.
- Dental colour: this method requires a standard colour reference guide for interpretation.
- Morphometrics: a method that is fast, consistent and cheap, *e.g.*, body length, but is not precise either for young animals, which may grow at variable rates, or older animals, which may achieve different ultimate sizes. Over-all growth may be too sensitive to energy intake to precisely measure age.

<u>Validation:</u>
Validation is essential to aging methods but has rarely been done in marine mammals. Validation can be effected through

- Known age, known-history animals. Photo-ID may help in tracking such free-living animals.
- Captive animals born in captivity or of known age when captured. GLG might not be as well defined as in wild animals
- Biomarkers, ideally administered on the animal's birthday and at set intervals,, *e.g.*, lead acetate or tetracycline antibiotics that leave a time-mark in hard tissues.
- Bomb radiocarbon isotope fallout (a natural biomarker), based on ^{14}C from nuclear experiments in the 1950s and 1960s. The method requires samples from before and after 1958. This is high technology and needs expensive equipment.
- Artifacts found in animals. These may include tags of natural or artificial origin, *e.g.*, "Discovery" tags, harpoon heads found in whales. It lacks precision due to the time span in which the technology was used and the life span of the animal before being 'tagged.'

<u>General conclusions:</u>

- Hard tissues, *e.g.*, teeth and bones, are good materials for aging but are species-specific.
- More than one method may be accurate for a species but time and funding constraints often preclude the use of more than one.
- There is a need for standardization among research labs for both method and reading GLG.
- All methods should be validated.

- The aging method chosen should reflect the purpose for which ages are required. Sometimes precise ages are not necessary.
- Combining complementary methods might be required for 'tricky' species.
- Often the ages estimated are only minimum ages.

Monodontids:

Beluga and narwhal are problematic species with respect to aging. To date, there are still discrepancies among methods and further work on validation is required. However, advances have been made for narwhal with the application of AAR techniques to eye lenses, although teeth (embedded or tusks) are not generally useable except in males. For belugas, teeth are potentially the most useful method of aging. There is a need for standardization of GLG counting, and especially for stating the number of GLG in addition to the age estimated. There is not yet full agreement on a deposition rate of GLG for beluga, although one per year is now favoured. Once GLG deposition rate is certain, all previous age data should be revised. Until agreement on GLG deposition rate is reached, management should be cautious about age parameters.

Focusing on belugas, a summary of methods for estimating age is provided in Table 1 where suitability, cost, source reference, and other factors are noted.

Discussion

Read was thanked for her comprehensive review. Steve Campana queried whether new imaging technology can reveal previously invisible structures in teeth of marine mammals. Imaging technology is relatively accessible. However, it is difficult to standardize the enhancements to the point where one does not see structures which do not relate to age. The possibility of enhancement by chelation by EDTA was raised. Care should be taken to interpret age artifacts which may be either opportunistic or experimental. It is important for animals tagged or marked at birth be followed throughout life for validating age methods.

Table 1. Different methods of age estimation in belugas with an appraisal of relative cost and efficacy. Green cells indicate preferred methods; yellow indicates some merit and areas for possible development; and red indicates little merit for routine aging.

BELUGA WHALE		Relative cost	Time required	Precision	Accuracy (where tested)	Pros	Cons	Reference
Teeth	Untreated-dentine	low	Short	medium	high	Clearer than cemental GLG. Does not close	Severe wear of the tip; some stocks show less distinct GLG	Perrin and Myrick 1980
	Untreated-cementum	low	Short	medium	medium		Cemental GLG form too closely to read; often the cemental GLG count is less than the dentinal GLG	Lockyer *et al.* 1999, Stewart *et al.* 2006
	Stained-dentine	medium	Long	high				
	Stained-cementum	medium	Long	high	high			

	Acid etching	low	Medium	low	low	GLG visible	Did not improve readability	Perrin and Myrick 1980, Pierce and Kajimura 1980
	Scanning Electron Microscope	high	Medium	high	low		GLG visible but not countable	Goren *et al.*1987
	Microradiography	medium	Short	low	n/a			
Mandible	**Untreated**	low	Short	medium	medium			
	Stained	medium	Long	high	medium			
Others	**Bone density**	medium	Medium	high	n/a			
	Genetic telomere	high	Long	medium	n/a			
Validation	**Aspartic acid racemization**	high	Long	high	n/a			
	Fatty acid signatures	high	Long	high	n/a			

	Relative age from ovarian *corpora*	low	Short	low	low		Accessory *corpora lutea*	Suydam 2009
	Known-age / history (incl. wild)	low	Long	high	medium/high	photo-id project has started		Hohn and Lockyer 1999, Lockyer *et al.* 2007
	Tetracycline	low	Long	high	medium			Brodie 1982, Hohn and Lockyer 1999, Lockyer *et al.* 2007
	Captive	low	Long	high	high			Brodie1982, Hohn and Lockyer 1999
	Bomb Radiocarbon	high	Long	high	high		Requires animals pre- and post 1958	Stewart *et al.* 2006
	Artifacts	low	Short	medium	n/a			George and Bockstoce 2008

4. Direct aging in dolphins, including belugas – Aleta Hohn

ABSTRACT: *Early studies suggested the possibility that teeth in dolphins (and pinnipeds) contained growth layers that served as an indicator of age. Since that time, most of the emphasis of direct age estimation in dolphins and porpoises has focused on validation of deposition rates, improved methods of preparing teeth for optimal resolution of growth layers, and standardizing protocols for counting growth layers. A workshop in 1978 discussed the complexity of growth layer patterns and the term "growth layer group" (GLG) was agreed to best represent that annual layers included smaller incremental growth layers. These incremental layers have been referred to in various ways, with particularly distinct incremental layers appearing as accessory layers that confuse readings of annual GLG or as marker lines, that represent life-history events. Despite remaining questions, with the exception of long-terms studies of known individuals, counts of GLG still serve as the best means of estimating age in dolphins.*

Hohn discussed the advantages of using teeth for age estimation and some caveats. Tooth structure reflects the animal’s physiology at the time of deposition, which is a bonus for life history and stock information. The anatomy of teeth with specific examples was presented. The disadvantages of using teeth included sub-annual incremental growth laminae, which confuse age estimation, and crown wear, which erodes layers. It is critical that the orientation of the section is in the midline from crown to root apex. In some species GLG become compressed with age, so that layers are missed towards the root apex in old animals. There can be variations in tooth ultrastructure within species according to stock and region. The use of teeth for aging is relatively easy and inexpensive leading many “non experts” to use it without training, producing erroneous, non-standard ages. Accurate age estimation is important, as it is important to be aware that there are biases associated with the techniques (Hohn and Fernandez 1999).

Discussion

The possibility that dentinal-cemental layers might not be consistent was raised, but this seems to be a species-specific question. The cemental GLG counts can help in cases where the young dentinal layers are missing, depending on the species and how the cementum is formed. With reference to harbour porpoise, the cement can be used to determine where the first year layer is placed.

With respect to potential differences between captive-held and free-living animals, it was stated that there are no differences in tooth GLG in *Tursiops* in captivity or in the wild.

5. Investigating the deposition of growth layer groups in dentine tissue of captive common dolphins - Sinéad Murphy, Matthew Perrott, Jill McVee, Wendi Roe and Karen Stockin.

ABSTRACT: *Knowledge of age structure and longevity (maximum age) are essential for modelling marine mammal population dynamics. Estimation of age in common*

dolphins (Delphinus sp.) *is primarily based on counting Growth Layer Groups (GLG) in thin sections of decalcified and stained hard dental tissues. The incremental deposition rate was validated for* Delphinus sp. *30 years ago through the use of tetracycline, an antibiotic that was employed as a fluorescent vital marker in teeth of captive dolphins. Although an annual GLG deposition rate was identified, it is not known if the pulp cavity becomes occluded in older individuals or if GLG continue to be deposited in dentine tissue. To date, the oldest wild common dolphin has been aged at 30 yrs. To investigate the deposition of GLG in dentine tissue, tooth? samples were obtained during the necropsies of two New Zealand common dolphins that were held in captivity for 31 and 34 years. Individuals were captured together in Hawkes Bay, and classified as juveniles based on physical appearance. Teeth were processed in two aging laboratories, using four different bone decalcifiers, two sectioning techniques incorporating the use of both a freezing microtome (-20°C) and paraffin microtome, and two different stains. Time required for decalcification was determined by manual assessment of pliability, calcium oxalate precipitation end point tests or radiography. A maximum age was estimated for one of the dolphins, in line with that proposed based on estimated age at capture and period in captivity. However, a hypermineralised area was observed in the dentine tissue close to the pulp cavity of the second individual, preventing estimation of maximum age. The presence and structure of this anomaly is explored further within the study.*

A general introduction was given on common dolphin from different regions of the world with estimates of longevity from teeth up to *ca.* 30 yr. However, this presentation focused on the species around New Zealand, where two common dolphins, *Delphinus sp.*, captured young, were held in captivity for more than three decades before death. Shona died in 2006 at 206 cm length, after 31.3 yrs in captivity, suggesting an age of 4 yr from body length at time of capture (Kastelein *et al.* 2000); Kelly died in 2008 at 204.5 cm length after being held captive for 33.75 yr, suggesting an age of 3 yr from length at time of capture (Kastelein *et al.* 2000). Two preparation methods were applied to the teeth although both fixed the teeth in 10% neutral buffered formalin initially. Wax embedding, sectioning at 5 micron, and haematoxylin staining were employed in St Andrews University, Scotland, and frozen sectioning at 18-25 micron with toluidine blue staining at Massey University, NZ. Before sectioning, different decalcification methods were tried and compared, using whole teeth from each animal:

St Andrews:

- RDO - up to 3 days
- Formical-4 - more than 6 months

Massey:

- 10% Formic Acid - up to 6 weeks
- 10% EDTA - up to 6 weeks

Different endpoint tests (radiology or ammonium oxalate) were found for all chemicals. In some instances, the period for decalcification extended into months, and the chemicals were not completely effective. RDO was the most effective. Estimated ages for Shona were up to 27-36 yr, while for Kelly were up to 19 yr, far less than anticipated due to area of hypomineralisation around the pulp cavity. Both captive dolphins had lighter skulls than wild dolphins of a similar skull length found stranded along the New Zealand coastline.

Discussion

There was a suggestion that the teeth be pared down so that only the central part of thickness of about 2-3 mm is decalcified. This method would facilitate and hasten the decalcification process because of better permeation of the decalcifying agent.

6. Age estimation in seals - Fiona L.Read

ABSTRACT: *Accurate age estimates provide valuable information about the age structure, age at sexual maturity, and longevity of a population and are fundamental for understanding and interpreting the dynamics of a population. Age estimation in seals is particularly important due to the large numbers harvested in management systems and their large fluctuations in population size resulting from viral epidemics, e.g., the harbour seal* Phoca vitulina *phocine distemper epidemics in northern Europe in 1988 and 2002. Traditionally in seals age is determined by counting growth layer groups GLG in the dentine and/or cementum of teeth and, less frequently, in claws. In recent years, more novel approaches of age estimation have also been attempted with varying degrees of success, e.g., telomere length and aspartic acid racemization. The following presentation will review the methods used to establish age estimates in seals, the pros and cons of each method, the best tooth for age estimation and how the methods have been validated and calibrated, e.g., known age animals and multi-reader experiments. The presentation will conclude with how our present knowledge for obtaining age estimates in seals can be applied to age estimation of monodontids (narwhals and belugas).*

Direct methods of aging include tagging, freeze-branding and photo-ID. For indirect methods, claws and teeth are used. The presentation covered the following species: grey seals *(Halichoerus grypus)*, harbour seals *(Phoca vitulina)*, harp seals *(Phoca groenlandica)*, and ringed seals *(Pusa hispida)*, although other species were mentioned (Table 2 below). The best tooth for aging is the canine, although others have been used, and tooth selection largely depends on whether the animal is alive or dead. Mineralisation anomalies such as pulp stones were discussed. Their presence complicates the counting of GLG. Other methods tried for aging were mentioned, *e.g.*, AAR, genetic telomere length, radiography and X-ray of bone density and teeth. However, teeth remain the best method for seals, although AAR and telomere length are promising.

Discussion

The possibility of scaling the weight of teeth with body size/age to obtain an approximate age was discussed.

Table 2. Tooth preparation and age estimation in seal species.

Seal Species	**Section**	**Untreated / Stained**	**Stain**	**Cementum / Dentine**	**Vali-dated**	**Reference**
Baikal	Longitudinal	Stained	Haema-toxylin	Cementum	-	Amano *et al.* 2000
Bearded	Transverse	Untreated	-	Cementum	With claws	Benjaminsen 1973
Grey	Longitudinal	Untreated	-	Cementum	Known -age	Hewer 1964; Mansfield 1991
Harbour	Longitudinal	Stained	Tolui-dine Blue	Cementum	Known -age	Dietz *et al.* 1991; Lockyer *et al.* 2010
Harp	Transverse	Untreated	-	Dentine	Known -age	Bowen *et al.* 1983; Frie *et al.* 2011
Monk	Longitudinal / Transverse	Untreated	-	Cementum	-	Murphy *et al.* 2012
Ringed	Longitudinal	Stained	Haema-toxylin	Cementum	-	Stewart *et al.* 1996

7. A brief review of age estimation in sirenians, focusing on dugong tusks - Christina Lockyer

ABSTRACT: *The different evolutionary origins of sirenians, with links to elephants, means that teeth in this Order cannot generally be used for age estimation. The specialised molars in manatees, erupt at different times and wear down and move forward so that they are replaced (Marsh 1980) – as in elephants. Dugongs however have molars and premolars, which wear down, and a pair of incisors. These incisors erupt in males and continue growing throughout life to become tusks. Internally their structure shows a regular annual incremental GLG pattern (Mitchell 1976, 1978). Longevity can exceed 60 yr. Tusks generally do not erupt in females, so other*

techniques must be employed for aging,, e.g., dry eye lens weight. In manatees, ear bones can be used for aging, but this topic is not discussed. The similarities between internal GLG patterning in dugong tusk and both sperm whale and beluga whale teeth are reported.

Lockyer emphasised the longevity of sirenians and the very similar GLG patterning in teeth of monodontids. In some respects the dugong tusk in males has similarities to the tusks of male narwhals.

