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Central and Arctic Region

Compte rendu 2011/054

Région du Centre et de l'Arctique

Evaluation of methods for estimating bowhead whale abundance

September 28 and 29, 2011
Teleconference and WebEx

D. Bowen
Meeting Chairperson

E. Chmelnitsky
Editor

Évaluation des méthodes d'estimation de l'abondance de baleines boréales

Les 28 et 29 septembre 2011
Téléconférence et WebEx

D. Bowen
Président de réunion

E. Chmelnitsky
Éditrice

Fisheries and Oceans Canada/Pêches et Océans Canada
Freshwater Institute/Institut des eaux douces
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Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings include research recommendations, uncertainties, and the rationale for decisions made by the meeting. Proceedings also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

Avant-propos

Le présent compte rendu a pour but de documenter les principales activités et discussions qui ont eu lieu au cours de la réunion. Il contient des recommandations sur les recherches à effectuer, traite des incertitudes et expose les motifs ayant mené à la prise de décisions pendant la réunion. En outre, il fait état de données, d’analyses ou d’interprétations passées en revue et rejetées pour des raisons scientifiques, en donnant la raison du rejet. Bien que les interprétations et les opinions contenues dans le présent rapport puissent être inexactes ou propres à induire en erreur, elles sont quand même reproduites aussi fidèlement que possible afin de refléter les échanges tenus au cours de la réunion. Ainsi, aucune partie de ce rapport ne doit être considérée en tant que reflet des conclusions de la réunion, à moins d’indication précise en ce sens. De plus, un examen ultérieur de la question pourrait entraîner des changements aux conclusions, notamment si l’information supplémentaire pertinente, non disponible au moment de la réunion, est fournie par la suite. Finalement, dans les rares cas où des opinions divergentes sont exprimées officiellement, celles-ci sont également consignées dans les annexes du compte rendu.

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SUMMARY

Fisheries and Oceans Canada (DFO) Central and Arctic Region held a science peer review meeting on September 28-29, 2011, in Winnipeg via WebEx and teleconference. The purpose of this meeting was to evaluate bowhead whale population abundance estimate techniques including aerial surveys (e.g., winter or summer range) and mark-recapture methods (e.g., photo-identification, genetics). Meeting participants included participants from DFO Science, DFO Fisheries Management, the Nunavut Wildlife Management Board, Nunavut Tunngavik Inc., LGL Limited, Greenland Institute of Natural Resources, the United States National Oceanic and Atmospheric Administration - Alaska Fisheries Science Center and the, Universities of Alberta, Manitoba, and Saint Mary's. During the meeting, participants discussed the disadvantages and advantages, as well as timeframes and other available information, of each method, particularly in relation to estimating the abundance of the Eastern Canada-West Greenland bowhead whale population. This information is needed to support both short- and longer-term management of this species. This proceedings report summarizes the relevant discussions and key conclusions reached at the meeting.

SOMMAIRE

La région du Centre et de l'Arctique de Pêches et Océans Canada (MPO) a tenu une réunion d'examen scientifique par des pairs à Winnipeg les 28 et 29 septembre 2011, par l'entremise de WebEx et d'une téléconférence. L'objectif de la réunion était d'évaluer les techniques d'estimation de l'abondance de la population de baleines boréales, notamment les relevés aériens (p. ex., aire de répartition d'hiver ou d'été) et les méthodes de marquage et recapture (p. ex., identification par photo, génétique). Parmi les participants à la réunion, on comptait des représentants des secteurs des Sciences et de la Gestion des pêches du MPO, du Conseil de gestion des ressources fauniques du Nunavut, de Nunavut Tunngavik Inc., de LGL Limited, de l'Institut des ressources naturelles du Groenland, de la United States National Oceanic and Atmospheric Administration – Alaska Fisheries Science Center et des universités de l'Alberta, du Manitoba et de Saint Mary's. Pendant la réunion, les participants ont discuté des avantages et des désavantages ainsi que des délais d'exécution et d'autres renseignements disponibles relatifs à chaque méthode, en particulier en ce qui a trait à l'estimation de la population de baleines boréales de l'est du Canada et de l'ouest du Groenland. Ces renseignements sont nécessaires pour appuyer la gestion de cette espèce à court et à long terme. Le présent compte rendu résume les discussions pertinentes au sujet et les conclusions importantes tirées de la réunion.

INTRODUCTION

The purpose of the meeting, as outlined in the Terms of Reference (Appendix 1), was to evaluate bowhead whale stock assessment techniques used to determine abundance including aerial surveys (e.g., winter or summer range) and mark-recapture methods (e.g., photo-identification, genetics). Meeting participants included participants from DFO Science, DFO Fisheries Management, the Nunavut Wildlife Management Board, Nunavut Tunngavik Inc., LGL Limited, Greenland Institute of Natural Resources, the United States National Oceanic and Atmospheric Administration - Alaska Fisheries Science Center and the universities of Alberta, Manitoba, and Saint Mary's. Firstly, information was presented on past estimates of abundance for the Eastern Canada-West Greenland (EC-WG) bowhead whale population. Secondly, information was presented on different survey methods used in Canada and/or elsewhere on large cetaceans including bowhead whales. Possible approaches to estimate population abundance were presented: aerial surveys, photographic mark-recapture, genetic mark-recapture, boat- and shore-based visual surveys, and acoustic surveys. The pros and cons of each method were discussed, particularly in relation to estimating the abundance of the EC-WG bowhead whale population. This information is needed to support both short- and longer-term management of this species.

PRESENTATIONS AND DISCUSSION

History

<u>Eastern Canada-Western Greenland bowhead whale (*Balaena mysticetus*) population abundance estimation</u>

Author and presenter: William R. Koski

Very little biological information is available for the EC-WG bowhead in part because they have not been harvested until recently. In comparison, more biological information is available for Bering-Chukchi-Beaufort (B-C-B) bowhead whales because they have been harvested over a longer period. Compared to other baleen whale species, bowhead whales have a slow growth rate, are long-lived (150+ years), mature late (females in their late 20s and males in their late teens or early 20s), and have high survival rates (juvenile = unknown, adults = 98.4% based on photo-identification). The B-C-B population has a relatively good growth rate of 3.4% and the EC-WG population is probably also growing as fast.

