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

<u>North Atlantic and North Sea</u>

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.

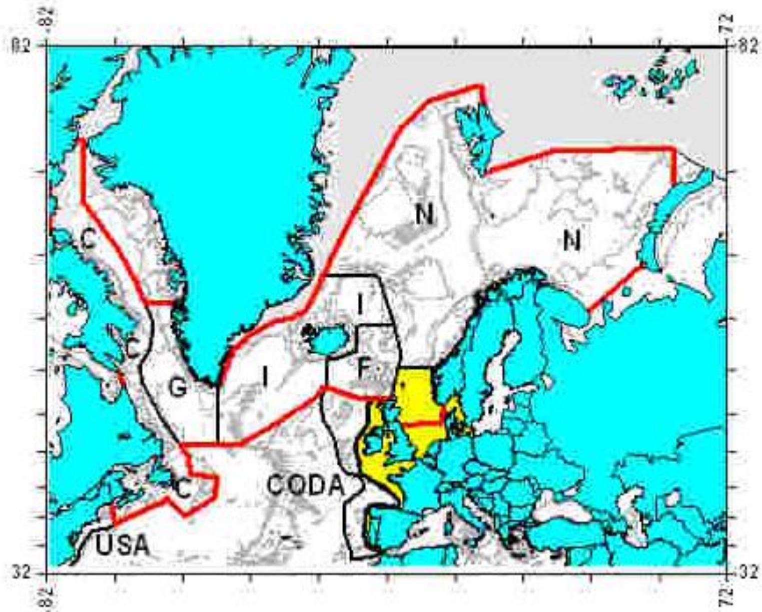


Figure 10. NAMMCO National Surveys with black boundaries and additional areas from additional synoptic surveys with red boundaries as in T-NASS 2007.

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

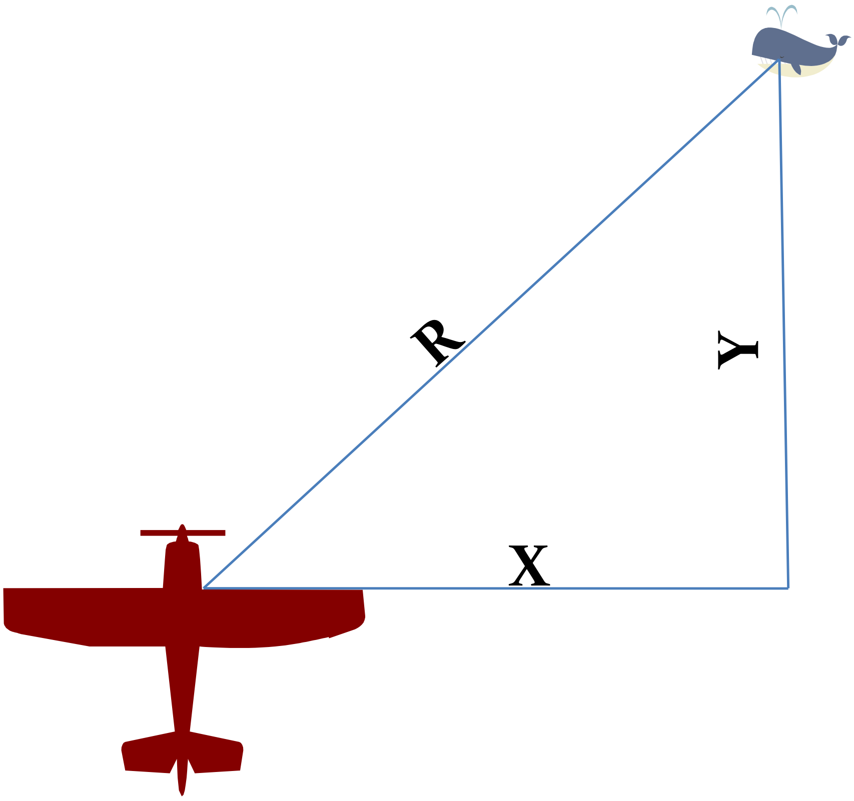
1. CHAIRMAN'S WELCOME AND OPENING REMARKS
2. ADOPTION OF AGENDA
3. APPOINTMENT OF RAPPORTEURS
4. BACKGROUND FOR AND RATIONALE BEHIND A NEW NASS
5. OVERVIEW OF PLANS AND AVAILABLE RESOURCES BY JURISDICTION
   - 5.1 Canada
   - 5.2 Greenland
   - 5.3 Iceland
   - 5.4 Faroes
   - 5.5 Norway
   - 5.6 EU 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).