8. **Prospects for genetic age estimation of cetaceans - Morten T. Olsen**, Martine Bérubé, Jooke Robbins and Per J.Palsbøll

ABSTRACT: *Although the proliferation of tools available to cetologists has increased our understanding of whale ecology and evolution, there are questions of a temporal nature that will remain unanswered until a reliable and accurate method of age estimation is developed for free-ranging Cetaceans. Telomeres are DNA sequences situated at the end of chromosomes and tend to shorten with age, suggesting that telomeres may be used as a marker for age estimation. Here we report on the relationship between telomere length and age in the humpback whale (*Megaptera novaeangliae*). We used four different qPCR methods to estimate the rate of telomere shortening both across samples and* in vivo *in individual humpback whales for which multiple skin samples were available. The overall correlation between telomere length and age was weak, and highly variable among individuals of similar age, suggesting that telomere length measured by the qPCR method is an imprecise predictor of chronological age in humpback whales. We discuss the potential factors responsible for the observed patterns as well as the prospects for age estimation of cetaceans by use of the above and alternative methods for telomeres length measurement, such as TRF analysis and the novel dot blot method.*

Olsen's presentation indicated genetic material had been isolated from skin biopsies of 56 humpback whales using quantitative PCR analysis. A ratio between T/S was made using a known reference gene (Cawthon 2002, 2009*)*. Telomere length was not precise for determining the absolute age, however, it might be used for characterizing the age classes of a population. Presently there are inherently large experimental errors. The method was nevertheless promising for relative age and for use in aging live animals. Telomeres can express biological age and are thus reflect external factors that may affect health and growth such as oxidative stress, *e.g.*, pollution, metabolism and diving hypoxia, reproduction and general health, which may affect the length of telomeres.

Comparing methods, TRF (telomere restriction fragmentation) has been found to be a precise and more accurate, while relatively expensive, technique for aging. The Dot Blot method (Kimura and Aviv 2011) requires less refined DNA and is relatively quick and inexpensive, and is useful for standard applications.

Species-specific calibration is required for aging. For humpback whales, additional older known-age animals are required for calibration and a cross-lab calibration is needed. The rate of telomere shortening is generally low although there is large individual variation. At best, telomeres may be proxies of life-history trade-offs.

Discussion
The study was accepted as preliminary but with interesting results. Although it is perhaps unlikely that this method may be useable for precise aging in any marine mammal, the technique has promise for defining broad age classes – useful in live populations, and may reflect life history of individuals.

9. Age estimation from teeth in large odontocetes - Christina Lockyer

ABSTRACT: *This presentation introduces the use of teeth from large whales to estimate age. The concept of counting Growth Layer Groups (GLG) that form throughout life is discussed with reference to its validity, and the assumption of an annual incremental rate of GLG. The species used as examples include sperm whales, killer whales, bottlenose whales, and beaked whales. The method of halving the tooth from crown through root for sperm whales,* Physeter macrocephalus*, and etching the smooth cut surface with 10% formic acid to throw the GLG into relief is satisfactory. However, methods of thin sectioning at 100-200 micron, as well as decalcification, thin-sectioning at 25 micron and subsequent staining, are discussed for smaller species such as beaked whales, e.g.,* Mesoplodon sp. *In sperm and killer whales, problems of wear at the crown of the tooth lead to under-estimation of age in old animals. The presentation concludes with comments on the relevance of the methods of tooth preparation to beluga, and finds similarities in sperm whale teeth GLG patterns as well as crown wear and possible longevity to belugas*

Methods described included acid-etching half-teeth with 10% formic acid or other agents (Gambell and Grzegorzewska 1967, Evans *et al.* 2002), thin sectioning, and decalcification methods with stained thin sectioning. For large teeth such as sperm whales, the best method is the simple acid-etching of half teeth. Special problems arise with teeth from some beaked whales (*Ziphiidae*) in which teeth are curved and difficult to cut/section. In conclusion, the size of the tooth dictates the method, but untreated sections work for small sperm whales, killer whales, beaked whales, and bottlenose whale, *Hyperoodon ampullatus*, teeth. The estimation of total age can be problematic when the crown is worn down and GLG are missing. The relevance to monodontids includes superficial similarities between beluga and sperm whale teeth; the untreated section method is good for both and crown wear is often severe and leads to underestimation of age. It is helpful to have body size data to compare with GLG age.

Validation of age has been feasible for known-history killer whales, some also with tetracycline antibiotic time-marking of teeth, but requires subsequent retrieval of teeth (Myrick *et al*. 1988). Bomb fallout radiocarbon isotope analysis may be possible in animals of all species born pre-1958.

10. Age estimation in mysticetes with a focus on ear plugs - Christina Lockyer

ABSTRACT: *The different methods that have been employed to age Mysticetes are briefly noted with comment on their applicability. The focus is on ear plugs as being the best method in Mysticetes. The ear plug (paired) which is of epidermal origin and is found in the external auditory meatus, grows continuously throughout life and thus holds a complete record of age. The incremental rate of deposition of GLG is annual and the ways this has been validated are reported. The ear plug anatomy, its collection, and the method of preparation for GLG counting are described and as are the internal GLG pattern that changes with age to permit estimation of age at sexual maturity at the transition phase. The ear plug is generally used successfully in fin, sei and minke whales, and also can be used in blue, Bryde and humpback whales. The total age and the transition phase enable life history parameters to be determined retrospectively. A comparison is made with beluga tooth GLG patterning, noting the occurrence of accessory lines which are primarily a juvenile feature in Mysticetes, and the compacting of GLG in old beluga teeth.*

Age estimation has been done using ear bones, jaw bones and tissues of epidermal origin (ear plugs and baleen plates) which contain GLG. Other methods relying on physical or chemical analysis include eye lens weight and opacity, AAR of eye lens, and isotopes in baleen plates. However, these latter require calibration using more precise methods that have GLG as a reference point.
The ear plug anatomy (Purves 1955) was described as was the method of extraction from carcasses. Ear plugs have been used for age estimation in several species of baleen whales (Ichihara 1964, Ohsumi 1964). The easiest approach for extraction is from the back of the skull when severed from the vertebral column so exposing the occipital condyles. However, this approach may require major flensing. Once the tympanic bullae are located the ear plugs can be found and extruded via the external auditory meatus. The ear plug is suitable for age estimation in balaenopterid whales, especially blue whales (*Balaenoptera musculus*), fin whales, humpback whales, sei whales (*Balaenoptera borealis*), and Bryde's whales (*Balaenoptera brydei*). Minke whales also have useable ear plugs but there are big problems in aging those from certain populations, *e.g.*, North Atlantic. Also, minke whale GLG are not as clear as in other balaenopterid species, and readability of the GLG can be variable (Kato 1984, Kato *et al.* 1991). Ear plugs from balaenid whales are problematic but ear plugs have been used in gray whales, *Eschrichtius robustus* (Rice and Wolman 1971).

The ear plug requires fixation and preservation in neutral buffered 10% formalin. The paired ear plugs are "shaved" down lengthways to the core centre using an old-fashioned straight hand razor, exposing the neonatal line and GLG above the "glove finger." Once exposed, the GLG can be counted using low-power magnification. A complete record of age is recorded as well as life-history stages from GLG growth pattern changes, *e.g.*, age at sexual maturity (transition phase) and even physical maturity (Lockyer 1972, 1974, 1984), providing parameters that can be used at a population level. Roe (1968) provided validation of annual GLG deposition in fin whales.

The relevance to monodontids is indirect. Ear plugs are very different structures to teeth and are not generally applicable in odontocetes. However, ear plugs and teeth have continued growth and potential for total age records; both have accessory lines that may confuse age estimation. The transition phase in ear plugs might be something to look for in teeth GLG patterns.

11. Feasibility study on the incorporation of the gelatinized collection method and the freeze-section technique of the ear plug in age estimation in common minke whales - Hikari Maeda, Tadafumi Kawamoto and Hidehiro Kato

ABSTRACT: *Because of its soft structure, ear plugs of common minke whales (*Balaenoptera acutorostrata*) are easily damaged during their collection from the external auditory meatus, especially among younger animals. In addition, there are still problems existing for ear plugs with unclear lamination on the bisected surface of the core. The present study tried to solve these two problems in age estimation of the common minke whales, by examining the feasibility of new techniques incorporating the gelatinized collection method and a histological approach by the freeze-sectioning of the core in ear plugs.*

For the first problem, we have tried a new ear plug collection method as follows; i) filling the space in the external auditory meatus with gelatin, ii) hardening the gelatin encasing the ear plug and any fragments by spraying a cooling gas, iii) removing the gelatinised ear plug from the meatus. Using a total of 214 trials on the minke whales at the scientific permit survey platform (JARPN II coastal program) in 2007 to 2009, it was revealed that embedding ear plugs with gelatin material minimized the proportion of breakages at the neonatal region, especially among ear plugs in younger animals. This obviously leads to an increased proportion of readable ear plugs and identifies high utility of the present gelatinized collection method. For the second problem, so as to have clearer core surface images of growth layers, we examined histological sections (thickness 5-10μm) sliced by the Kawamoto specialized frozen sectioning techniques (Kawamoto 2003), with staining by three different agents: Sudan III, Haematoxylin – Eosin, and Alizarin red. Through a total of 8 experiments, the histological section with Alizarin red gave the clearest growth laminations where we easily identified both dark and pale laminations, suggesting a close relation to the seasonal changes in intake of calcium through feeding. The present frozen section is also useful for investigating further detailed structure of ear plugs.

This presentation concluded that using the gelatinized technique for collection of ear plugs with the injection of liquid gelatin around the ear plug and the solidification, improves ease of extraction and, by maintaining the integrity of the ear plug, also improves the subsequent readability of GLG. The histological experiments indicated that the frozen sectioning technique and staining with Alizarin red helps clarify the GLG.

Discussion

The point was raised that probably the gelatin extraction technique could be used on the bowhead whale in which the ear plug is generally very soft and disintegrates easily. In general, the gelatin technique seems to be improving the extraction of ear plugs.

Kato noted that the correlation of GLG between ear plug and tympanic bullae in minke whales was good and that such a correlation might be sought for GLG in teeth and tympanic bullae in odontocetes, *e.g.*, belugas, especially for predicting real age when wear was present in the tooth crown. The ear bones are common to all whales.

12. Age estimation with age validation from eye lens of fin whales and harbour porpoises - Nynne Hjort-Nielsen

ABSTRACT: *The aspartic acid racemization (AAR) method is based on the fact that the amino acids in nearly all living tissue, consists solely of L-isomers, but once the life process has ceased, the L-isomer amino acids undergo racemization to its D-isomer. This racemization occurs at a constant rate and it is thus theoretically possible to calculate the time that has elapsed once the racemization rate (k) and the ratio of D and L at birth ((D/L)0) are known. However, k is highly temperature-dependent and it is thus of great importance to keep this in mind when handling the samples. The AAR method was originally developed for dating marine sediments (Bada* et al. *1970) and fossils (Bada 1972; Bada and Protsch 1973) but later it has been applied in forensic science on human tooth enamel and dentine (for a review, see Meissner and Ritz-Timme 2010) and on human eye lens nuclei (Masters* et al. *1977, 1978). Studies of known-age humans (Ohtani* et al. *1995) and zoo animals (Eva Garde pers. comm.) found conclusive agreement between AAR age estimates and actual ages. This study estimated the age of 121 fin whales (*Balaenoptera physalus*) and 83 harbour porpoises (*Phocoena phocoena*) by the AAR method and by counting the growth layer groups (GLG) in teeth (harbour porpoises) and ear plug (fin whales) respectively. The aspartic racemization rate (k_{Asp}) for fin whales was established from 15 foetuses classified to age, based on body length, and 15 adult whales age estimated by counting the GLG in the ear plugs. The k_{Asp} for harbour porpoises was derived from thirteen 1+ yr old porpoises age-estimated by counting GLG in the teeth and four neonate porpoises classified to age based on length. The k_{Asp} values were determined by regression of GLG against aspartic acid D/L ratios. For the fin whales k_{Asp} of 1.10 x 10-3 yr-1 (SE ± 0.00005) and a D/L ratio at birth ((D/L)0) of 0.028 (SE ± 0.0012) were determined. For the harbour porpoises a k_{Asp} of 3.10 x 10-3 yr-1 (SE ± 0.0004) and a (D/L)0 value of 0.023 (SE ± 0.0018) were determined. The fin whale k_{Asp} is in agreement with rates for other baleen whales, whereas the rate for harbour porpoise is considerably higher. Correlation between age estimates from AAR and GLG counts (individuals not included in the estimation of k_{Asp}) indicated that AAR might be a suitable method for determining age in marine mammals.*

The theory and history of the AAR method were presented. Details of the method used in marine mammals were described, specifically for fin whales (n = 121) and harbour porpoises (n = 83) for which a known method of age estimation (GLG in ear plugs and teeth respectively) was available for calibration. The art of extracting the nucleus from the eye lens, which is surrounded by layers like an onion, is in rolling the lens until the nucleus is exposed and then peeling off the outer layers. Sources of error in the analysis can come from contamination and also cataracts in the lens. Calibration of the AAR age was by GLG in ear plugs for fin whales and GLG in teeth for porpoises. There were large variations in D/L ratios in young animals and a high racemization rate, k_{Asp}, in harbour porpoises for which this was the first study.

One surprising finding was an AAR estimated age of 120 yr for an old stranded fin whale off coastal Denmark in 2010. This is the oldest estimated age for this species hitherto.

Validation of the AAR ages still requires reference to known-age animals.

13. Comparison of aging techniques, estimation of racemization rates and validation - Eva Garde

13.1 Background, the harp seal study and the known age animals study

ABSTRACT: *This talk will focus on the aspartic acid racemization (AAR) technique and the AAR results from two different studies. One study (Garde* et al. *2010) compares age estimates of harp seals (*Pagophilus groenlandicus*) obtained by 3 different methods, the traditional technique of counting growth layer groups (GLG) in teeth and 2 novel approaches, aspartic acid racemization (AAR) in eye lens nuclei and telomere sequence analyses as a proxy for telomere length. The other (Garde* et al. *submitted) uses animals of known age or ages estimated by another aging method to determine species-specific racemization rates and to examine the effect of body temperature on the rate of racemization. Both studies address the question of the AAR technique as a valid method for age estimation of mammals.*

*Lower jaws (containing the teeth), eyes, and skin samples were collected from harp seals (*Pagophilus groenlandicus*) in the southeastern Barents Sea for the purpose of comparing age estimates obtained by 3 different methods, the traditional technique of counting growth layer groups (GLG) in teeth and 2 novel approaches, AAR in eye lens nuclei and telomere sequence analyses as a proxy for telomere length. A significant correlation between age estimates obtained using GLG and AAR was found, whereas no correlation was found between GLG and telomere length. An AAR rate (k_{Asp}) of 0.00130/yr ± 0.00005 SE and a D-enantiomer to L-enantiomer ratio at birth (D/L_0 value) of 0.01933 ± 0.00048 SE were estimated by regression of D/L ratios against GLG ages from 25 animals (12 selected teeth that had high readability and 13 known-aged animals). AAR could prove to be useful, particularly for aging older animals in species such as harp seals where difficulties in counting GLG tend to increase with age. Age estimation by telomere length did not show any correlation with GLG ages and is not recommended for aging harp seals.*

The AAR technique has been applied for age estimation of humans and other animals over the past three decades. In this study, eyeballs from mammals (n =124; 25 species) of known age or age estimated by another aging method were used to determine species-specific racemization rates and to examine the effect of body *temperature on the rate of racemization. Strong correlations (range: r = 0.93-0.99) were found by regression of D/L ratios against known/estimated ages for 7 mammal species. Racemization rates (as $2k_{Asp}$ values) were well correlated (r = 0.91) with average core temperatures (°C), and a linear relationship was found between rate and temperature.*

The presentation demonstrated that the AAR method is valid for several mammal species for which age is known, showing a strong correlation of D/L ratio with actual age. A total of 124 animals from 3 groups of species were examined. In pygmy goats the known age was similar to the AAR age. Racemization rates were different among species and racemization rates correlated well with core temperatures. When applied specifically to harp seals (n=113), there was also a strong correlation between tooth GLG and D/L ratio. AAR and GLG ages were similar but the AAR method appeared more accurate for old animals. The eye lens in narwhal was soft and clear in young animals but became hard and yellow in old animals. Some fine tuning and further calibration are still needed for harp seals. However, there was no correlation with telomere length which was deemed as an unsuitable method of aging in harp seals.