The primary predators of bowhead whales are humans and killer whales. Rates of predation from both have been low until recently. Bowheads tend to be associated with ice, most likely for a combination of reasons including feeding and protection from killer whales. Many of their summering areas are ice covered but the amount of ice has declined in recent years and killer whales are more abundant so they have become a more prominent predator. Since 2008, Greenland has harvested an average of two bowheads per year from the EC-WG bowhead population under a quota issued by the International Whaling Commission (IWC). Canadian Inuit harvested three EC-WG bowheads in 2008 (four were struck), three in 2009 (three were struck) and two in 2010 (four were struck). Each hunt is conducted under a DFO License that authorizes two strikes. Single bowheads were harvested in each of 1996, 1998, 2000, 2002, and 2005. In comparison, for the B-C-B population there are an average of 65 strikes and 52 landings per year under a quota issued by IWC.

In the 1970s and 1980s, aerial surveys were conducted for narwhal and beluga mostly around Lancaster Sound, Prince Regent Inlet, Admiralty Inlet, and other small inlets during which some bowheads were seen. At the time, the EC-WG population was thought to be comprised of two populations and that influenced how surveys were conducted. The estimate of abundance for the Davis Strait-Baffin Bay (DS-BB) population was 350 but it was negatively biased because it was based on (1) photographic mark-recapture estimate that included only marked individuals, and (2) shore-based watches that did not extend late enough and could not see whales that may have migrated offshore. The estimate for the Hudson Bay-Foxe Basin (HB-FB) population was 100 but was really just an educated guess. Given current understanding of bowhead movements through ice, it is likely bowheads were able to travel through Fury and Hecla Strait, in spite of more ice at that time, and therefore there was mixing between so-called BB-DS and HB-FB bowheads in most years.

Surveys were also conducted in 1981 and 1982 in offshore Baffin Bay to look a potential natural gas shipping route. In 1981, a winter survey was flown covering 27,500 km including 6,837 km in Hudson Strait. Sixteen groups of bowheads were seen in Hudson Strait which produced an estimate of 1,349 (corrected for availability and perception bias). At the same time, an estimated 200 bowheads were seen off West Greenland. Adding 8% to allow for whales seen outside the two main wintering areas, a final estimate of 1,684 was calculated (roughly four times the previous estimate). When extrapolated to the present time, the 1981 estimate is within the range of current estimates.

<u>The bowhead whale in Greenland - past and present abundance estimates</u>

Authors: Rikke Guldborg Hansen and Mads Peter Heide-Jørgensen
Presenter: Rikke Guldborg Hansen

Bowhead whale studies in Greenland have taken place in Disko Bay which is an active glacial outlet, a deep basin (up to 400m) with complex bathymetry, and a very productive area. Bowheads arrive there in February to feed and stay until mid-May; they have arrived at the same time each year with records dating back to 1780.

Different methods have been used to estimate the number of whales in Disko Bay, including aerial survey, genetic mark-recapture, satellite telemetry, and acoustics.

a) Aerial surveys have been conducted since 1981, with double observers being used since 2006. Cameras were also used to monitor the trackline and 14 bowheads were satellite tagged at the same time in 2006 to allow for real-time availability bias correction. A participant pointed out that the correction factor for availability bias in this survey may have been underestimated, because the diving patterns and distribution of the tagged whales did not match exactly the survey area. The presenter agreed that this was possible. The survey was also corrected for perception bias, and produced an abundance estimate of 1,200 whales. The pros of aerial surveys in Disko Bay are that a double observer platform allows for correction of missed animals, the weather is usually good, the survey can cover a large area, and multiple species can be surveyed (narwhal, beluga, and walrus). However, the cons are that aerial surveys are expensive, and there is high variance associated with the abundance estimate as a result of animals being clumped, perception bias, availability bias and trackline width.

b) Genetic mark-recapture studies were conducted using 710 samples obtained between 1995 and 2010 in Disko Bay and Canada (Foxe Basin, Kugaaruk, Repulse Bay, and Cumberland Sound). From 2000-2010, 346 whale samples were obtained from Disko Bay and 21 (6%) of these were recaptured after 1-9 years. An abundance estimate was calculated using samples from 259 whales collected between 2000-2009 and samples from 75 whales collected in 2010. There were 13 recaptures in this collection, producing an abundance estimate of 1,410 whales (SE= 320, 95% CI: 783-2,038). About 80% of the bowheads sampled in Disko Bay were females, compared to 50% of those sampled in Nunavut. Pros of using genetic mark-recapture in this area are that whales aggregate around Disko Bay and near communities so samples are relatively easy to collect, the estimate is in the same magnitude as aerial survey estimate, additional data can be obtained (i.e., sex), it is relatively cheap ($9000 /year), and involves local hunter participation. The cons are that a large sample size is required to obtain a population estimate, the abundance is underestimated because generally samples are local and an extensive time period is required before sufficient data have been accumulated.

c) Satellite tag research has also been conducted and recent data from 2010 shows that the movements of a bowhead tagged in Greenland and a bowhead tagged in Alaska overlapped around Melville Island. In Disko Bay, 78 satellite transmitters were deployed between February and June (most in April) in 2009 and 2010; in 2011 an additional eight were deployed. All tags deployed in spring 2009 were tracked through December; some lasted longer. All tags deployed in spring 2010 were tracked through August of that year. One of the tagged whales circumnavigated Baffin Island. Information *in press* was used to illustrate seasonal home ranges.

Of the bowheads tagged in Disko Bay in 2009, three were transmitting data from Isabella Bay at the same time as a dedicated bowhead whale aerial survey was conducted on 19 September 2009. Twenty-eight bowheads were counted on-effort, producing an estimate of 1,108. Aerial surveys for beluga and narwhal were conducted in the North Water in May 2009 and 2010 during which no bowheads were seen in 2009 and four in 2010.

d) Acoustic behaviour and photo-identification work from a boat has also been conducted in Disko Bay by a PhD student over the past three years.