<u>Evaluation</u>

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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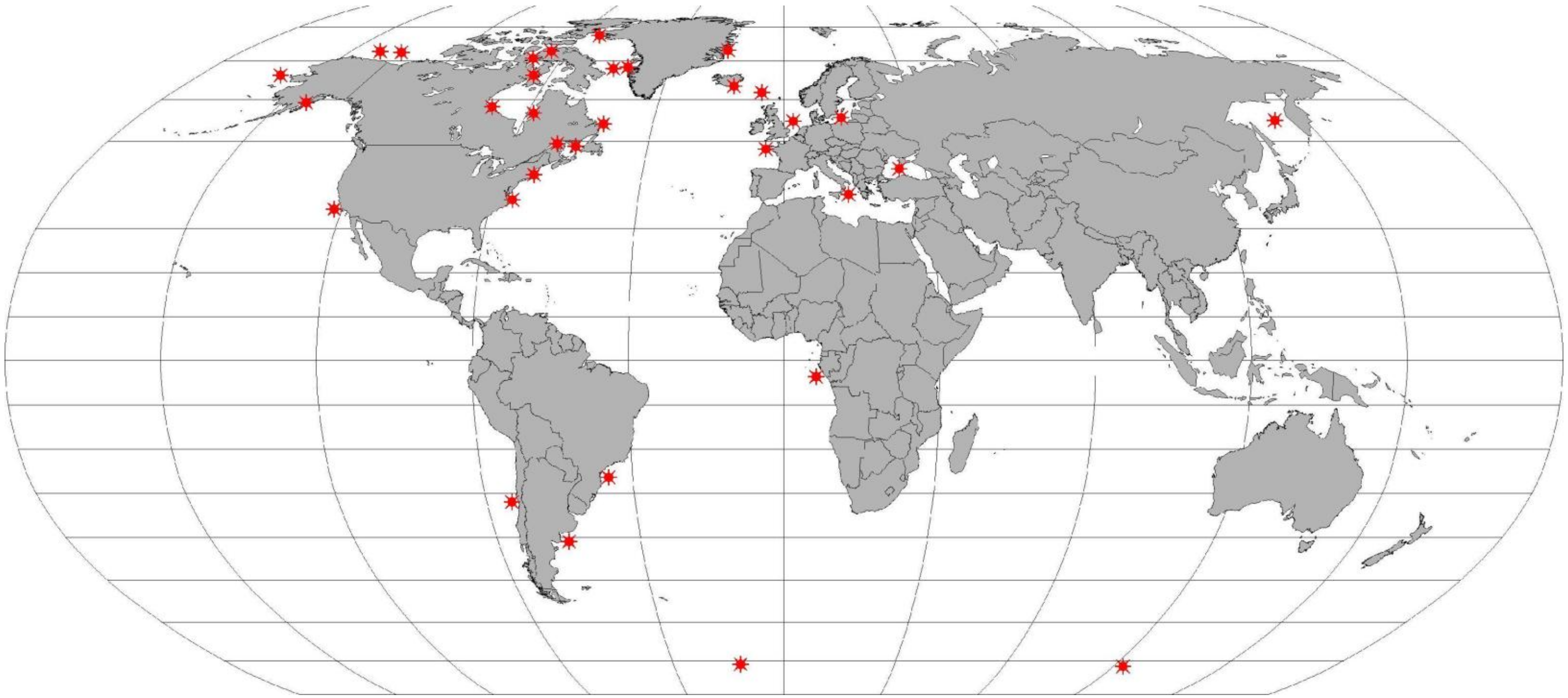


Figure 1. Locations of aerial surveys used in the assessment.