13.2 Narwhal age from eye lens and age validation

ABSTRACT: *This talk will focus on the AAR technique in age estimation of narwhals (*Monodon monoceros*). I will present the results from two studies. One (Garde* et al. *submitted 2) estimate a species-specific racemization rate for narwhals by regressing aspartic acid D/L ratios in eye lens nuclei against growth layer groups in tusks. The other (Garde* et al. *ms) is a large-scale study of age estimation in narwhals using the AAR technique, followed by construction of age distributions and estimation of life history parameters. The obtained parameters were subsequently used in a population dynamic analysis.*

Ages of marine mammals have traditionally been estimated by counting of dentinal growth layers in teeth. This method is, however, difficult to use on narwhals because of their special tooth structures. Alternative methods are therefore needed. The AAR technique has been used in age estimation studies of cetaceans, including narwhals (Garde et al. *2007). The purpose of this study was to estimate a species-specific racemization rate for narwhals by regressing aspartic acid D/L ratios in eye lens nuclei against growth layer groups in tusks. Two racemization rates were estimated: one by linear regression (r^2 = 0.98) based on the assumption that age was known without error, and one based on a bootstrap study, taking into account the uncertainty in the age estimation (r^2 between 0.88 and 0.98). The two estimated $2k_{Asp}$ values were identical to two significant digits. The $2k_{Asp}$ value from the bootstrap study was found to be 0.00229 ± 0.000089 SE, which corresponds to a racemization rate of 0.00114-yr ± 0.000044 SE. The intercept of 0.0580 ± 0.00185 SE corresponds to twice the $(D/L)_0$ value, which is then 0.0290± 0.00093 SE. We recommend that this species-specific racemization rate and $(D/L)_0$ value be used in future AAR aging studies of narwhals.*

Eyes, reproductive organs and body length measures were collected from 280 narwhalsin East and West Greenland in 1993, 2004, and 2007 – 2010. The purpose

was a large-scale study of age estimation using the AAR technique, followed by construction of age distributions and estimation of life history parameters. The obtained parameters were subsequently used in a population dynamic analysis. Age estimates were based on the racemization of L-aspartic acid to D-aspartic acid in the nucleus of the eye lens. The ratio of D- and L-enantiomers was measured using high-performance liquid chromatography (HPLC). The age equation used was determined from data from Garde et al. *(ms). Asymptotic body length was estimated to be 405 cm for females and 462 cm for males from East Greenland, and 399 cm for females and 456 cm for males from West Greenland. Age at sexual maturity based on data from reproductive organs was estimated to be 8 yr.s for females and 17 yr.s for males. Pregnancy rates for East and West Greenland were 0.42 and 0.38, respectively. Maximum lifespan expectancy for narwhals was found to be ~100 yr.s of age. A population projection matrix was parameterized with narwhal data on age structure and fertility rates. Under the assumption of stable age structure it is calculated that narwhals in East Greenland have a potential annual growth rate of 3.8% while narwhals in West Greenland have a potential growth at about 2.6%.*

Narwhal tusks were sectioned using a jig saw so that the cut surface of a half tusk was prepared. The surface was acid-etched with acetic acid by immersing the tusks in specially built tanks for many hours. The etched tusks were subsequently rinsed in water and then dried so that the GLG were thrown into relief and could be counted. The surface was also rubbed with soft pencil lead to emphasise the GLG. Deposition rate of GLG in narwhal is not known but inter-GLG spacing is very thick (ca 3 mm) and thus likely represents annual growth. A species-specific racemization rate was estimated for narwhals by using the tusk age as a calibration.

Discussion

This method showed great promise for a species where age is largely unknown. The possibility of using embedded tusks in young animals was suggested, as these are relatively easy and inexpensive to acquire. It was recommended that comparisons be made in future studies of narwhal population dynamics, age distribution and life-history parameters between samples from east and west Greenland using reproductive status and AAR techniques.

14. Aging beluga (white) whales from measurements of specific fatty acids present in their outer-blubber biopsy tissues - David P. Herman, Roderick C. Hobbs, Barbara A. Mahoney and **Gina M. Ylitalo**

ABSTRACT: *Age estimation of individual cetaceans and estimation of the age distribution of entire whale populations is fundamental to assessments of status and long-term viability. Until recently, there was no reliable benign method to determine the specific ages of live animals for remote populations where long-term longitudinal sighting studies were not practical. In two recent studies involving populations of eastern North Pacific (ENP) killer whales and humpback whales from both the ENP and western North Atlantic, we described a new method by which age could be estimated with good precision from measurements of specific endogenous fatty acids (FAs) and FA ratios present in the outer blubber layers obtained by remote dart*

biopsy techniques. Although the precisions (±σ) of the FA-age models derived for these populations of whales were somewhat variable (ranging between ±3.1 and ±5.3 yr), the results indicated that it should be possible to estimate the age of an individual whale from any population of these two species with better than decadal resolution using this approach. In this presentation, we provide some new preliminary data suggesting that it should be possible to age individual Cook Inlet beluga (white) whales following this approach based on FA results obtained from a combination of capture and release (biopsy) and stranded (necropsy) samples acquired between 2001 and 2007. Unlike the two previous studies in which exact or minimum known-ages were known and thus served as calibration standards to derive empirical FA-age models, ages of the Cook Inlet belugas described in this study were initially estimated from the von Bertalanffy allometric relationship between body length and teeth growth layer groups (hence age, assuming 1 GLG/yr) derived for this population of belugas in the 1990s from a large number of stranded animals, (Vos 2003). Whereas body lengths may only be used to derive crude age estimates for juvenile and sub-adult whales not yet having achieved maximum physical maturity (size), the proposed FA ratio – age model described in this presentation seemingly should enable the ages of physically mature adult whales of both sexes to be estimated following this approach.

The paper reviewed studies employing this method using specific endogenous fatty acids (FAs) and FA ratios (Herman *et al.* 2008, 2009). The method is robust and generally viable for age estimation, and is a non-lethal method that can use biopsies of blubber. Focusing on N.E. Pacific killer whales, despite some differences in blubber FAs in residents and transients, an empirical killer whale age-FA model was developed using this technique, which can predict ages with a precision of ±3.9 yr.

In humpback whale FA studies (endogenous and dietary in origin), where there has been a comparison with Photo-ID aging (S.E. Alaska vs Gulf of Maine), a robust model could predict ages within ±5.3 yr regardless of stock, sex and dietary preference. A generic species model is not optimal for precise age. The humpback whale studies highlighted the need to develop individual stock-based models. This may in part be due to different dietary habits affecting the FA composition. However, the underlying biological mechanism is not well understood. The outliers appear mainly to be very young and suckling animals. When the two stocks were analysed separately, a greater precision of ±3.1 yr for Gulf of Maine and ±4.5 yr for S.E. Alaska was obtained.

When FA techniques were applied to Cook Inlet belugas, body lengths and ages from teeth (Vos 2003) were compared with FA ratio-derived ages for 11 males and 11 females, using outer blubber. Analysis was based on the ratio of a single pair of blubber FA: C16:1n9/iso-C16:0. Preliminary results indicated that such a model can be used to predict ages within ±5.8 yr for juvenile/sub-adult belugas and appears to be independent of sex. Results appear to be contiguous thus enabling the ages of physically mature adult belugas to also be estimated. It is anticipated that age prediction uncertainties will be substantially reduced when biopsy samples from animals of exact known age are acquired and their blubber FA compositions fit to a linear combination of two FA ratios, similar to the killer whale and humpback whale models. However, as in humpbacks, there is no clear understanding of the underlying biological mechanisms responsible for the beluga age/FA relationship.

Discussion

One issue with using FAs, especially from remote biopsy sampling, is that small differences in the sampling of blubber might be significant. The sample would be affected by the angle of penetration of the biopsy tip or the selection of blubber analysed. The beluga work is in progress and, although the age precision is not as high as for killer whales, the technique is promising and should be investigated further. In time, the technique may be applicable to narwhal if there is an independent method for aging available.

15. Growth and maturity of belugas in Cumberland Sound compared to those raised in captivity - Paul Brodie, K. Ramirez and M. Haulena

ABSTRACT: *The beluga* (Delphinapterus leucas) *is one of the few odontocetes to adapt, year-round, to a polar environment, one of the most challenging marine habitats in the world, with shallow estuaries, high turbidity, shifting pack-ice and extreme tidal ranges. Adaptation is attributed in part, to year-round herd integrity and synchrony, occupying a sequence of restricted seasonal habitats and calving sites, which are reflected in tooth laminae. Newborn and the first four year-classes are recognizable by comparing length, body colour and morphology. Assessment of body colour is highly subjective in the field and provides a crude index of maturity. Field research, 1966-1969, led to the conclusion that females are sexually mature at 5.75 yr and males are at 8.75 yr, gestation is 15-16 months, and the reproductive cycle is 3 yr, with a lifespan of 30-35 yr. The 2- year nursing period results in rapid growth of the calf, coincident with a training period to acquire social, feeding and crucial navigational skills. The population in Cumberland Sound had been reduced through exploitation, thus it is unlikely that the present numbers are food limited, reflecting maximum rate of increase for a wild stock. We examine similar growth indices for captive belugas, some captured as calves, as well as first and second generations born in captivity, to compare known-age animals. Growth to onset of sexual maturity of males and females is similar to findings for the Cumberland Sound population, which was based on two growth layer groups per year in the teeth, or GLG/2. We analyse studies where previous oral doses of tetracycline, as well as bomb ^{14}C were used to argue for single annual GLG. Dedicated field studies, using appropriate dosage of intramuscular tetracycline, provide evidence for GLG/2. The ^{14}C study appears to have been compromised by preparation technique, and burdens sampled in the 1990s are probably of maternal origin, transferred during foetal growth and lactation. Direct observations and cross-referenced parameters fail to substantiate GLG/1, which requires halving the somatic growth rate, thus doubling the age of sexual and physical maturity as well as lifespan, resulting in a 40% reduction in the intrinsic rate of natural increase.*

This presentation gathers together diverse information regarding age, reproductive history and growth rate for the Cumberland Sound belugas during the pre-1970 period, and a comparison with biological parameters from known-history captive belugas primarily from Churchill, western Hudson Bay, the source of most captive beluga. Based on younger, known-age belugas from Churchill, the conclusions are that the deposition rate of tooth GLG is two per year. The ages at capture of two belugas in Hohn and Lockyer (1999) and later included in Lockyer *et al* (2007) were assessed as wrongly estimated and GLG counts based on realistic ages at capture (Robeck *et al* 2005) were more consistent with GLG/2 for

- Churchill (male) at total age 12.7yr (4.9 yr wild+7.83yr captive) = an expected 25.4 GLG, the average count of five readers being 27.8 (SD 3.63, range 24-32), while for
- SW-DL-7903 (female) at total age 10.75 yr (2.75 yr wild+ 8 yr captive) = an expected 21.5 GLG, the average count of five readers being 18.20 (SD 2.17, range 16-21) – neither consistent with GLG/1 nor GLG/2. (However, with reference to Lockyer *et al* (2007), this animal had a tetracycline mark which clearly established a GLG/1 rate at least in the adult phase – see Fig. 5 later under presentation 26. by Hohn and Lockyer.)

When appropriate ages at capture, and estimated GLG loss, were applied to the other captive belugas examined in Lockyer *et al* (2007), they were all (sample of 10) assessed as not conforming with GLG/1. Examples were:

- Aurora, a 246 cm female, possibly as old as 3.2 yr, plus 15.2 yr captivity = 18.3yr, thus 36.6 GLG. The average count in Lockyer *et al* (2007) Table 4, is 35 (SD 3.32, range 27-35).
- No-See-Um, a 257 cm male was a maximum of 3.2 yr at capture in August, plus 21.7 yr captivity = 24.9 yr, thus 49.8 GLG. The maximum count in Lockyer *et al* (2007) Table 4, is 46+, the "+" indicating lack of neonatal line and possible tooth wear. The average count was 42.8 (SD 4.66, range 35-46).

Discussion

There was much discussion, particularly with respect to the apparently circular arguments pertaining to GLG deposition rates, used in the presentation. The full arguments on interpretation of all GLG counts are discussed in Lockyer *et al* (2007), and different scenarios were tested based on both minimum and maximum GLG counts estimated, which clearly diminishes the strength of an argument for GLG/2 based on using the average count alone.

While body length can be taken as an indicator of age, especially in juvenile animals, growth rates and parameters vary among both stocks and individuals. It is important to compare like with like. With reference to the phasing of colour from grey to white, Brodie (1971) stated: "Whitening of female beluga in Cumberland Sound occurs after 6 yr, and of males after 7 yr. The white colour can be used in the field to establish at least a minimum age and to indicate that the animal is near physically mature size…" Light grey beluga females of 6 + yr of age have been observed to be pregnant both in Cumberland Sound and in Hudson Bay. Body colour which can change from grey to white in adult belugas, is not a knife-edge transition, and there are many documented cases of so-called "juveniles" of grey colouration that have produced a few young before becoming white (see presentation 20. by Michaud below; also Stewart, pers. comm., who reports dissecting foetuses from grey female belugas). Colour can therefore not be used reliably to assess maturity. In terms of allometric life-history, it seemed odd that belugas alone would live only half as long as pilot whales (*Globicephala sp.*), for example, which are about the same size, and be the only species of mammal that has a different tooth GLG deposition rate.