Seven bowheads were killed during 2009-2011: one male and six pregnant females. All were hunted in the Disko Bay area.

Review of past EC-WG bowhead population estimates and stock assessments in Canada

Author and presenter: Pierre R. Richard

Combined bowhead and narwhal aerial surveys were conducted from 2002-2004. At that time it was assumed that there were two populations (DS-BB and HB-FB) of bowhead in Canada. The HB-FB population had been surveyed and, since funding was available to survey High Arctic narwhal, surveys of bowhead abundance in Prince Regent Inlet, Eclipse Sound, Gulf of Boothia and Admiralty Inlet were planned. These areas were thought to be the primary areas of bowhead whale aggregation. In 2002, bad weather prevented Admiralty Inlet from being surveyed. In 2003, Admiralty Inlet was surveyed but in marginal weather. The survey also extended along the coast of east Baffin Island that year. More bowheads were seen than expected. A second plane conducted simultaneous surveys in southern Gulf of Boothia, Foxe Basin, and northwestern Hudson Bay.

Tagging data have since shown that there is likely one, not two, bowhead populations so data from the first survey year (2002), which covered the most area (Gulf of Boothia, Prince Regent Inlet and Eclipse Sound and adjacent passages and fiords) within the known range, were analyzed. Initial analysis used conventional Distance sampling and adjusted for availability bias and included all non-duplicate sightings. The strip transect estimate was 7,300 whales with a large coefficient of variation (CV) of 43%. The data were later reanalyzed using distance sampling methods that had just been developed and which corrects for both perception and availability biases. The revised population estimate was around 14,400 with a large CV.

The pros of aerial surveys are that an estimate can be obtained within 6-12 months of flying a survey compared to other methods that take longer, a large area can be covered (with enough money) and survey methods are well established for large cetaceans. The cons of aerial surveys are that bowheads are distributed in low densities over a large area, they are difficult to spot (black skin in black waters, often logging at the surface), a substantial perception bias leads to a low recapture rate, it is difficult to survey the entire range in one year (due to funding and weather), 2-3 experienced crews are required, and the CV is high because there are many transect lines with no sightings and only a few with all (the dive correction also adds to the CV).

The IWC working group (WG) assessed the EC-WG population estimate and their main criticism was with the low recapture rate of five because they thought Distance software would overestimate perception bias. The IWC WG re-analyzed the data and got an estimate of about 6,000 whales. They acknowledged that this estimate, like the previously mentioned ones, covered only part of the range of bowhead whales. Other parts could not be included due to the fact that other parts had not been surveyed in the same year and the possibility of double-counting. Bowhead numbers may have also been underestimated because the surveys were multi-species surveys and it is possible the other species distracted from sighting bowhead since other species are easier to see and/or can occur in larger groups which makes them more visible.

A participant pointed out that the IWC WG also had a problem with the surveys being conducted in fiords. The presenter said that for safety reasons the pilots only wanted to fly down the middle of fiords rather than zigzag transects. As some fiords are narrower than the farthest possible observation from the trackline, the IWC WG thought this would introduce a negative bias. The fiord numbers were not used anyway since they were flown in a different year than the 2002 surveys used for the above-mentioned estimate.

Cetacean population estimation approaches from other jurisdictions

North Atlantic megafauna surveys – considerations for the next Trans North Atlantic Sightings Survey (**TNASS)**

Authors: Jack Lawson and Jean-François Gosselin
Presenter: Jack Lawson

East coast cetacean population estimates were obtained in 2007 as part of the TNASS. This was the first time DFO surveyed from Northern Labrador to the South Scotian Shelf (covering multiple DFO regions). The geographic scale and need for synoptic surveys in TNASS necessitated aerial survey methods. Jack Lawson and crew flew 21,000 nautical miles (on effort) in Newfoundland-Labrador (NL) and Jean-Francois Gosselin and crew flew the Gulf of St. Lawrence and Scotian Shelf; the total survey was just short of 33,000 nautical miles. In NL, tracklines were designed to maximize coverage from the shoreline to the shelf break; the Distance software was used to develop equal angle zigzag tracklines that allowed maximum survey coverage between airports. Parallel lines with higher effort were flown over the Scotian Shelf.

Three aircraft were used to conduct the survey: one Twin Otter (NL) and two Cessna Skymasters (Scotian Shelf). The Twin Otter was more expensive to contract and slower but used Jet-A fuel which is more accessible. The Twin Otter is larger, and allows for a double platform survey method which is not possible in the Skymaster. The Twin Otter had large bubble windows that allowed viewing of the trackline (bubble windows in Skymasters were smaller so the trackline could not be viewed). The Twin Otter also allowed for more data to be collected including GPS location, sea surface temperature taken every 300 ms, and sightings collected in real time onto a laptop with a visual recording program developed by the National Oceanic and Atmospheric Administration (NOAA) and updated by DFO. In the Skymasters, voice recordings were used to capture sightings and camera capability was not good.

A participant asked if the extra costs (personnel, flight time) associated with using a double platform survey method are offset by the reduction in flight time to acquire re-sightings needed to estimate G_0. The presenter said he was concerned about the size of the rear bubble window but the pilot reported a change of less than 2 knots air speed. That may have reduced the plane's range a little. Seats were removed to lighten the load but it was noted that the weight of the fuel far exceeds the weight of the crew.

The pros of the Canadian TNASS aerial surveys were that they were large-scale and provide relatively synoptic coverage, the speed and range of aircraft allowed flexibility in responding to weather,daily return of aircraft allowed crew changes and data entry/backup/analyses, they are less expensive than large ship surveys (~$650,000), the double-platform positions (Twin Otter only) allowed for estimation of perception bias correction factors, and for the Twin Otter there was little evidence of response from whales.

The cons of the Canadian TNASS aerial surveys were that for Atlantic Canada, commercial aircraft bidders from outside the region were very expensive, double-platform positions were not possible on the Skymaster, good photographic images to enhance species identification, count large groups, or conduct photo-identification studies could not be obtained through windows, they cannot be augmented with acoustic data (towed arrays) possible with ship surveys and the survey could not cover Davis Strait or farther offshore because the aircraft did not have extended fuel tanks.