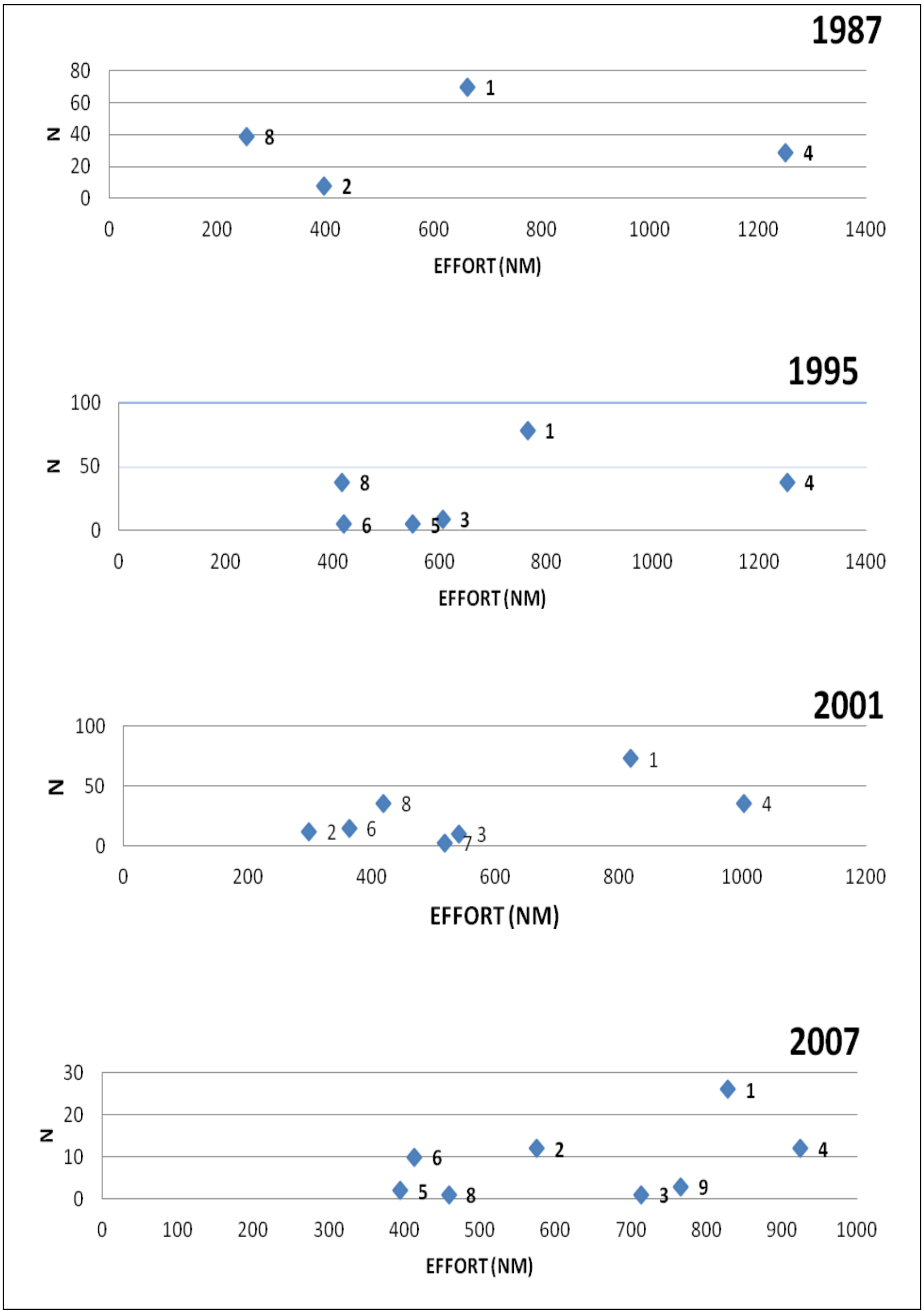


Figure 2. Numbers of sightings (N) by stratum in Icelandic aerial surveys. Strata labelled in the graphs.