Convincing evidence for the one GLG per yr hypothesis requires appropriate numbers of productive females within a population, either pregnant and/or lactating, whose ages can be verified at 30-60 yr. Moby, a female, appears to be one of the oldest known history belugas, dying after 30 yr in captivity. According to Lockyer *et al.* (2007), among 5 readers, at least 30-43 GLG were observed in the tooth dentine which was worn at the crown. According to length, she was a juvenile on capture.

On balance the workshop members supported the current interpretation of annual GLG deposition rate. There were now many other studies (see Michaud presentation 20) that confirmed an annual deposition rate.

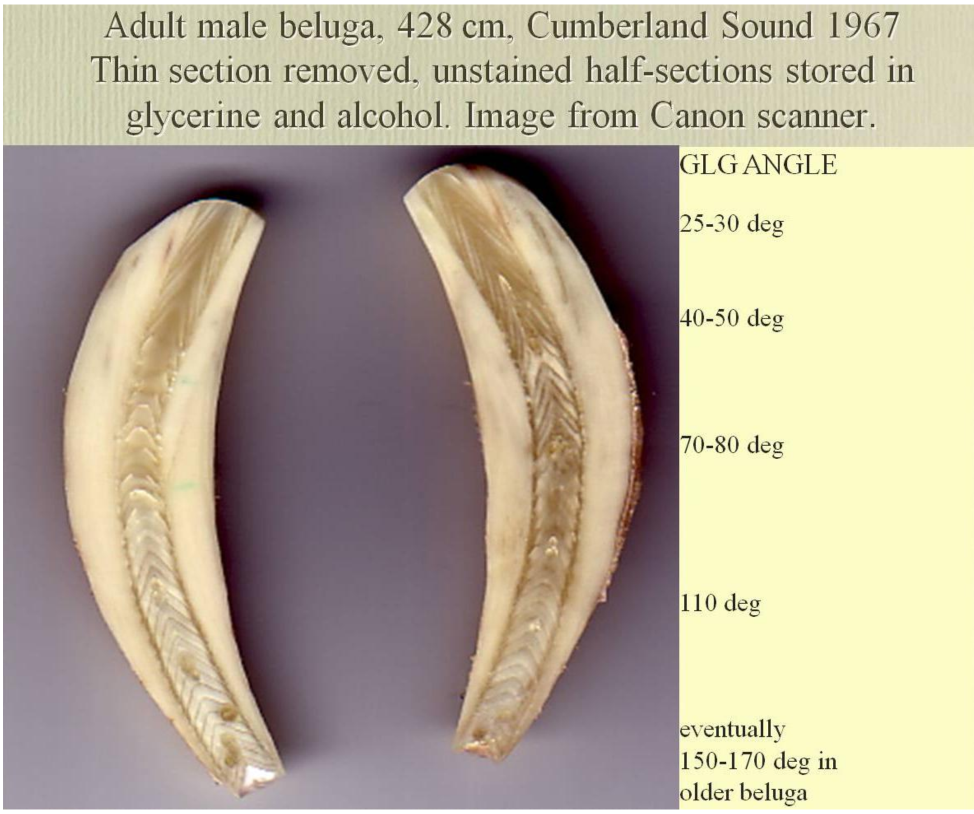

Figure 2. Beluga tooth sections showing the change in total angle of the GLG at the pulp cavity with age. Picture by courtesy of Paul Brodie, Balaena Dynamics Ltd, Halifax, Canada.

One detail from the presentation that the workshop found promising was a simple technique, whereby GLG lost to erosion could be estimated. As additional GLG are added to the pre-natal tooth, the total angle at the dentine interface with the root tissue expands in increments of 1-2 degrees, beginning at 25-30 deg, 40-50 deg after approx.12 GLG, 70-80 deg after approx 18 GLG; ultimately to 150-170 deg (see Fig. 2 above). Examining this matter in detail, perhaps through a special study specific to the population, could help identify cases where crown wear results in lost GLG and help to estimate the number of GLG worn away.

16. Use of micro-computed tomography for dental studies - Carolina Loch, Donald Schwass, Jules A. Kieser and R. Ewan Fordyce

ABSTRACT: *Teeth are important elements in studies of modern and fossil cetaceans, providing information on feeding habits, estimations of age, and phylogenetic relationships. The growth layer groups (GLG) recorded in dentine have demonstrated application for aging studies, but also have the potential to elucidate life history phenomena such as metabolic or physiologic events. Micro-Computed Tomography (Micro-CT) is a non-invasive and non-destructive technique that allows 3-dimensional study of mineralized tissues and their physical properties. It has mostly been used for qualitative dental studies in humans. Teeth from extant dolphins (*Globicephala *sp. and* Sotalia guianensis*) and an unnamed Oligocene fossil dolphin (OU 22108) were scanned in a Skyscan 1172 Micro-CT desktop system. X-rays were generated at 100 kV and 100 µA for extant samples and at 80kV and 124 µA for the fossil tooth. Aluminum and copper filters, 0.5 mm thick, were used in the beam. Reconstructed images were finely resolved for the fossil, showing the enamel, internal layers of dentine, and the pulp cavity. The enamel layer was well defined in both extant species throughout the images, but the dentinal layers were less resolved. We are refining the use of Micro-CT for dental studies in cetaceans, to allow resolution of internal structure and potential application in non-destructive aging techniques. Imaging software should elucidate greyscale values observed in the dentinal region of extant specimens and their relation to GLG. Future Micro-CT analysis will involve paired scans of teeth alongside resin-hydroxyapatite calibration standards of known densities to quantify mineral density of dental tissues in odontocetes.*

This technique, Micro-CT, is a non-destructive alternative for looking into hard structures such as bones and teeth of fossil and living animals to investigate internal structures. This may be very helpful for examining teeth that are difficult to cut / section because of shape or fragility. The examples shown demonstrated internal layering, and thus may have potential use in age estimation from tooth GLG. The technique is promising albeit still being developed. A significant limitation on application is that the actual size of the teeth that can be scanned is limited because of the dimensions of the investigative chamber.

17. Ear bones for aging manatees - Amber Howell

This presentation was a spontaneous review of the age estimation in manatees. The method entails thin sectioning of periotic bone which shows GLG (Marmontel *et al.* 1996). The sections are stained and examined in transmitted light. Fig. 3 shows GLG in a stained ear bone section of a 10 yr old manatee.

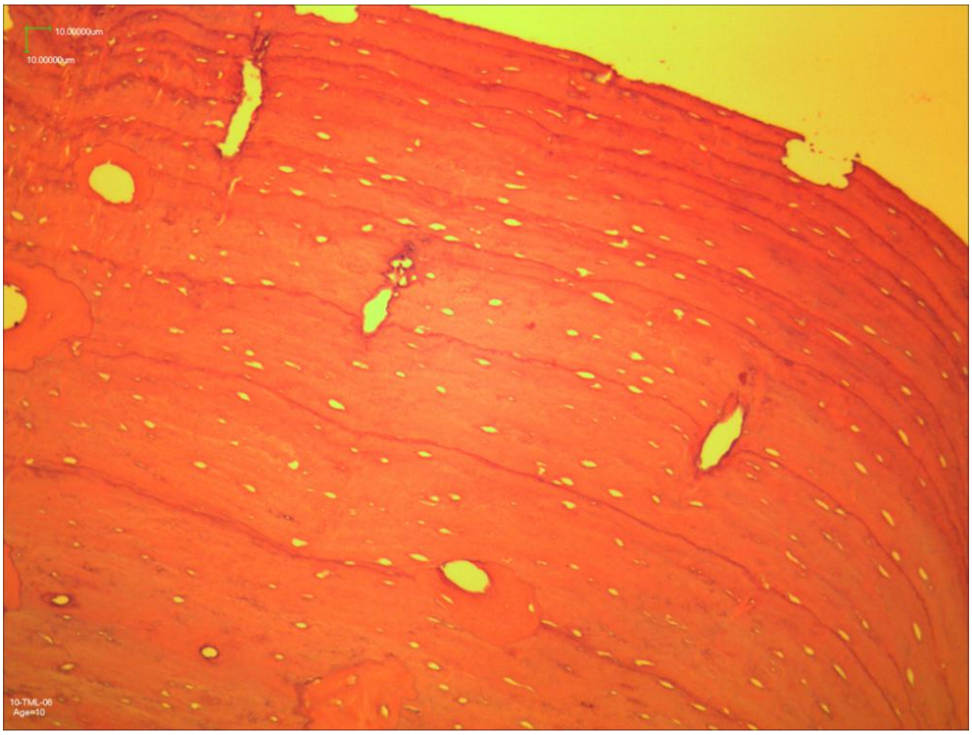

Figure 3. Stained section of ear bone of a 10 yr old manatee. Courtesy of Katherine Brill.

There is some degree of blurring of the layering above 12 GLG, and despite possible resorption, the oldest recorded age using this method is nearly 60 GLG (O'Shea *et al.* 1995). There are difficulties in interpreting GLG because of double laminae and merging of laminae. However, these problems are common to other methods of aging using layered hard tissues.

18. Informal progress report on *trace element profiles* in beluga teeth - Cory Matthews

This informal presentation reported the interim progress on an ongoing pilot study. Matthews reported on stable isotope ratios for diet and ecological determination of beluga, killer *(Orcinus orca)* and bowhead whales *(Balaena mysticetus)*. The teeth of belugas were micro-milled in the light and dark bands of the dentinal GLG and analysed for nitrogen ($^{15}N/^{14}N$) and carbon ($^{13}C/^{12}C$) isotope ratios, which varied among GLG. Dark bands seem enriched in both ^{15}N and ^{13}C. It may be feasible to cross-date at the population level using these chemical signals in teeth GLG. In addition, it appears possible to assess the weaning age using ^{15}N in early GLG in killer whales, and this may be similar in belugas.

Trace elements measured using laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) show regular oscillations in the GLG, but this is not consistent for all teeth. However, if changes in element concentration can be linked to environment, such as oscillations caused by seasonal movements between summer and winter distributions, the method could be used to calibrate tooth structure. The method might be useful to look at the structure of the teeth to learn more about life history at both the population and the individual levels.

Discussion

It was pointed out that as of yet replicates of the same animals have not been made, so that the results must be treated with caution. It was suggested that the element ^{18}O could also be useful. There was encouragement that this work should continue.

19. Applications of Aspartic Acid Racemization for Aging Bowhead Whales - Craig George

ABSTRACT: *The Aspartic Acid Racemization (AAR) technique has been applied to estimating the age of several mammals. For bowhead whales, the technique has been applied in several publications on cetacean age, growth, animal health, and management advice (Bada 1972, Bada* et al.*1970, 1980, 1983, Rosa* et al. *2004, Rosa* et al. in press*, George* et al. *2011, Garde* et al. *2007).*

While age estimates for bowheads have high SEs there has been no indication of bias (George et al. *1999, Rosa* et al. in press*). For sub-adult bowheads (<15 yr), the CV of the AAR estimates exceeds 100% and should be applied cautiously. For young animals, the "baleen aging" technique (stable carbon cycles in baleen) is recommended as it is more accurate.*

With regard to the question of accuracy and bias, the age estimates for bowheads have been verified independently by several different approaches. These are reviewed below:

1. *The "baleen aging" technique suggested age at sexual maturity (ASM) for bowheads in their early 20 yr (Lubetkin* et al. *2008 , Schell and Saupe 1993) corroborating the AAR estimates of* ca *25 yr. (Rosa* et al. in press*).*
2. *Growth rate data from photogrammetry estimated ASM to be late 20 yr (Koski* et al.*2004). In their approach, they estimated growth rates using inter-year photographs and calculated the number of years to reach 13-14;, i.e., the well-documented length at sexual maturity.*
3. *Recovery of stone weapons in harvested bowhead whales indirectly confirms that bowhead whales live in excess of 100 yr, also corroborating the AAR maximum longevity estimates.*
4. *The recovery of a Yankee whaling projectile patented in 1879 in a recently harvested bowhead whale also corroborated the longevity estimates (George and Bockstoce 2008).*
5. *Population dynamics models for bowhead whales suggest that low values for ASM are unlikely and favour over 20 yr (Givens* et al.*1995).*

In view of the above, the AAR technique appears useful for long-lived cetaceans and possibly other vertebrates; however, its applications to species with shorter life spans (<30 yr) must be approached cautiously.

Samples of eyes of bowhead whales hunted in the traditional hunt were collected for analysis using AAR (George *et al.* 1999). For females, ovarian *corpora* were used as an age proxy for calibration. Investigating carbon isotopes in baleen plates of younger animals indicated an age at sexual maturation of 17-20 yr from the regular annual oscillations associated with feeding migration (Schell *et al*. 1989a, b). These data, together with the knowledge of potential longevity from artifacts, and relative age from body length, could be used to calibrate age derived from the AAR method. Improvement of the AAR method (Wetzel and Reynolds 2011) and testing of the consistency of k_{Asp} with calibration using known rates for humans and fin whales has allowed more reliable estimation of age. Results of investigating racemization rate k_{Asp} indicated a possible age at sexual maturation of >20 yr in females and a longevity of *ca* 120 yr in males.

In summary, the AAR technique was found useful for long-lived species as bowhead whales, for which other techniques are unavailable. There is no evidence of bias but there is a high variance, especially for young animals. Baleen plates are recommended for age estimation in young animals, *i.e.*, <20 yr. To get reliable results using AAR, repeated measures/samples are required, together with a good lab procedure and corroborative age estimates.

Discussion

Details were provided on age estimation using the ovarian *corpora* counts. The estimates of age at sexual maturity must necessarily be added to *corpora* age to obtain total age and are not totally independent from AAR ages. There is thus some circular dependency of the data. However, the AAR technique demonstrates reliably that bowheads are long-lived. In this respect, the apparent old ages estimated using AAR for narwhal (Garde presentation 13.2 above) must be seriously considered feasible.

20. Individual identification and life history of the St. Lawrence beluga - Robert Michaud

This presentation was offered and accepted during the workshop. The ongoing work started in 1989 (Michaud 1989, 1993, http://bed2.gremm.org/eng/pag.php?PagRef=Nws&NwsId=4569). To date there have been about 60 surveys per year in which belugas were photographed for reliable marks, identified and classified into 3 classes of re-sightability (RI). Common marks are nicks on the dorsal ridge and small scars including round indentations that were likely bullet wounds. The beluga population is about 1,000 animals, and a photo-identification catalogue holds files of 341 individuals (RI $\geq$ 1) identified from both sides, 265 first identified as white and 76 first identified as grey animals. Biopsies were taken during surveys and these used for sexing and genetic profiling. A genetic profile is known for 95 males and 38 females. Males have more scars than females. Between 1983 and 2011, over 350 beluga carcasses were recovered for detailed necropsy and identification. Teeth for aging and reproductive material were collected for determining life-history parameters. Histories of individuals first identified alive and recovered dead provided information on first age at parturition, longevity, calving interval, and a validation for tooth GLG deposition rate at one per year.