A participant asked why some species produce better detection curves than others. This is not always based on body size because even though some species are smaller if they travel in herds they are easier to sight.

Aerial surveys appear to be the best means to collect sufficient data in a relatively short period of time for the least cost. Twin Otters are preferred for future surveys because they offer enhanced capabilities and safety offshore. A high-resolution camera could be used to videotape the trackline to improve detections and facilitate photo-identification. One was not used during the 2007 survey because the aircraft company would not allow a camera to be set up. The purpose of using a high-resolution camera would be to determine whether you get 100% detection at the trackline, especially for the Skymaster. The camera could be run in "continuous" mode (a video) and used for training. However, because of its wide field of view it may not be good at detecting animals from an altitude of 600'. A participant pointed out the video would provide a good record for future use.

Eastern Canada-Western Greenland bowhead whale (*Balaena mysticetus*) population abundance estimation

Author and presenter: William R. Koski

In the mid 1970s, the B-C-B bowhead population was thought to be very low and whales were being hunted so NOAA investigated different options for estimating bowhead abundance on which to base a minimum harvest size. Unlike the EC-WG population, the annual spring migration of B-C-B bowheads consists of one route which passes close to the ice edge or shore in several places making shore-based counts possible. In 1976 and 1977, counts were done at Cape Lisburne and at the ice-edge off Point Barrow (Cape Lisburne was high but often above the fog so Point Barrow was a better viewing platform). Counts there were conducted annually until the early 1990s and every 8 or 9 years since then. In these first two years (1976 and 1977), whales within 4 km of a perch were simply counted and no correction was made for missed whales. In 1978, two perches were used to estimate whales being missed by the primary perch. Time, position, direction of movement, travel speeds between locations, and markings were used to estimate whether whales seen at the two perches were new or duplicate sightings. Over time, recording and matching algorithms became more elaborate.

In 1984/5, acoustic data were integrated to estimate whales passing offshore (beyond the observers' sight), when the lead closed up and observations were impossible, or when sightability was poor (i.e., fog). The ratio of acoustic detections within and beyond 4 km of the perch was used to account for whales passing offshore out of sight of observers.

Half of the attempted counts between 1976-2001 were unsuccessful because ice deteriorated before the census was completed. Recent attempts have encountered more problems because of poorer ice conditions; 2011 was the first successful survey since 2001. Ice-based censuses are still preferred because of the long time series of counts and the large number of animals actually counted. However, the estimate and CV obtained by photographic mark-recapture (1985-86 photographs) yielded similar results to the ice-based census; although the photographs were collected with really high effort (CV is generally wider for mark-recapture methods unless there is a lot of funding and a lot of pictures can be taken). Because of deteriorating ice conditions, photographic studies were funded again in 2003-2005 so that comparisons could be made before ice-based censuses became impossible.

Whales were photographed through a camera port in a Twin Otter as they migrated past Point Barrow from mid-April to early June; this covers about 96% of their migration. In years with ice-based surveys, information on passage rates can be obtained and photographic effort focused accordingly. Migration past Point Barrow is size-age structured with young whales passing early in the season and large, well-marked whales at the end.

To conduct the photographic mark-recapture study, photographs are scored separately for image quality and degree of marking on the whale in four identified zones: on the rostrum, mid-back, lower back and fluke. Inclusion of images (considered marked individuals) in the mark-recapture database depends on a combination of quality and degree of marking. For example, a very low quality photograph of a highly marked whale may be used but not a moderately- or low-marked whale for which only higher quality photographs could be used. A participant asked about what could be done with lower quality photographs. The presenter responded that models can be used to include variable photographic quality or low markings as being lower probability of recapture but right now most lower quality or lower marked photographs are taken out.

Procedures have been developed to account for biases. Reduced effort during periods with poor weather is accounted for in the analysis. For days when surveying does not occur, the number of missed animals is corrected using estimated passage rates from ice-based data. Differences in dive times and time at the surface between different segments of the population are accounted for. For example, mother/calf pairs are more likely to be photographed so they were given lower probability of selection during boot-strapping. Also, because the estimate is for marked individuals, unmarked individuals have to be accounted for so in areas where all whales are photographed an estimate of the percentage of marked and unmarked individuals can be obtained.

A participant asked what is considered a mark. The presenter answered that marks are naturally acquired but usually from trauma such as breaking through ice. Mark accumulation occurs slowly; whales photographed 23 years later showed little variation.

A participant asked if there is reason to think there are a smaller proportion of marked whales in EC-WG than in B-C-B. The presenter said that a similar proportion of bowheads may receive marks in both populations, both from ice and predators (killer whales in the EC-WG and hunters in the B-C-B).

<u>Large cetaceans off Canada's west coast: assessing abundance, distribution, population structure, and critical habitat</u>

Author: John K.B. Ford
Presenter: Steven H. Ferguson

The presenter remarked on the contrast between stock assessment from the west coast to the east coast. On the west coast the priority species are North Pacific right whale, and blue and sei whales which are all endangered, and fin and humpback whales which are threatened. All these species were depleted by whaling which ended in 1967. The goals and objectives of the Cetacean Research Program are to undertake studies to address gaps in abundance, distribution, population structure, and habitat use identified by Recovery Strategies and draft Action Plans to promote recovery and identify critical habitat.

Six primary approaches have been used to address these gaps: (1) visual ship-based reconnaissance and line-transect surveys to estimate relative and absolute abundance, (2) photographic identification for mark-recapture abundance estimation, (3) genetic sampling for population structure and identity, (4) remote Passive Acoustic Monitoring (PAM) to determine seasonal occurrence and relative abundance, (5) ship-based hydro-acoustic surveys to quantify zooplankton prey densities, and (6) movement tracking using LIMPET satellite tags.