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

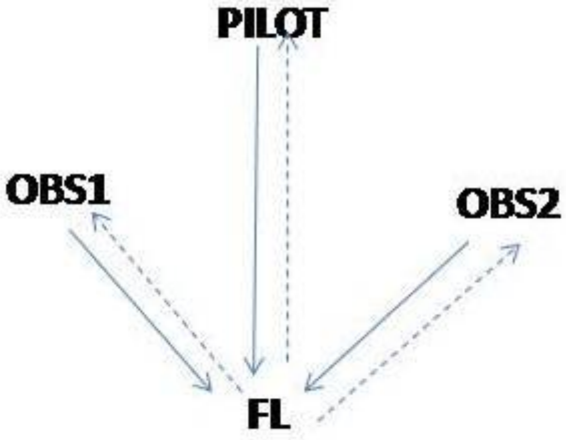
1. The software “HVAL2004” is intended for ship surveys and records time with at 1 second intervals. While this is adequate for a slow moving ship it is not for a plane, which moves over 50 m in 1 second. In addition the software can be adjusted to record positions at a minimum of 1 minute intervals, 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

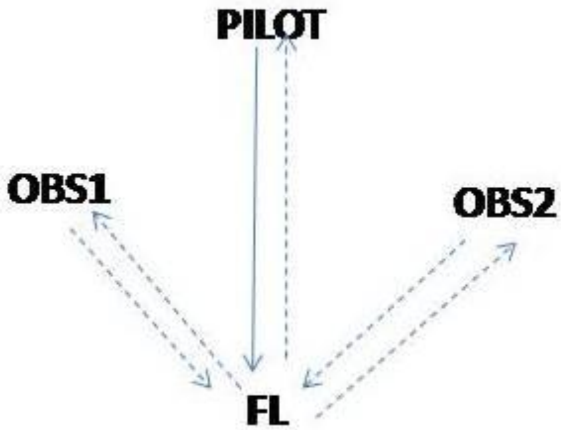
The system used is nearly 10 years old and was developed at a time when computer memory was much more expensive and bulky than it is now. Hence it was reasonable to have a system that minimized the consumption of memory by recording observations only. Now computer memory is inexpensive and compact, and 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):

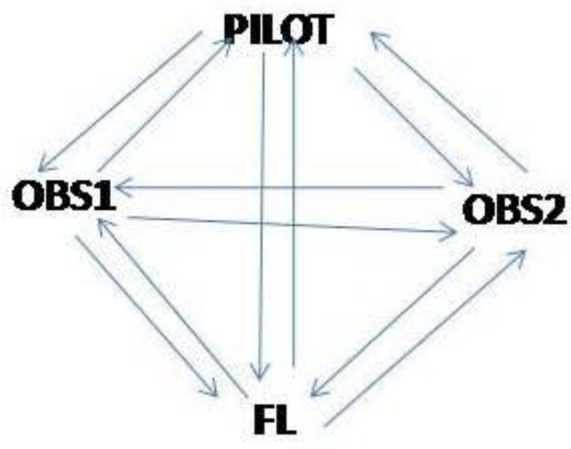
1. **Mode 1.** When FL is a non-independent observer. This would likely be used during training flights.



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.

1.2.1 IO Mode – one-way independence or trial independence*:*

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)

1.2.2 IO Mode with cetacean schools as sighting unit:

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)

1.2.3 IO Mode with tracks of cues as sighting unit:

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			2n e	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* 1n e	8	ToughBook, VisSurv_NE	AMAPPS 2011ab