- Atomic – DL006, female, was first sighted in 1986, presumably born in 1984, first seen with a calf in 1992, She subsequently had calves in 1994 and 1996, (while she was still light grey), 2000 (when she turned white), 2002, and 2004. She was last sighted in 2007.
- Ligne ligne – DL225, male, first sighted as big grey in 1991, turned light grey in 1993, white in 1997 and died in 2007 at 21 yr old assuming 1 GLG per year deposition in the teeth. Assuming 2 GLG a year, Dl225 would have been white at its birth!
- Dl172 – female, first sighted in 1980 as a large white died in 2008 at 46 yr old assuming 1 GLG per year deposition in the teeth. Assuming 2 GLG per year, Dl172 would have been seen as a white whale before its birth!

Discussion

This study, apart from monitoring the distribution and social movements of the individuals, has been able to make valuable observations on age, growth and reproductive history. The recovery of biological samples after death provides a means to verify age from teeth and calving history based on reproductive tissues. The limitation of this work has been that there are fewer marked animals now since the end of the hunt (1979) when struck but escaped animals bore scars. In addition, it is not yet possible to quickly access beach-cast carcasses to recover fresh eyes for possible AAR analysis. The workshop welcomed this long-term work which potentially may provide a wealth of life history data and a means for absolute age validation using tooth GLG.

21. Value of long-term studies of humpback whales for determining population parameters and ground-truthing new age estimation methods - Christine M. Gabriele

ABSTRACT: *Photo-identification of individual animals has become an important source of information on humpback whale behaviour and population parameters via long-term studies occurring at several sites worldwide. Through photo-identification, researchers have determined age at first calving, reproductive rates and calf mortality for this species. The sheer length of sighting histories in long-term studies is also shedding light on the lifespan of humpbacks, in that many whales have sighting histories approaching 40 yr, although this species was earlier thought to have a 30 yr lifespan. Tissue samples from known-age humpback whales are also contributing to development of techniques for determining the age of unidentified individuals (i.e. stranded animals or those without a sighting history) from blubber fatty acids, chromosome telomeres, and eye lens aspartic acid racemization.*

This method of direct observation of free-living animals demonstrates the value of long-term monitoring for assessing age and life history. Since 1974, 626 animals have been identified using marks on tail flukes and supplemental marks on dorsal fins. Recently, validation of ear plug GLG deposition rate (one per year) was possible for a known-history female # 68 from Glacier Bay, Alaska, which was first sighted in 1975 as an adult with a calf and washed up dead 25+ yr later after a ship strike in July 2001. Her estimated age from the ear plugs was 44 yr with a likely age at sexual maturation (from the transition phase) of 7 yr (Gabriele *et al.* 2010). From sighting histories it is possible to get a minimum age estimation and age at first calving. Biopsy analysis has enabled comparative age studies to be undertaken on this population, including telomere length analysis (Olsen presentation 8 above) and endogenous FA ratios (Ylitalo presentation 14 above), which have also correlated with an annual GLG deposition rate in known-age animals. The AAR technique is now being applied to eye lenses from recovered dead animals.

Discussion

The Glacier Bay photo-ID sightings database has been used to validate several other aging techniques such as FA ratios, eye lens extraction for AAR, and genetic telomere length analysis. The previous presentation on photo-ID in belugas, also indicates the potential of this kind of study, although it is labour intensive and will probably never cover all members of a population. Humpbacks are coastal and migratory but generally return to their mother's feeding range, so that resighting is feasible. The oldest known-age whale so far recorded is 37 yr (first sighted in 1974). The importance of collection of ear plugs from stranded known animals was stressed.

22. Validation of growth layer deposition rates from known history and photo-ID (dolphins) - Aleta A.Hohn

ABSTRACT: *Long-term field studies have provided the opportunity to know the age or the approximate age of free-ranging studies. These studies are valuable for validating growth layers because the alternative generally is use of captive animals, for which it is possible that captivity, itself, has affected growth layer deposition patterns or rates. The best study, to date, that has provided and continues to provide teeth from free-ranging animals occurs in the Sarasota Bay region of Florida (Hohn* et al. *1989). From that study, teeth have been extracted from live animals during temporary catching and holding of animals. Additional teeth have been available when known dolphins died. In some cases, teeth available after death represent a second opportunity to examine a tooth from the same individual. These studies will be limited due to the nature of conducting such studies, but what has been learned is invaluable.*

The Sarasota Bay Photo-ID project on *Tursiops truncatus* has now run for at least 5 generations of dolphins and has provided a mass of life-history data for known individuals. The oldest known-age female, Nicklo, is 61 yr old and produced her last known calf at age 48 yr, but several females of age >40 yr have produced up to 8 calves during the monitoring programme. Although this study is a special case in that animals have been regularly captured and released to monitor individual health, growth, and development, aspects may be applicable to belugas. By extracting teeth from live animals, it has been possible to validate aging methods by comparing actual known age to the numbers of tooth GLG counted blind without reference to any data. Again, the value of long-term studies was underlined.

23. Bio markers and tetracycline antibiotic time marking - Aleta A.Hohn

ABSTRACT: *Examining teeth from known-age animals does not, in itself, calibrate*

growth-layer deposition. That is, a count of growth layer groups (GLG) in teeth that corresponds to a known or approximately-known age could match but that does not allow for the actual GLG boundaries to be known. Actual calibration would be required to be certain when an annual layering pattern starts and ends. A means to obtain this information is using a bio-marker. The most common biomarker for cetaceans has been oxytetracycline. This compound is incorporated into actively mineralized teeth. When those teeth are sectioned (not decalcified) and viewed under reflected UV light, the incorporated tetracycline fluoresces. This technique has been used across a spectrum of mammals (terrestrial and marine).

The most commonly used bio-marker for marking teeth is tetracycline which can be administered orally or intra-muscularly. The former method is perhaps better as the drug, which may be required in a relatively large quantity, is absorbed and circulated in the body quickly without potential damage to muscle tissue. The dosage must be calculated according to the body weight and can be administered once or in lower dosages over a few days. A typical dosage is between 10-50 mg/kg body weight and the intensity of the mark appears to increase with dosage. Circumstances will dictate which is practicable. The tetracycline binds with calcium during new growth of the tissue. The method is reliable for time-marking (Myrick *et al.* 1984), but it is important to recognize that the drug can also be transferred via milk during lactation and that, rarely, undocumented marks in teeth may be the result of food or prey ingested. Other problems that may affect the correct interpretation in teeth are the effect of captivity on GLG deposition and autofluorescence, an edge effect, including that due to cracks in the tooth. When teeth so-marked are extracted for age estimation, it is important not to fix in formalin or decalcify as these processes leach out the chemical. Exposure to light will also degrade the mark in teeth.

24. Bomb dating and age validation: conclusive results in a fuzzy world - Steve Campana

ABSTRACT: *Atmospheric testing of atomic bombs in the late 1950s resulted in an abrupt increase in atmospheric radiocarbon which was soon incorporated into all organisms that were growing at the time. Thus the period is analogous to a large-scale chemical tagging experiment, wherein all body hard parts formed before 1958 contain relatively little ^{14}C and all those formed after 1968 contain elevated levels. For fish and aquatic organisms born between 1958 and 1968, bomb radiocarbon in growth increments can be used to confirm the accuracy of more traditional aging approaches with an accuracy of ± 1-3 yr. This approach has proven to be effective in validating the age of fish, bivalves, sharks and belugas, and would be expected to be effective in many other organisms.*

The method is based on identifying and quantifying nuclear fallout elements from atomic testing, namely ^{14}C. The increase in concentration of radiocarbon first started in 1958 in surface marine waters around the world. The ^{14}C concentration curve reached a peak and plateau in the late 1960s, and is now slowly declining although still strong. Hard tissues bearing GLG were micro-milled for internal sampling of individual GLG. About 2 mg of material is sufficient for testing. The analysis is expensive – *ca* 1,000 – 1,500 USD per sample, but only 5 samples are needed for pre-1958 born animals. During the presentation, examples of the technique were given for halibut, *Hippoglossus sp.*, and yellowtail flounder, *Limanda ferruginea*, otoliths. There is a difference between freshwater and marine environments and an offset for surface or deep animals. Other examples included porbeagle shark, *Lamna nasus*, mako shark, *Isurus sp.*, and dogfish, *Squalus acanthias,* for which radiocarbon was used to calibrate ages.

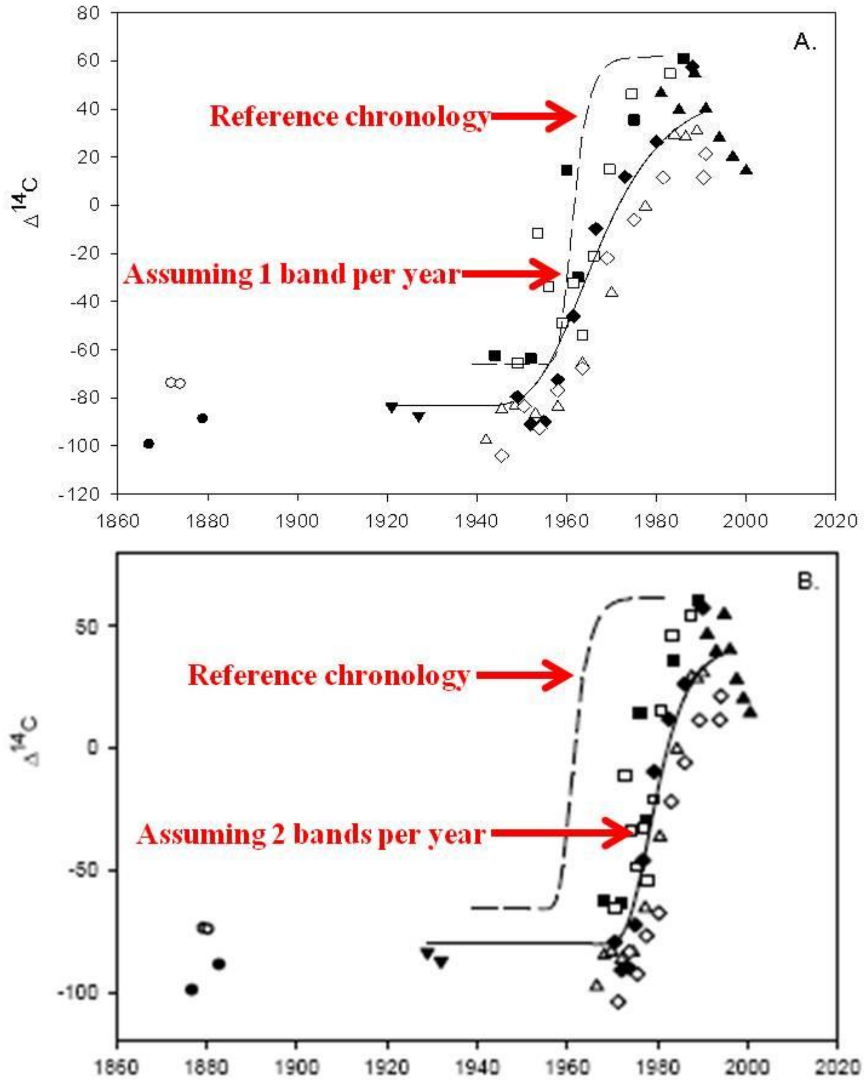

Figure 4. The radiocarbon ^{14}C signatures for belugas pre- and post atomic bomb fallout. The reference graph is shown in both A and B. The graphs overlap only for the assumption of one GLG per year in A. (After Stewart *et al.* 2006).

The method is suitable for all hard tissues, including beluga teeth and narwhal tusks, and also investigating individual GLG. In the study of beluga teeth (Stewart *et al.*

2006), the radiocarbon method was robust enough to validate age from GLG. A comparison of results making assumptions of deposition rate of one or two GLG per year had a strong offset (Fig. 4). Concluding, bomb radiocarbon is an excellent age validation method for long lived animals; the age of individual animals can be validated; and marine mammals, especially monodontids, are good study subjects.

Discussion

Earlier, Paul Brodie (presentation 15), had raised criticism to the findings of the bomb radiocarbon method. Brodie mentioned that the study by Stewart *et al* (2006) using bomb radiocarbon had been examined by B. Buchholz, senior research physicist, Center for AMS Livermore, California, who provided the following assessment:

> *"My problems with the paper are the incomplete methods and corrections they used to remove large amounts of dead carbon from the embedded samples. None of the samples embedded in epoxy are suitable for these measurement. The corrections seem arbitrary, and can be used to obtain whatever answer you want. You can make GLG/1 fit the late 1950s rise with a suitable correction. Ignoring all data after 1982 is not justified. If the corrections are accurate, they should work for the entire curve, not just a segment. Hence the data have significant problems." (Pers. comm. to P. Brodie; see also Brodie* et al. *in press.)*

Brodie also commented that an additional complication is that the radiocarbon burdens in the belugas may not have originated during their lifetime and were actually transferred during gestation and two years of intensive nursing. Campana responded that there is no difference in ^{14}C signature for animals feeding directly or lactating. The ^{14}C signal comes through milk or diet to calves, but the signal is the same. Even if gross resorption took place in the mother's skeleton, this would not have an appreciable effect on ^{14}C content and transfer. Thus maternal transfer to sucklings should not be a confounding factor in the deposition rate controversy.

25. Artifacts - Craig George

This presentation (no abstract available) traced the start of the investigations that were triggered by the discovery of a historic slate end-blade in the mattak of a bowhead whale caught recently in Alaska. Since then there has been a recovery of many stone weapons indicating a possible age of up to 117 yr, and also Former Yankee whaling bomb lance fragments (George and Bockstoce 2008), indicating a possible age of up to 129 yr. However, with respect to the stone weapons, some may still be employed today in some areas, so that the certainty that these were placed historically is in doubt. Nevertheless, such artifacts indicate a relative age of the animals in which they are found and indicate great longevity in bowhead whales. In summary, recording artifacts is a useful technique for long-lived species where other techniques are unavailable.

Discussion

There was an extended discussion about interpreting the finding of an artifact. An artifact such as a Yankee harpoon head clearly could not be placed in a whale before it was invented but it could be placed anytime after it was invented. The presence of a harpoon that was introduced in 1879 tells us that the whale was struck after 1879 but it could have been struck in 1979 if the artifact had been held and deployed later in time. One needs to be aware of such possible biases. The possibility of recovery of historic artifacts from monodontids is a possibility, but longevity is far less than in bowheads.