There are a number of considerations in determining the study approach, including costs associated with different methods, the information desired (for example, large scale line-transect surveys are useful for abundance estimation only, but yield little information on seasonal habitat use, population identity, movement patterns, site fidelity, etc.), and target species. Most priority species occur in densities that are too low to allow abundance estimation using Distance software, but all priority species have reliable natural markings that enable mark-recapture abundance estimation using photo identification. Photo identification also provides useful data on site fidelity, movement patterns, migratory destinations, and life history parameters. Examples of information obtained by photo-identification studies on Pacific humpbacks and blue whales were given, including abundance, survival and population growth rates, and movements (for example, a blue whale was photographed off British Columbia in

2003 and off California in 2004). For both humpbacks and blue whales, photographic collection was combined with biopsies to be used in genetics studies.

From 2002-08, an extensive area was covered by ship-based surveys (total on-effort survey distance = 29,890 km, total time = 1,815 effort hours, total cetacean sightings = 3,353, and total individuals sighted = 17,749). In a typical research cruise on Canadian Coast Guard ships (10-14 days per season or year), non-systematic reconnaissance surveys can be done to investigate 'hot spots' identified from previous surveys, incidental sighting reports, and historical whaling records. And, deployment of small vessels (5-7 m rigid hulled inflatable boats (RHIBs)) from ships allows collection of photo-identification data, skin and blubber biopsies, and prey fragments.

Review of possible approaches

Eastern Canada-Western Greenland bowhead whale (*Balaena mysticetus*) population abundance estimation

Author and presenter: William R. Koski

Possible approaches to estimating abundance include aerial surveys (summering or wintering areas), photographic mark-recapture surveys, genetic mark-recapture surveys, boat- and shore-based surveys, and acoustic surveys. The working paper describes how each method could be used to estimate abundance for the EC-WG bowhead population and its advantages and disadvantages. The author presented this information to the meeting participants.

Aerial surveys (summering and wintering areas)

Aerial surveys are a widely accepted, and probably the most widely used, method to survey large cetaceans. To survey the EC-WG bowhead summering area, three aircraft and crews would be required to cover the area within 10-12 days (weather permitting). Cost of surveying known summering areas would be about $650,000 and if bad weather extended the survey it would cost an additional $50,000 per day. Bowhead distribution is more restricted in the winter so the survey area would be smaller and therefore less costly. The cost of surveying the main wintering areas would be about $260,000 and extending for one day would cost about $17,000 per aircraft.

The advantages of aerial surveys are that the method is widely accepted, trained observers are available (although there may not be enough), analysis methods are already established so the estimate may be more widely accepted, and a population estimate is available after one season (shorter time frame than other methods).

There are several disadvantages of aerial surveys: (1) a large area needs to be surveyed in short period of time (especially for summering areas but also not certain about whether winter distribution has changed since 1981, when populations increase their range often expands), (2) the window for surveying is very short in winter (the days are too short before the end of February and whales start to leave Hudson Strait in mid-to-late March when survey could be done) and weather could prevent completion of the survey, (3) 15 experienced observers and three aircraft flying concurrently are needed for summer surveys (less for winter surveys), (4) surveys do not provide life history information that would be useful for stock assessments, (5) partial surveys do not contribute to future population estimates but just produce a biased estimate, and (6) there is high potential for a large cost overrun or failure if bad weather is encountered.

A participant pointed out that in past surveys conducted by the Government of Nunavut for other species, using a double platform survey, Inuit observers were used and it was challenging to find enough people who were experienced or wanted to do the surveys. It was suggested that more training may help this. A participant suggested that another disadvantage to surveying in the winter is that ice can make it more difficult to spot bowheads when they surface in the ice. The detection/perception bias will correct for whales missed by both observers but it may not be sufficient in ice and may need to be dealt with in a different way.

A participant wanted clarification on the statement that bowhead distribution is more restricted in the winter. The presenter responded that this is based on the 1981 winter surveys that covered all potential bowhead wintering areas except the North Water (covered in other survey years) and confirmed by tracking data. Bowheads seem to be restricted mostly to Hudson Strait and west Greenland in winter/spring. A participant suggested that if surveys are done in the winter, more consideration be taken to determine the areas to survey so that bowhead aggregations are not missed. It was pointed out that it is not known what influences bowhead winter distribution; ice conditions, food availability, or some other another factor may be the driver(s). It was also pointed out that community members see bowheads in areas other than those defined as winter aggregations.

Photographic mark-recapture

Photographic mark-recapture is another widely accepted method and second most widely used to aerial surveys. It has been successfully used on other whale stocks with large ranges (e.g., southern right whales). This method works best when the population is small and becomes expensive if it is large. Assuming a current population of 13,500 bowheads in EC-WG and a two-year field season which is required for this method, the cost estimate is about $850,000 (more expensive than aerial surveys).

An advantage to photographic mark-recapture is that significantly more information is obtained than by aerial surveys. In addition to a population estimate, stock structure information and life history information, such as growth rates, survival, and calving intervals, can be obtained as well as body condition indices which can be used to monitor the health of the population. Information on other factors affecting the population such as killer whale predation can also be obtained. Another advantage is that methods and models that have been developed for analysis of B-C-B photographs can be used for the EC-WG population. A computer-assisted matching program has been developed for the B-C-B population to facilitate between-year matching. Future surveys can use more complex models which require less effort once a time series of photographs is established and a new population estimate can be obtained in one year. If movement between the B-C-B and EC-WG populations occurs, this can be documented by photographs, unlike genetic mark-recapture which relies on genetic samples from only hunted whales.

In comparison to other methods, there are other advantages to photographic mark-recapture. A smaller crew is required than for aerial surveys and there is less risk of a cost overrun during the survey. Also, if the survey is not completed, photographs still contribute to an unbiased population estimate and different years can be combined to increase precision (unlike partially aerial surveys). Additionally, boat-based photographic surveys can also be integrated although, in general, a lower percentage of photographs will be included in the analysis because less of the whale is photographed and cannot be compared to aerial photographs. A participant suggested that a boat with a high perch may work better. Collecting photographs may be more expensive, but they are generally easier to obtain than genetic samples, particularly in ice-covered waters; an aircraft can cover areas not accessible by boat. Photographic mark-recapture also requires fewer years to produce an estimate than genetic sampling.

Disadvantages to photographic mark-recapture are that an estimate takes longer than for aerial surveys (two or three years compared to one) and more training is required for crews to obtain photographs and conduct matching and there are currently less trained crew members than for aerial surveys. Also, the cost of a two-year photographic survey is higher than either a one-year aerial survey (particularly of wintering areas) or genetic mark-recapture.

A participant pointed out that the aerial visual survey costs are under-estimated because the collection of time-depth information through satellite-linked tags to correct surface estimates was not included in the survey costs. So, the cost of photographic mark-recapture and aerial survey methods may be quite comparable. Another participant asked if photographs can be taken using small cameras through aircraft windows. They could, but photograph quality would not be as good and it is more difficult to make some measurements as it is unknown if the camera was vertical when the photograph was taken.

A participant asked how long it takes to collect photographs (number of whales per effort) compared to aerial surveys. The presenter responded that off Point Barrow, 1,500-2,000 whales can be photographed during the spring migration season. In Isabella Bay, 120 whales were photographed during three hours of flying. So, it is possible to get a large number of photographs quickly in areas with a number of bowheads such as at the Igloolik ice-edge in spring, and in Isabella Bay, Admiralty Inlet and around Bellot Strait in summer. Photographic studies can also document whales that aerial surveys miss. Often if only a few are seen on a survey transect, there may actually be many more present in the vicinity. For example, during an aerial survey conducted in Isabella Bay, four whales were counted on a systematic transect line into the bay, while about 100 were counted from shore over a period of hours around that transect flight.

Genetic mark-recapture

Genetic mark-recapture methods have been successful for other large cetaceans and have good potential for obtaining an unbiased population estimate if sampling is conducted over several years in main summering areas or along migration routes. Bowheads segregate by age and sex so samples from all major aggregation areas are needed. A participant asked if mixing over time would take care of the problem of not being able to collect samples from important areas. The presenter responded that while there may be some wandering (probably adolescents) bowheads tend to be segregate geographically by age and/or sex (e.g., females in West Greenland).

When photographic and genetic mark-recapture methods were done at the same time there were very small differences between the calculated abundance estimates. The CV is often wider for genetic mark-recapture because fewer samples are usually collected but both generally have lower CVs than aerial surveys. However, the precision for photographic mark-recapture may be overestimated because other than using a complex model, missed matches are not accounted for.

There are several advantages of using this method: (1) is it less expensive than other methods except perhaps a winter aerial survey, (2) some genetic samples have already been collected although more are required, (3) re-identification is more accurate than with photographs, (4) re-sampling provides accurate error rates (more quantifiable), and (5) it can be used to identify movements between stocks although not if samples are from hunted whales. The disadvantages are that it may be difficult to collect samples from some important areas (e.g., Isabella Bay and Prince Regent Inlet), the estimate may be negatively biased if not all segments of population are sampled, it takes more years to get population estimate than other methods (five to six years compared to one or two), and if sampling occurs over many years, mortality may need to be incorporated into models. A participant asked if a Bayesian approach could be used to update the population estimate every year rather than having to wait five years. Some participants agreed this may be possible. A participant pointed out that another disadvantage to genetic mark-recapture is decades may be required to get a time series of abundance.

A participant questioned whether the genetic mark-recapture method is really cheaper than other methods if it takes five plus years to get enough samples. The presenter responded that based on the crude cost analysis in the working paper it is. It may be more expensive if samples need to be collected from more remote locations and/or from larger boats than from current methods. But it was also pointed out that genetic samples can be collected at the same time as boat-based photographs and tagging.

Boat- and shore-based surveys

The advantage to both these methods is local involvement and incorporation of local traditional knowledge (LTK). One disadvantage is that because bowheads avoid boats or modify their behaviour, they are very difficult to see and count from boats so boat-based population estimation would be negatively biased. Also, the area to be surveyed is too large to survey over a short period of time using boats. Additionally, because the majority of EC-WG bowheads do not pass through one or two locations where they could be counted, as they do in Alaska, shore- or ice-based surveys are not possible.

A participant asked if the use of an unmanned aerial vehicle (UAV) had been considered from boat-based surveys to extend strip width. There may be some issues with permitting although it is easier in Canada than in the U.S. Cameras used in the past have not been good enough for photo-identification but now an 84 megapixels (70 mm) camera is in development. Using UAVs may be the approach used in the future. They would not have the same range as a Twin Otter but a camp could be used as a base. This approach may just provide an index but not necessarily a population estimate. As capabilities increase and high-definition cameras are implemented, UAVs may be used for aerial surveying and photographic mark-recapture in the future. A participant asked if a boat or kayak could be used at the same time as the UAV for data collection. A kayak is not safe for offshore use and bowheads avoid larger boats.

Acoustic surveys

PAMs and stationary buoys have been used to document marine mammal vocalizations but towed arrays do not work well for low-frequency species like bowheads; background noise levels from flow noise are too loud at low frequencies and mask whale calls further from the boat. Also, whales may go quiet when boats around so they will not be detected even if they are present.

Call rates vary from day to day and season to season so call rates are not a good indication of number of whales but can be used to examine changes in distribution over time. Acoustic surveys can also be useful to supplement visual surveys from boats, shore, or ice because acoustic data can be collected in all weather or light conditions and animals can be detected at large distances. These are the advantages of acoustic surveys. The disadvantages are that because call rates vary concurrent visual observations are required to convert calls to numbers of whales and as mentioned earlier towed PAM systems do not work for bowheads. A participant asked if bowheads can be individually identified by their calls. The presenter responded no.

A participant asked about the possibility of deploying sonobuoys from the aircraft, a method that has been useful at finding some whale species (e.g., right whales). The presenter responded that this method was mostly used to find whales not estimate their abundance and bowheads are not as hard to find as some other species.

Summary

Participants agreed that no method has a clear advantage over the others, but noted that boat-based and acoustic surveys cannot provide unbiased population estimates for the EC-WG bowhead population. The suitability of other methods depends on the timeframe, available funding, and what other information is to be collected.