26. Age validation through known history captive studies in belugas – Aleta A. Hohn and **Christina Lockyer**

ABSTRACT: *This presentation is a recap of the now published work on examination of known-history captive beluga teeth (Lockyer* et al*. 2007). A sample of teeth from 10 beluga specimens was examined for total age. Data on sex, capture date, length at capture, history of tetracycline antibiotic medication, general health, and date of death were available. The results of agreed GLG counts for the sample teeth were compared to the life history, including time in captivity (ranging 4 – 30 yr), of each animal under two hypotheses: one and two GLG deposited annually. Resulting counts were more consistent with the hypothesis of one GLG per year. In five of the seven animals for which the neonatal line was present, given the length of the animal at capture and time in captivity before death, under the assumption of two GLG per year, the animals were younger than would be possible. The number of GLG between the tetracycline mark and death also corresponded to a deposition rate of one GLG per year. We believe the evidence supports that beluga whales deposit GLG at the same rate (one GLG per year) as other cetaceans for which this has been calibrated. Additional support for this conclusion is drawn from reference to other techniques that indicate an annual deposition rate.*

The tooth samples were from 10 animals all captured near Churchill, Manitoba, Canada. Details of tooth preparation were presented for thin untreated sections and thin stained sections. The untreated sections were examined under magnification using reflected UV light which makes tetracycline marks fluoresce. The belugas had been captive for 4-30 yr and, although none was of known age, all were captured when very young. Problems of crown wear in some animals meant that only minimum age could be estimated but many had an intact neonatal line. Although the evidence was not clear for some animals, from actual time in captivity and GLG age, at least 3 supported an annual GLG deposition rate, while a further 5 neither supported nor refuted an annual GLG deposition. There were however, another 2 specimens that supported an annual rate from tetracycline marking (see Fig. 5). On balance, the annual GLG deposition was accepted.

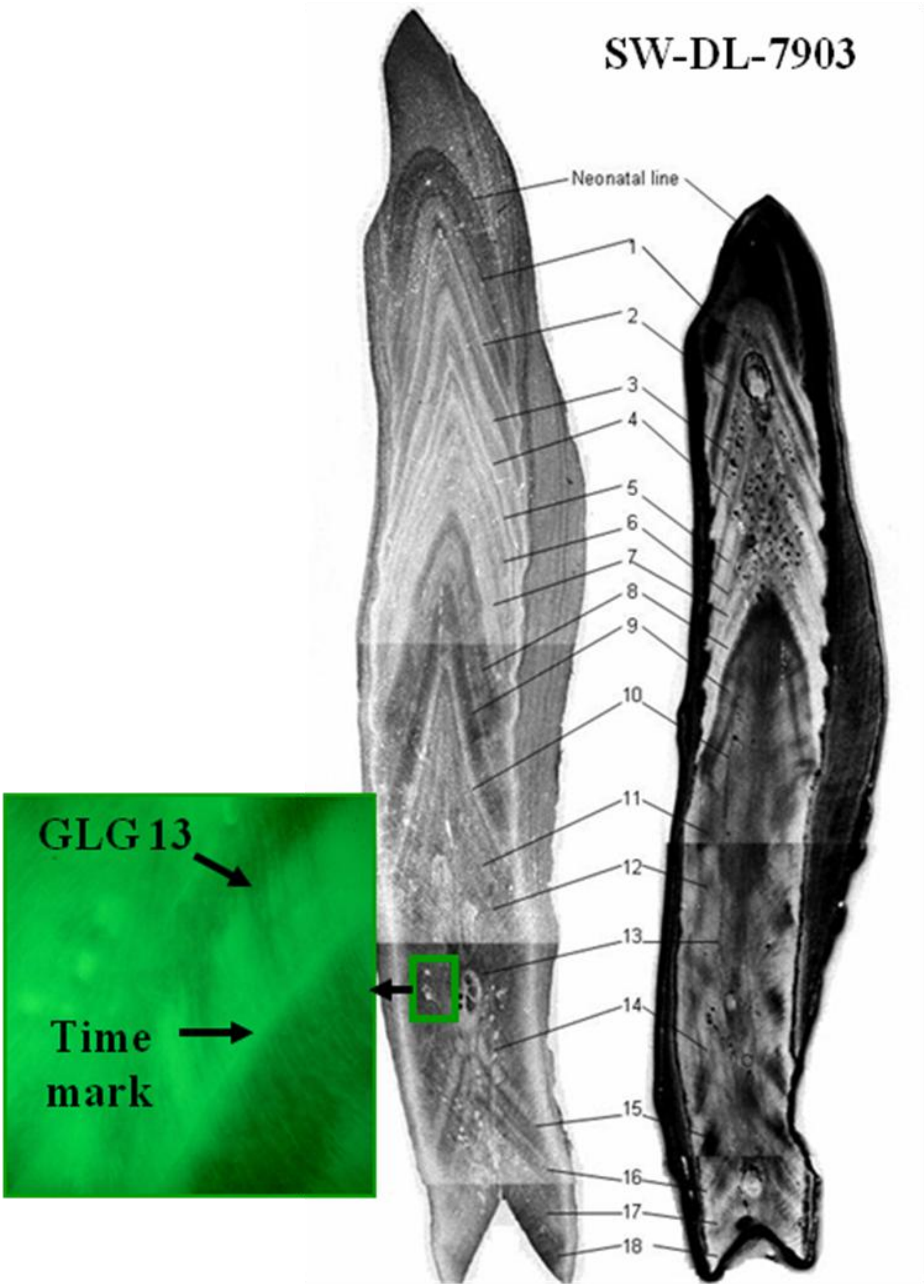

Figure 5. To the left is the decalcified and stained section of the tooth of SW-DL-7903, and to the right is the untreated section from the same tooth. There are 18 GLG marked up in the dentine, and the neonatal line is intact. This animal was in captivity almost 8 yr. Presence of a fluorescent time mark in the dentine around GLG 14 originates from a tetracycline treatment 4 yr and

2 mo before death. The conclusion is that a one GLG per year deposition rate is validated for this animal.

Discussion

Brodie queried the authors' conclusions and offered an alternative conclusion for possible evidence of two GLG deposition rate instead, based on his experience with size and growth of free-living animals. He drew attention to specific examples used by Hohn and Lockyer in his earlier presentation 15, and he believed that all the animals presented could be interpreted this way based on body lengths at capture. Suydam raised the issue of potential problems in growth, especially tooth growth, with the change from wild to captive status. For other species, *e.g.*, *Tursiops*, there has not been evidence of a change in tooth structure due to captivity. Lockyer noted that geographical variations in ultrastructure occur in teeth (Lockyer 1999) and that probably climatic events also leave traces in the teeth (Manzanilla 1989). Possibly some animals taken into captivity also show such events in tooth ultrastructure. The events of capture (when often an animal fails to eat for a while), ill health, and reproductive events (births) can change the GLG pattern in short-finned pilot whales, *Globicephala macrocephalus* (Lockyer 1993) but these do not eliminate any GLG. Hohn noted that in dusky dolphins, *Lagenorhynchus obscurus*, the difference is in mineral density of GLG deposited during El Niño years. However, the changes were not deposition rate or thickness of the GLG. Clearly response to captivity is likely species-specific.

Stewart argued that there seemed to be no physiological rationale for 2 GLG per year in comparison with other species in which one per year is normal. Brodie persisted that the length at birth of two of the animals mentioned by Lockyer, plus the time in captivity, matches the two GLG per year hypothesis. For example, one beluga (Moby, captive 30 yr, and age > 43yr) should be consistent with two GLG per year if extra GLG are added for crown wear and the age at first capture was as a calf. Lockyer concluded that the juvenile phase in the teeth is the controversial item where most GLG identification problems exist and effort should be put there into assessing deposition rates and patterns and how to identify a GLG in the juvenile period.

27. The sensitivity of age structured population dynamics models to bias and precision in ages - Roderick C. Hobbs

There was no abstract provided for this talk. Published and sourced data on age parameters for belugas were presented as the basis of the talk. The sources of errors were listed as:

1. Ambiguous aging material
    a. Poor or interrupted growth layer groups (GLG) in teeth
        i. Estimation bias and variance increase with age
        ii. GLG formation may be correlated temporally by environmental events
    b. Worn or broken structures (crown, root, etc.) in teeth
        i. Minimum age only. If wear rate is > 1 GLG per yr, minimum age declines with age

2. Interpretation of material
    a. Deposition rate of GLG in teeth
        i. Was thought to be 2 per yr now 1 per yr.
        ii. Do older animals continue to add GLG's?
    b. Racemization rate (AAR method)
        i. Initial value may vary among individuals
        ii. May vary by population and species.

In investigating age structured models, the following were assumed for belugas:

1. Leslie Matrix
    a. Maximum age (80 yr)
    b. Age at first reproduction (11 yr)
    c. Survival rate (.95/yr)
    d. Birth rate (0.3/yr)
2. 100 individuals were drawn from a stable age distribution for the analyses.

For the analyses, the following were derived sequentially:

1. Age at first reproduction and survival rate estimated from age data.
2. Bias and variation drawn for each individual to simulate aging error.
3. Age at first reproduction and survival rate estimated from simulated aging data.
4. Intrinsic growth rates estimated for each data set for comparison.

In conclusion, errors in estimation of parameters can arise from errors in aging with both negative and positive bias and varying degrees of variance. In turn, these translate to errors in estimation of growth rates. Efforts should be made to quantify bias and precision.

28. Accuracy, precision and quality control in the age estimation of aquatic animals - Steve Campana

ABSTRACT: *Many calcified structures produce periodic growth increments useful for age estimation at the annual scale. However, age estimation is invariably accompanied by various sources of error, some of which can have a serious effect on age-structured calculations. This review highlights the best available methods for insuring aging accuracy and quantifying aging precision, whether in support of large-scale production aging or a small-scale research project. Through use of quality control monitoring, aging errors can be readily detected and quantified; reference collections are the key to both quality control and reduction of costs.*

Aging is a very important aspect of living resource management. Some examples of precisely wrong ages in different species were presented, which were only identified when known ages became available. Age validation methods are essential and age corroboration using different methods provides support for the ultimate age. In producing a successful aging programme a method must first be developed. This must be followed by validation of the method. Preparation of a reference collection, ideally of known-age hard parts or, at least, hard parts aged by international experts is necessary. The reference collection is best for monitoring aging consistency through time, in the training of new age readers, and for testing consistency among readers.

Quality control must also exist with regular monitoring and preparation of age bias graphs for readers and CVs. The best measures of precision were coefficient of variation (CV), average percent error (APE) and index of dispersion (D); the least reliable was percent agreement among readers (Campana 2001).

In conclusion, accuracy is not equal to consistency and age validation methods are not all created equal. Chemical mark-recapture and bomb radiocarbon are the most reliable age validation methods. A reference collection is the key to effective quality control.

Discussion

There was much discussion about the desirability of reference collections and also the usefulness of internationally available digital and accessible images. This would facilitate standardization and training in methods among diverse labs and workers, and obviate the need to exchange actual material when CITES permitting was problematic.

29. Summary of the main findings of the workshop with specific reference to monodontids – Christina Lockyer

The breadth and depth of the presentations made it clear that most issues concerning monodontid age estimation are not unique. Many researchers investigating many taxa have considered a diversity of methods and tissues to establish biological records of age. Aside from the biological materials, they have pondered accuracy and precision of the counts or metric, as well as their interpretation.

Relative age can be estimated using biological or chemical changes if the rate of change is known. Attempts to use **telomere length** to estimate age (Olsen presentation 8) show telomere lengths provide a measure of individual body fitness and condition rather than age, as environment, migration, health, and reproduction affect telomere length. The method has potential but is still under investigation; problems include locating long-lived known-age humpback whales for calibration. A review of **AAR** techniques on fin whale and harbour porpoise (Hjort-Nielsen presentation 12) warned that the presence of cataracts in the eye lens could seriously bias the age estimation and give falsely old ages. Longer-lived animals may be better candidates for the AAR technique, although neither fin whales nor porpoises had a good correlation of ear plug GLG and tooth GLG with AAR age respectively. There is an underestimation of age by AAR in harp seals, as in most animals (Garde presentation 13.1) although in narwhal (Garde presentation 13.2) tusk GLG correlated well with AAR age. The AAR technique using eye lens in bowhead whale (George presentation 19) showed good correlation with other age estimation methods, *e.g.*, known-age (from photo-ID), baleen plates, and ovarian *corpora* counts. Recent modifications to the hydrolysis technique and heating process at the Mote Marine Lab, Florida, had allowed refinement of the k_{Asp} rate (L_D/L_L) ratio which was found constant over time. Age models using endogenous **fatty acid** (FA) ratios have been successfully derived for killer whales and humpback whales (Ylitalo presentation 14), and preliminary results using a single fatty acid ratio for Cook Inlet belugas correlated with age from tooth GLG for physically immature animals. The maximum age from fatty acid ratio was *ca*

76 yr using C16:ln9/iso-C16:0. Future work plans to get two FA ratios is expected to provide more precision in age. It may be possible to use **bone density** as a proxy for age in beluga and narwhal flippers (Read presentation 3). The method would need to be calibrated with reference to beluga tooth GLG and AAR ages in narwhal. The recording of historic hunting **artifacts** recovered in bowhead whales (George presentation 25) in Alaska has presented an opportunistic and remarkable insight into longevity of this species which exceeds 100 yr. Other evidence of age from AAR aging technique would support this.

One technique shows promise for bridging relative ages from bone density and counting changes in density. Micro-CT scanning of teeth (Loch presentation 16) demonstrated great potential for investigating internal structure of teeth and other hard tissue specimens that are difficult or impossible to section, as there is no destruction of the specimen and it can be viewed in 3-dimensionally. It is also suitable for tympanic bones. The resolution from the technique was 5-50 micron. The main limitation is the small size of the experimental chamber, the height of which is 7-8 cm.

Counts of presumed annual markers can provide a more accurate (absolute) estimate of age than other tissues which show gradual changes with age. Among taxa, hard structures that show regular episodic growth are the most commonly used tissues to investigate for records of age. These can include bones, otoliths, claws, and ear plugs (Read presentations 3 and 6) although teeth are most widely used. **Ear plugs** in baleen whales provide a permanent record of total age from GLG, as long as there is no damage (Lockyer presentation 10). Apart from longevity, life-history parameters of age at sexual maturity and possibly physical maturity can be identified form the GLG patterns. Such patterns might exist in some teeth and should be investigated. Ear plug extraction from carcasses of minke whales (Maeda presentation 11) is facilitated by a new method involving injection of molten gelatin into the surrounding ear canal. Upon cooling, the gelatin supports the fragile ear plug structure, so increasing the possibility of extracting whole and undamaged ear plugs. This method should be tried in bowhead whales in which ear plugs are soft and fragile. The histological study of frozen thin sections of ear plug stained with Alizarin Red was successful in clarifying GLG in minke whale ear plugs.