Aerial survey of EC-WG wintering areas could potentially be the cheapest method, assuming that the required coverage is smaller than in summer (there was no consensus on this point) and can provide a population estimate from one survey. Where there is an immediate need for a population abundance estimate, aerial survey may be the best method. But with winter surveys, there is a narrow window to conduct the survey and a high risk of failure. Genetic mark-recapture is also relatively inexpensive and offers high precision, but several years of sampling are needed and remote locations would be difficult to sample. If these areas cannot be sampled, the estimate will be negatively biased. Aerial photographic mark-recapture is the most expensive, but could sample all major aggregation areas and provide an unbiased estimate of abundance as well as life history data useful in stock assessments.

To help guide the discussion during the second day of the meeting, participants summarized the specific objective(s) for this assessment of alternate methods to estimate bowhead population abundance. This discussion was conducted following the meeting on day 1.

A new abundance estimate for the EC-WG bowhead population is needed to provide sustainable harvest advice. A multi-year timeline developed by Regional DFO (Science, Fisheries Management) proposed the following steps: complete planning/logistics/equipment needs (2011-12), conduct the aerial survey (2012-13), complete data analysis, peer review and Canadian Science Advisory Secretariat (CSAS) advice process (2013-14); and develop Precautionary Approach reference points for inclusion in the EC-WG management plan (2014-15).

Participants identified two broad objectives, i.e. immediate needs and longer term research needs. The goal of the discussion on day 2 was to assess alternative methods for bowhead population abundance estimation in order to address:

- The immediate need to provide sustainable harvest advice to the Nunavut Wildlife Management Board (NWMB) using the Potential Biological Removal method (PBR) by 2015; and
- A longer-term research plan (i.e., 5+ years) to develop Precautionary Approach reference points and refine stock assessment advice for EC-WG bowheads including sustainable harvest levels.

The two objectives were distributed to all meeting participants by e-mail.

On the second day, the meeting participants reviewed the two objectives and discussed how to meet them using one or more of the three more favourable methods: aerial surveys, photographic mark-recapture and genetic mark-recapture estimates. The feasibility (timeframe, cost, and logistics) of each method was discussed in the context of the two objectives. The decision to conduct an aerial survey or photographic mark-recapture in 2012 would have to be made in the next couple months to apply for funding and plan the surveys.

It was suggested that another option is to use the previous estimate of abundance to provide advice (interim measure of N_{min}). Some participants agreed that if nothing else could be done, this is possible but the purpose of this meeting was to discuss feasibility of other methods based on timeframe, cost, logistics, etc. because the old estimate is not reliable.

Population estimate in the short term

Aerial surveys

A participant suggested that it is important to stratify the survey to increase its precision, and that adequate funding should be available to cover all areas used by bowhead. A participant asked if joint tagging and aerial surveys would better define which areas to survey and stratify. It would require a significant number of tags but a participant pointed out that it would it be more cost effective to deploy tags than surveying for an extra day or two. It was suggested that because of changing summer ice conditions, bowhead distribution may change over the years and that tagging would be useful in monitoring these changes.

It was asked if the three survey aircraft scenario included Disko Bay in the cost analysis. The author responded that the winter survey cost estimate includes Greenland but not the summer survey because whales have left Disko Bay by then. Two aircrafts were used in the previous winter survey but they were not trying to cover all known bowhead areas. It should be possible to find three survey aircraft but it may be challenging to find enough experienced survey crew to fill them.

It was pointed out that another disadvantage to aerial surveys is that for the analysis, accurate availability bias needs to be obtained from tagging data. While the availability bias is better understood than for the previous surveys, including more tagging data from Greenland, it may not be adequately known for some areas. A participant suggested that another reason for putting out tags is to get seasonal information on diving behaviour for different segments of the population. This is important because there are large differences (~3-4x) in the proportion of time spent at the water surface by different ages and because bowheads segregate based on age, availability bias is likely different for different areas. A participant suggested circling the aircraft back to get availability bias but this does not work for bowheads because their dives are too long. It was also asked how far down bowheads can be seen but it was suggested that because bowheads do not spend a lot of time just below the surface, this is not likely an issue that needs to be addressed.

Participants discussed how adaptive sampling could be used for aerial surveys. Systematic transects would be flown until a high enough density is reached (for bowheads this may only be one or two animals) then more transect lines are added in between existing lines in that area. This would likely only apply to small areas so cost can be factored in and adaptive sampling can be dealt with in the statistical analysis. As discussed previously, it may be possible to use adaptive sampling to collect photographs, especially using a high-resolution camera, which may reduce CVs which are typically high for aerial surveys. However, adaptive sampling may actually increase the CV and it can be difficult to finish the aerial survey if you are stopping to take photographs. It was suggested that if it does increase the CV, it would be advisable to return to systematic aerial survey. Participants agreed that other information could be collected as long as the main objective was not compromised.

Participants discussed the use of bubble windows during aerial surveys. DFO owns one set of large bubble windows (about 4 feet high) which allow observers to see the entire transect (it increases the effective strip width). It would cost about $30,000 for another rear set and about $10,000 for a set of forward bubble windows. In Greenland, the aircraft comes with bubble windows. If bubble windows are not available, a camera or video could be mounted in the camera port to cover the trackline missed by observers. (It is not possible to take photographs from the bubble windows, even the larger ones.) The camera or video can monitor about a 600 m wide strip area which would cover the 200-250 m observer loss on each side (without bubble widows). It was noted that video may not provide high enough quality photographs. It was suggested that if there are two cameras looking at oblique angles out of the camera port, then only two observers may be needed. It was pointed out that there is a different detection between video/camera and people so they may not be directly comparable. But it was suggested that the Multiple Covariate Distance Sampling methods can deal with this.