Manatee periotic **bones** are suitable for age estimation in manatees (Howell presentation 17) where a thin section is cut from the middle of the periotic bone rostral lobe, decalcified, sectioned again to 5 micron, stained with Haematoxylin and Eosin, and examined with transmitted light under a microscope. Although some bone resorption occurs after age 15 yr, maximum ages up to 59 yr have been recorded.

Teeth are commonly used to age carnivorous mammals, including marine mammals. The seal age estimation review (Read presentation 6) indicated that canines are the optimal choice for aging, but that other teeth can be selected, especially in live animals. Techniques for preparing teeth vary. All are directed to obtaining the most complete record of clear lines. The dolphin age estimation review (Hohn presentation 4) noted the importance of quality tooth section preparations that included correct orientation providing a central section through crown and root when dentine was examined. The discussions following the dolphin tooth histology and preparation presentation (Murphy presentation 5) recommended that teeth prepared for decalcification should be wafered and sectioned thick initially at *ca* 2.5 mm to facilitate permeation of the decalcifying agent. A review of aging in sirenians (Lockyer presentation 7) indicated that dugong tusks had many internal similarities with beluga teeth and also perhaps narwhal tusks. GLG deposition rate in dugongs is annual. The most suitable method of age estimation in large odontocetes (Lockyer presentation 9) is using acid-etched half teeth in a crown to root-apex orientation, *e.g.*, in sperm whales, although thin untreated sections (*ca* 150-200 micron) are successful for smaller odontocetes, *e.g.*, killer whales and some beaked whales. Although the former method is unsuitable for belugas, the latter method is suitable. GLG patterns in sperm whales and belugas are very similar.

In beluga, counts of GLG in dentine as seen in medial longitudinal sections of teeth is the standard method and completely consistent with methods used in other taxa. Discussion on the use of cemental GLG for estimating age, which was not so usual for cetaceans, might, in the case of belugas where cement is thick, be used to help estimate age when the dentine is worn down at the crown.

The most direct age estimation technique is the 'birth certificate' method whereby known and recognizable individuals are followed though time. This approach is not applicable to many species and but is important in providing calibration animals for other techniques. **Long-term photo-ID** monitoring and surveys of the Gulf of St Lawrence belugas (Michaud presentation 20) resulted in a mass of reliable data on life history, age, reproduction, growth, and colour change. Necropsies on recovered known-age and known-history animals have provided teeth for verifying age. A photo-ID study of Alaskan humpback whales (Gabriele presentation 21) has also demonstrated the value of long-term monitoring of individuals. Calving intervals and reproductive history are known for several animals and many have been monitored since birth. Validation of an annual GLG deposition rate in humpback whale ear plugs was possible because of the recovery of samples and data from a stranded known-history female in Glacier Bay, Alaska. A long-term monitoring study of bottlenose dolphins in Sarasota Bay (Hohn presentation 22), involving capture and release, has enabled 5 generations to be monitored for life history. Extraction of teeth from live animals has permitted validation of the tooth GLG age technique for known-age animals, and knowledge of life-history parameters.

Once GLG are identified and counted, the next universal issue in age estimation is assessing the repeatability of the counts and validating their relationship to time. The first is precision; the second is accuracy and it is not the same as precision. Quality control is essential for both (Campana presentation 28). For quality control, there must be regular monitoring of an aging programme. The best measures of age precision are coefficient of variation (CV), average percent error (APE), and index of dispersion (D); the least reliable is percent agreement among readers which is usually the most commonly used. A permanent reference collection of aging materials, *e.g.*, known-age beluga teeth, is the key to effective quality control. An investigation of precision and bias in aging, focused on belugas with reference to tooth age data (Hobbs presentation

27). In conclusion, errors in estimation of parameters can arise from errors in aging with both negative and positive bias and varying degrees of variance. In turn these translate to errors in estimation of growth rates. Efforts should be made to quantify bias and precision.

One of the most persistent debates pertaining to age estimation in the beluga, has been about the accurate translation of GLG counts into time units (years). The measurement of radiocarbon, ^{14}C, in laminated hard structures of animals (Campana presentation 24) has been a precise and successful method for validating age in many species, including belugas where GLG deposition rate was found to be unquestionably annual. Necropsies on recovered known-age and -history animals have provided teeth for verifying age. Several examples support a GLG deposition rate of one per year in beluga teeth (Michaud presentation 20). Investigation of the age from teeth of known-history captive belugas, together with data on tetracycline time-marking of teeth (Hohn and Lockyer presentation 26), generally supported an annual deposition rate of GLG. However, GLG definition was unclear in some specimens, particularly in the juvenile phase. The use of tetracycline drugs for time-marking of hard tissues (Hohn presentation 23) has been proven to be a valuable method of validating age in teeth GLG. Oral administration to both captive and free-living (Sarasota Bay study) animals has enabled precise information on GLG deposition rate and is recommended as the bio-marker of choice.

Claims in support of 2 GLG per year deposition rate based on examination of growth and reproduction in Cumberland Sound belugas (Brodie presentation 15) were criticized on a number of counts. The information did not agree with other evidence presented at the workshop where 1 GLG per year deposition rates were verified by using radiocarbon techniques and photo-ID studies of known-age and -history belugas for which teeth were available.

Future research was identified in several areas to fine tune our understanding. One potential technique for estimating total age from worn beluga teeth by using the angle of the boundary layers relative to the pulp cavity edge appeared promising and should be pursued.. Of a broader nature is the potential to understand the ecological correlates to line formation. Laser ablation (ICPMS) for trace elements showing periodic oscillations in beluga tooth GLG (Matthews presentation 18) may be promising, and stable isotope ratios focusing on ^{13}C and ^{15}N. The point of weaning can be identified from the N depletion up to this point. Chemical oscillations in the teeth may be linked to ecology and movements associated with feeding and migration, although these may not be annual and thus cannot be used as an age proxy presently. The method offered great potential, and should be investigated further, especially looking at O_2.

30. Recommendations of the Workshop

The following recommendations for further studies on monodontids were agreed upon by participants:

1. Inter-method comparisons of alternative aging methods using wild, known-age animals (*e.g.* Sable Island grey seals, St Lawrence belugas).

2. Augmenting the number of samples of known age captive beluga from which teeth can be collected and comprehensive sampling of other materials useful for age estimation.
3. Examination of the immature phase of growth in teeth in beluga with reference to captive animals to determine GLG patterns.
4. Establishment of reference collections (hard parts) and consideration of a digital image exchange for calibration and training among labs.
5. Establishment of quality control routines.
6. Periodic exchanges among labs and inter-laboratory calibration for all aging techniques.
7. Comparison of tooth preparation methodologies among labs.
8. Estimation of crown wear from the angle of the boundary layers relative to the pulp cavity edge in beluga teeth, perhaps leading to estimation of the number of GLG that have disappeared.
9. Chemical time-marking for age calibration of hard parts.
10. Bomb radiocarbon validation of hard parts and eye lenses.
11. Comparison of GLG structure among stocks (wild and captive).
12. Compare GLG in teeth to growth layers in ear bones from belugas to determine if ear bones might have value for aging belugas and also narwhals.

31. Conclusions of the Workshop on aging methods applicable to monodontids

The workshop members agreed on the methods which are or may be applicable to monodontids, presented in Table 3. The methods are graded according to relative accuracy, feasibility, validity and assumptions made. New methods not yet applied to monodontids are also listed. The limitations of each technique are also given. Some methods, depending on the type of tissue required for analysis, may be applicable both to living and dead animals.

Overall, tooth GLG are judged to be the best and most precise method. Presently, tooth GLG are only useable in belugas, but AAR is promising in narwhals. More work needs to be undertaken on embedded tusks of young narwhals to help establish the AAR rate. The AAR method should also be applied to beluga eye lenses to provide a correlation with beluga tooth GLG. Such a study might provide more reliability on the narwhal AAR work presently done.

Other than known-age animals, the method that provides the most accurate ages and can be used for calibration is that of bomb radiocarbon. However, the main limitation is that at least some of the teeth or hard tissues must come from animals that were born before the fallout commenced, *i.e.*, pre-1958.

Currently, the workshop members agreed that an annual deposition rate of tooth GLG was to be the accepted standard. New evidence from known-age and -history belugas in the Gulf of St Lawrence, combining photo-ID, tooth GLG and known age, also supported this tenet. Any doubts regarding interpretation of GLG would be taken up in detail at the forthcoming workshop at the NOAA lab in Beaufort, North Carolina, where aging experts would examine beluga tooth ultrastructure and define a standard protocol for tooth preparation and GLG counting method.

32. Publication of the Proceedings from the Workshop

Acquarone presented the NAMMCO Scientific Publication Series to participants of the workshop, explaining that papers submitted to the workshop would be welcomed as submissions to a volume addressing *Age estimation in marine mammals with a focus on monodontids*. Presenters at the workshop and potential other authors would be contacted in early 2012 regarding an invitation to contribute a paper to the volume. The approval for the proposed volume had already been taken in NAMMCO, and the likely publication date would be in 2013. The editors would comprise the members of the Steering Committee, in addition to the technical editor, Mario Acquarone.

Table 3. Age estimation methods that are or may be applicable to monodontids with an appraisal.

Methods/ Techniques of Aging	Absolute/ Relative age	New to monodontids ?	Validated method?	Correl-ational support?	Precision for age at sexual maturation	Alive or dead source	Assumptions	Comments
Eye lens Aspartic Acid Racemization (AAR) with matching tooth-based age estimates	Relative	No -narwhals, yes - belugas	Not in marine mammals	Yes	Not sufficient	Dead	Lens metabolically stable. Racemization rate is constant.	Find surrogate species for testing. Encourage animal facilities to collect samples from known-age animals. Sample storage needs are specific.
Erupted tusks in narwhal	Absolute	No	No	No	Yes if accurate age	Dead	Interpret annual deposition correctly	Relatively difficult to obtain large specimen.
Embedded tusk studies in narwhal	Absolute	Hay (1980), Barner Neve (1995)	No	Pending	Unknown	Dead		Good for the first decades of life. Compare embedded to erupted tooth.
Trace element studies (in teeth and hard tissues)	Relative; unless there are periodic cycles	Yes (other models)	No	Unknown	Unknown	Dead mainly	Trace elements in the diet are cyclically incorporated in the teeth..	Could corroborate direct reading.Work in progress, encourage continuation.

Bone density of flippers	Relative	Yes	No	No	Unknown	Dead mainly	Requires that age and length are correlated	Samples available from some locations. .
Telomeres	Relative	Yes	No	?	Probably low	Alive mainly		Requires high quality DNA.
Photo-ID and known age studies in free living animals	Absolute	No	Yes	Not applicable	Yes	Alive	Existing marks do not change over time or can identify changes. Calves accurately identified.	Frequent and continuous sampling is essential. Can be an ideal validation method.
Bomb radiocarbon	Absolute	No for beluga, Yes for narwhal	Yes	Not applicable	Yes	Dead	Some of the animals have to have been born before 1958	On teeth, the core of the eye-lens (and in the ear plug).
Teeth (GLG in dentine/cementum)	Absolute	No	Yes for beluga	Not applicable	Yes	Dead mainly	Interpreting annual deposition correctly	
Ear bones (tympanic bullae)	Absolute	Yes	Not applicable		Yes - potentially	Dead	Interpreting annual deposition correctly. There is no significant resorption.	

MicroCT scanning	Absolute	Yes			Probably	Dead	Mineralized differences can be found in modern teeth.	
Artifacts (found in hunted animals, *e.g.*, harpoon heads, bullets)	Relative	No	No	?	?	Dead	Artifact used close to manufacture date. Correct identification of that date.	Rare, opportunistic. Dead animals only.
Scar accumulation on the body	Relative	Yes	No		No	Both	Can determine scarring rate and permanency.	Crude ages.
Fatty Acid (FA) analysis	Relative	In progress for beluga (2011)	No		No	Dead or biopsy samples	FA are changing consistently from year to year and with age.	Requires analyses specific to the population / stock. Investigate sensitivity to ambient temperature.
Stable isotope ratios	Relative	In progress for beluga (2011)	No	To be done	To be done	Dead mainly	Preliminary studies of ^{13}C and ^{15}N are promising. .	Could corroborate direct reading. Work in progress, encourage continuation.

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Appendix 1

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Appendix 2

SCHEDULE FOR THE
AGE ESTIMATION WORKSHOP

26-27 November 2011 -- Venue Room #19, Tampa Convention Center, Tampa, Florida

PROGRAMME

Terms of Reference (TOR)

1. Review current methods of age estimation in marine mammals with a focus on monodontids.
2. Recommend the method(s) most suitable for monodontids; and trials of any new techniques that are as yet untried in monodontids.
3. Compile papers submitted to the workshop and relevant to age estimation in monodontids in a publication volume entitled "Age estimation in marine mammals" of the NAMMCO Scientific Publication Series.

Day 1: 26 November

08:30 hr	**Registration**	
Opening, Welcome and Introduction		
09:00 hr	Background and the basis for the workshop and its aims (TOR)	Christina Lockyer
Review – Chair: Christina Lockyer		
09:15 hr	Age estimation methods applicable in mammals with special emphasis on marine mammals and especially monodontids	Fiona Read
09:55 hr	**Discussion and questions – led by Chair of session**	
10:15 hr	**Refreshments (30 min)**	

Direct methods of aging - Chair: Aleta Hohn

10:45 hr	Aging in dolphins including belugas	Aleta Hohn
11:00 hr	Investigating the deposition of growth layer groups in dentine tissue of captive common dolphins *Delphinus sp.*	Sinead Murphy
11:20 hr	Age estimation in seals	Fiona Read
11:35 hr	Age estimation from teeth in large odontocetes	Christina Lockyer
11:50 hr	A brief review of age estimation in sirenians focusing on dugong tusks	Christina Lockyer
12:00 hr	**Discussion - led by Chair of session**	
12:15 hr	**Lunch (1 hr 15 min)**	
13:30 hr	Age estimation in mysticetes with a focus on ear plugs	Christina Lockyer
13:50hr	Feasibility study on the incorporation of the gelatinized collection method and the freeze-section technique of the ear plug in age estimation in common minke whales	Hikari Maeda
14:10 hr	**Discussion – led by Chair of session**	

Indirect methods of aging – Chair: Rob Stewart

14:30 hr	Porpoise / fin whale age from eye lens and age validation	Nynne Hjort-Nielsen
14:45 hr	Background, the harp seal study and the known age animals study	Eva Garde
15:00 hr	Narwhal age from eye lens and age validation	Eva Garde
15:25 hr	Aging beluga (white) whales from measurements of specific fatty acids present in their outer-blubber biopsy tissues	Gina Ylitalo
15:45 hr	**Refreshments (30 min)**	
16.15 hr	Prospects for genetic age estimation of cetaceans	Morten Tang Olsen
16.35 hr	Growth and maturity of belugas (*Delphinapterus leucas*) in Cumberland Sound, Canada, compared to those raised in captivity	Paul Brodie

17:05 hr	**Discussion led by Chair of session**	
17:25 hr	Summing up for Day 1	Christina Lockyer
17:30 hr	**BREAK FOR DAY 1**	

DAY 2: 27 November

New techniques – Chair: Rod Hobbs

08:30 hr	Use of micro-computed tomography for dental studies	Carolina Loch
08:50 hr	Ear bones used for aging of manatees	Amber Howell
09:10 hr	Informal progress report on *Trace element profiles in beluga teeth*	Cory Matthews
09:20 hr	An overview on aspartic acid aging-strengths and weaknesses	Craig George
09:40 hr	Individual identification and life history of the St. Lawrence beluga	Robert Michaud
10:00 hr	**Discussion - led by Chair of session**	

Validation techniques – Chair: Rod Hobbs

10:15 hr	Long-term studies with respect to humpbacks photo-ID, age and reproduction	Chris Gabriele
10:25 hr	Known history and photo-ID (dolphins)	Aleta Hohn
10:35 hr	Bio-markers and tetracycline antibiotic time-marking	Aleta Hohn
10:50 hr	**Refreshments (10 min)**	
11:00 hr	Bomb dating and age validation: conclusive results in a fuzzy world	Steve Campana
11:20 hr	Artifacts (e.g. historic whaling weapon recovery from carcasses)	Craig George
11:35 hr	Age validation through known history captive studies in belugas	Christina Lockyer
11:50 hr	**Discussion - led by Chair of session**	

Application of age data – Chair: Christina Lockyer

12:00 hr	Sensitivity of age structured population dynamics models to bias and precision in ages	Rod Hobbs
12:20 hr	Accuracy, precision and quality control in the age estimation of aquatic animals	Steve Campana
12:40 hr	**Discussion - led by Chair of session**	
13:00 hr	**Lunch (1 hr 30 min)**	
Concluding the workshop - Chair: Christina Lockyer		
14:30 hr	Summing up of Days 1 and 2	Christina Lockyer
14:45 hr	Draft recommendations: • *Accepted methods for monodontids* • *Unsuitable methods for monodontids* • *New methods for trial with monodontids* • *Validation methods for monodontids* • *Conclusions on validation of GLG in teeth* • *Conclusions on quality control and any actions arising (e.g. standardisation)*	
15:30 hr	**Refreshments (30 min)**	
16:00 hr	Draft recommendations for the report – on screen Deadline for completion and circulation of the workshop report.	Mario Acquarone
16:30 hr	Contributions to the ***NAMMCO Scientific Publications***: who will contribute, deadlines for submissions, and editors. Author guidelines and planned publication date.	Mario Acquarone, Christina Lockyer
17:00 hr	**CONCLUSION OF WORKSHOP**	

ANNEX 4

PROGRESS REPORT ON BELUGA AGE-ESTIMATION WORKSHOP

Beaufort North Carolina, USA, 5-9 December 2011
(JCNB/NAMMCO cooperative project)

SUMMARY

INTRODUCTION

The Beluga Age-estimationWorkshop organized by the JCNB and NAMMCO was conducted with the following Terms of Reference:

1. Provide a guide as to acceptable levels of accuracy and precision for age reading that will enable ages to be used in population models.
2. Conduct an inter-reader/laboratory comparison for calibration and standardization of age readings from Growth Layer Groups (GLG) in teeth among all readers/laboratories.
3. Provide information on validation that will enable GLG to be translated to real age.
4. Produce a manual of guidelines for the preparation and reading of GLG in beluga teeth.

The workshop was comprised of three parts: 1) a pre-meeting reading of images by several participants to assess the existing level of agreement among readers and identify areas of discrepancy; 2) the meeting itself at which methods, images and sections were discussed; and 3) a post-meeting reading of images by the participants. Part 1 was completed during October and November of 2011. The meeting, Part 2, was held at the Beaufort Laboratory of the US National Oceanographic and Atmospheric Administration in Beaufort, North Carolina, from 5-9 December, 2011. It consisted of general discussions with short presentations, lab-work to examine images of tooth sections and and physical specimens, and further discussion about what had been learned during the lab session. A report on Parts 1 and 2 and a set of example images developed following the guidelines determined during the meeting are in preparation. Part 3[11] will be completed during spring 2012 when the report from Part 2 is available for guidance and the new set of images is developed.

HISTORY

At its meeting in February 2009, the Joint Scientific Working Group on Narwhal and Beluga (JWG) of the North Atlantic Marine Mammal Commission (NAMMCO) and Joint Commission on Narwhal and Beluga (JCNB) supported the initiative of a workshop to produce a report and a manual for the guidance of researchers on age determination from teeth in belugas and narwhals. The JWG also recommended that a steering Committee (SC, chaired by Lockyer and including Hobbs, Hohn and Stewart)

[11] This process has been delayed and will be completed during 2013.

work inter-sessionally to scope the problems and produce draft terms of reference for one or more workshops.

In 2010, NAMMCO noted the need to standardize ages using growth layers with new methods involving aspartic acid racemisation (AAR) and recommended that a workshop on age estimation be held to review age estimation methods, and discuss of how to standardize ages using growth layers with new methods. NAMMCO encouraged the SC to proceed with the workshop's organisation following the direction provided by the NAMMCO/JCNB JWG. The steering committee determined that two separate workshops were required: 1) A workshop on Marine mammal aging generally; focusing on mondontid age estimation which was held during the workshop sessions of the 19th biennial meeting of the Society for Marine Mammalogy in Tampa, Florida in the US, to be reported in a special volume of the NAMMCO publications; and 2) A focussed workshop to address the specific issue of beluga age estimation based on teeth; this report documents those proceedings.

While interest continued in tooth aging of narwhal, the steering committee acknowledged that there was limited available material for aging, and great difficulty and expense involved in bringing it to a workshop in the USA, and currently only one lab was working on this approach. Consequently the narwhal tooth (tusk) aging workshop was separated and conducted as a presentation during the meeting of the JWG in Copenhagen in February of 2012.

The workshop was provided with a background document developed under a contract by DFO CANADA Central and Arctic Region (Stewart 2012), which described the basic biology of tooth development and growth of beluga teeth. The document and its accompanying glossary were accepted by the workshop group as the basic reference on tooth development and an excerpted version is included in the workshop report.

WORKSHOP

Part 1: Pre-workshop Readings

In October 2011 a set of 60 images was circulated to the workshop participants (Appendix 1). The images were from different stocks and were made by various means following typical practices of the contributing laboratories. All images were considered to be usable for the purpose of estimating age. The participants were asked to estimate the age of each individual represented by the tooth image and provide an assessment of relative quality and readability.

All of the experienced readers attending the workshop provided readings for Part 1, and statistical analysis of these readings was presented during day the first day of the workshop at the Beaufort lab.

Part 2: Meeting at Beaufort Laboratory

The Workshop in Beaufort was conducted December 5-9, 2011. Participants included 2 readers from the Dept of Fisheries and Oceans (DFO) Canada, 2 readers from the Wildlife board of Nunavik in northern Quebec, 1 experienced reader and 3 inexperienced from National Marine Fisheries Service (NMFS) Alaska Fisheries Science Center, an experienced reader from the North Slope Borough in Alaska, 1 experienced and 1 inexperienced readers from NAMMCO and an experienced reader at the Beaufort Lab. In-kind support was provided by the Beaufort lab in the form of laboratory space and equipment, a laboratory technician and logistical support. General support was provided by NAMMCO.

Presentations

The meeting began with presentations by participants from labs currently engaged in aging belugas as a brief oral summary of their protocols which are included in more detail in the full workshop report. In general techniques were similar, and when possible, most participants choose one or more large straight teeth, usually from the mid-posterior area, and most used one side of the jaw routinely. Two labs used milling machines, the other a low speed saw but all used circular diamond wafering blades. Only Alaskan labs routinely used a 2-blade gang to cut a section in a single pass. Most labs chose the optimal line through recurved teeth although in one lab, highly curved teeth were bisected and the two parts each sectioned along its own optimal line. Most sections were stored wet and all were viewed, wet, using a dissection microscope. Transmitted light was used commonly while reflected or polarized light was used for added clarity of problematic sections. In most labs, the sections are read multiple times, sometime by multiple readers. One lab routinely prepared stained sections and another used this technique when required.

Rob Stewart presented a brief analysis of the efficacy of 3 or 5 blind readings and initial results of an inter-lab comparison of images and physical specimens. In general, 3 readings were sufficient to determine if the tooth would provide a reliable GLG count but up to 5 readings were necessary to provide a reliable median for teeth where counts did not result in a useable mode. Counts beyond 5 were considered to be of diminishing value. Comparison between the DFO Lab in Winnipeg and in Quebec showed that there was no consistent bias in counts between the two regions but that considerable variation could occur on the reading of individual teeth.

Results from the Part 1 pre-workshop readings were presented and had been analyzed for consistency and bias, by reader, image preparation method and estimated age. Estimated age was a strong predictor of precision comparability among readers in that for the most part when the tooth was properly prepared and a good quality image was obtained then animals less than 30 years old could be consistently aged to within 1-3 years. After age 30 yr, even very good images often resulted in wide discrepancies of 5-10 years. Following the statistical review the group then reviewed some example images and then formulated the plan for the laboratory analysis.

Laboratory Sessions

Specific issues addressed during the laboratory sessions included: 1) Direct comparisons of preparation method, thin sections (0.1-0.3mm), half tooth and stained sections. 2) Comparison of images with the actual sections. 3) Methods for interpreting the initial growth layers, the final growth layer, initial layers in teeth with missing or worn neonatal cap, and teeth where the pulp chamber has completely filled and the subsequent GLG are compressed and distorted. 4) Age determination of known-age individuals.

Based on the findings during the laboratory sessions and subsequent discussion, the group recommended best practices for tooth and section preparation, reading, imaging and documenting the counts. The draft workshop report is not yet complete and some of the findings remain to be articulated. However the following conclusions will be included in the final version.

CONCLUSIONS FROM THE BEAUFORT WORKSHOP

With respect to the objectives in the Terms of Reference:

1. Accuracy and precision (objective 2 is a specific action item aimed at addressing objective 1)
    a. A comparative study was initiated and quantification of differences presented here. The resulting training process for calibration and standardization is underway.
    b. Precision of experienced readers was better than that reported in the literature for sperm whale (Evans *et al.* 2002) and spotted dolphin (Reilly *et al.* 1983) age estimation.
    c. Efforts to continue to improve precision should be tempered by the need for better precision in the application of age data (example applications are analyses of: harvest age structure, age at maturation, body growth, age-structured population models.
    d. Good thin sections that are not stained generally allowed the greatest agreement among readers (precision).

2. Translate GLG into ages
    a. Workshop 1 (Tampa 26-27 November 2011) concluded that the evidence for interpreting one GLG as an annual record irrefutable.
    b. Teeth from captive beluga were particularly problematic both as untreated sections and stained sections and did not inform the reading of wild beluga teeth.

3. Guidelines = Best Practices
    a. ROUTINE AGE ESTIMATION: The working group recommends using thin medial sections from teeth known to yield, on average, the most complete GLG record, viewed wet on a dissecting microscope with transmitted light. Detailed data should be recorded on a standardized form which will include an annotated image. End-users should be provided with all the data but the default reduction would be the mode of at least 3 readings or median of at least 5 readings.
    b. IMAGING: The working group recommends using a high-resolution slide scanner to make images of thin sections of teeth known. Images should be stored in RAW format or TIFF format which retain the entire image, protected from changes and securely archived with complete metadata. Processing that allows hidden layers of data is preferred.

Other General conclusions:

1. Sections, stained with haematoxylin, allow examination of microstructure better than untreated sections.
2. Reading half-tooth sections was more difficult than thin sections for counts of 30 or more. These sections were also more labour intensive than thin sections because the surface must be polished every time it is examined.
3. Images were generally less satisfactory than the physical specimen.

RECOMMENDATIONS

1. For presenting age estimates to the two Commissions (JCNB and NAMMCO), authors should adopt the relevant Best Practice outlines here or provide a detailed rationale for deviating from it.
2. Continue to explore new methods and technologies to clarify or enhance GLG to increase precision.
3. New approaches should use, as the “control”, the Best Practices for section preparation and reading to quantitatively calibrate the new method.
4. A reference collection of thin sections with high quality digital images should be prepared for training new readers, for refreshing experienced readers and for use in inter-lab comparison studies and standardization.
5. Reports should present GLG counts as well as their estimated age.
6. Inter-lab comparisons of precision are necessary when data are to be combined or results compared.

Recommended research topics

1. Accuracy would be improved by a better understanding of why GLG lines form. Examination of life-history correlates associated with GLG and accessory lines, the season of light and dark band formation, isotopic changes from wild to captive conditions, and known-age (or bio-marked) free-living whales could all contribute.
2. Accuracy may improve with a better understanding of how many lines are lost through occlusional wear.
3. Variation exists among stocks and a comparison of readability among stocks could guide the development of stock-specific methods. Topics could include characterization of the GLG, tooth growth and selection, and differences in seasonality.
4. Identifying GLG in juvenile belugas remains a challenge and further research on the life-history correlates, the season of formation, isotopic changes associated with weaning, and known-age free-living whales would be useful. Specifically, the influence of the protracted season of birth on the relative width and general characteristics of the early formed GLG would assist in their interpretation.
5. Investigation of cementum lines, and develop techniques. In some teeth the cementum lines are very clear and as detailed as the dentinal lines. Comparison of counts in both tissues would be useful to verify the comparability when cementum counts are used in place of dentine in difficult to read teeth.
6. Maximize use of teeth from captive animals including: tetracycline-marked, or diet studies.

7. Dental ontogeny and physiology of beluga: formation and resorption of deciduous dentition; developmental sequences of cementum and dentine growth layer deposits in permanent dentition, fetal cementum-postnatal cementum interface characteristics, eruption dynamics – embedded, partial eruption or full eruption relative to GLG count.
8. Categorization of the typical progression of occlusional wear *i.e.*, shape of cusp and tissues present, may provide a numerical approach for relative age analysis.
9. Categorization of the change in pulp cavity/root tip shape may provide a numerical approach for relative age analysis.
10. Stock differences: relative and absolute thickness of cementum *vs.* dentine; occlusional wear characteristics; quantity and type of inclusions, *etc.*
11. Measurement of the angle of GLG boundary lines at the dentin-cement junction to identify possible worn and lost GLGs.

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