Participants discussed winter versus summer surveys. There are fewer identified bowhead aggregations in the winter but daylight hours are short and cold temperatures may be a problem. It was pointed out that the availability correction from tagged animals may not be as applicable in the winter because even if whales are at the surface, they may be missed; whales are more difficult to sight in the ice and they may be near the surface but below the ice. It was suggested that a lower sun angle in the winter may also affect the ability to see whales at depth. However, surveying in winter is in leads and you can often see surface disturbance from a whale more easily then during open water in summer. Winter surveying would be late February to mid-March concentrated in Hudson Strait and Disko Bay (Disko Bay has been surveyed over the last 30 years). Depending on funding, other areas where whales might occur could be surveyed but Hudson Strait and Disko Bay are the key areas and should cover about 90% of the population. It was pointed out that the winter distribution in Hudson Strait in 1981 may not represent the current distribution especially since the population has increased, ice conditions have changed, and bowheads are seen in other areas earlier. Movement data also suggested that by March whales are starting to move to spring areas so a winter survey may miss an unspecified portion of the population. If a winter survey is done, it would be necessary to check tagging data for late February to mid-March to see where the whales are during that period. A participant asked if there are enough tagged whales for them to be representative of the population. There are many tags from Disko Bay and these should be included in determining winter areas. It was also pointed out that there is more tracking data for spring and summer than for fall and winter because tags are usually deployed in spring and summer and do not always last into fall or winter.

A participant pointed out that bowheads are now seen in the Labrador Sea during winter although the coast of Labrador had been surveyed extensively in early March in 1983 and no bowheads were seen. Because of the uncertainty in areas to survey and limitations to winter surveys, summer surveys may be preferred. Areas not identified as bowhead summer aggregations may still have to be surveyed, although less extensively, to cover all possible areas. For example, Hudson Strait is not considered part of summer area but there has been a hunt conducted in Nunavik in August and two have been taken. It was also suggested that there may also be some partitioning in the summer between whales found in Greenland and those found in Canadian water.

Photographic mark-recapture

The current photographic image catalogue for the EC-WG bowhead population is small. There are boat-based photographs taken over the last 8-10 years. These are not yet analyzed, but it is possible that only a small fraction will be suitable for inclusion in the image catalogue. Some aerial photographs have also been taken in the Canadian Arctic; 130 in 1985, 30-40 in 1986, and few from around 1990 in Isabella Bay. Few aerial photographs (not more than 50) have been taken in Disko Bay, Greenland. Participants agreed that for estimating abundance, a photographic study would require starting from the beginning because most of the available photographs are dated.

It is possible to photograph many whales in a short period. Two years would likely be required; the first set of ("mark") photographs would be acquired in the first year and the "recapture" photographs in the second year. A pilot year is not really necessary as photographic techniques have been well established in other areas. A participant suggested a possible survey plan: in spring (late June) photograph in the pack ice in Baffin Bay east of Eclipse Sound, northern Foxe Basin, near Disko Bay, and in summer, photograph Prince Regent Inlet, Admiralty Inlet, Pond Inlet, Isabella Bay, Repulse Bay, and Cumberland Sound. About 20-25 hours would be required in each location. Resample in year two for mark-recapture. It may be possible to do a mark-recapture in one year (spring as first sample and summer/fall as recapture period) but this would require a lot of effort. A participant asked about taking photographs in the winter. Even though the whales are more concentrated and not too far from communities, this has not been very successful in the past because of the cold and condensation on the camera.

As with other methods, photographic data collection would benefit from tagging information, probably even more so than for genetics data collection, to help define areas to survey. A well defined area may cut down costs.

A participant asked if collecting photographs was as susceptible to bad weather as aerial surveys. While good weather is required, photographs are taken at lower altitudes (500 feet versus 1000 feet) so photographs can be collected on some days when aerial surveys can not (when the ceiling is lower than 1000 feet). Also, because one aircraft would be hired for a longer period, compared to three aircraft for shorter periods, there is also less risk of cost overrun. If major weather problems or any other problem precludes the completion of photographic collection, any photographs taken can be used in the future; this is not true for aerial surveys.

For the first few years, collecting photographs appears to be more expensive than aerial surveys though once a catalogue is set up, costs may actually be cheaper because only one year would be required to obtain another estimate. However analysis costs increase as more photographs are collected and the need to sample broadly remains. If the budget was increased for one year to increase the chances of getting recaptures, costs would be lower than if photographs were collected over two years. Also, as previously stated, there is still a lower risk of cost overrun conducting photographic data collection compared to aerial surveys.

A participant cautioned that because at least two years of sampling is required, CEMAM funding is set up to provide funding for only one year for each stock so there is a risk of not getting funding for a second year. The two years of data collection combined are higher cost compared to one aerial survey but one year of photographic collection is lower so it was pointed out that it is not necessary to conducted data collection in two consecutive years. It was also noted that the photographic survey provides more information and this may outweigh the short-term cost advantage of a single aerial survey.

A participant suggested that if funding is only available in large sums for about one of every five years, photographic collection could be combined with aerial surveys using an adaptive sampling method. However, to obtain photographs of sufficient quality would likely require stopping a transect in order to fly at a lower altitude and over top of the whale (not more than 200 m off to the side). This may not be feasible in areas with higher densities of whales (including Greenland). A high-resolution camera would help and an adaptive design could be devised to incorporate both; for example, photographs could be taken after finishing a transect with bowhead sightings then returning to the systematic survey after collecting the photographs, or the aircraft could go back to the area the next day to collect photographs.

Genetic mark-recapture

Two concerns were raised about this method. The first is knowing when and where bowheads migrate to ensure that all important bowhead areas are sampled so the population estimate would not be biased. The second is the logistics of collecting genetic samples. It was suggested that it would be relatively easy to train local people to collect genetic samples, including areas where bowheads are not normally seen. Genetics would also provide information on population structure within an area and migration which is important information for a population assessment; however, for a quick population estimate, aerial surveys and photo-identification techniques raise fewer concerns. Without full coverage, genetics can provide an estimate of how many animals use an area, which may be useful in places where whales are hunted, but not a reliable population estimate. It was pointed out that because bowheads are separated by age and sex and because of changing ice conditions, movements will change over time and, therefore, some animals will be more susceptible to hunting at different stages of their lives. But given the scale and complexity of bowhead movements and population structuring, without an estimate of the entire population, long-term tracking of the population will be more difficult. Participants agreed that an abundance of the entire population, not just the hunted stock, is required.

So, the problem with genetics is the timeframe; it takes longer than the other methods to obtain a reliable population estimate. This method may be useful for longer-term research goals. Participants agreed that for the first objective of needing a population estimate by 2015, genetic sampling is not the best option. However, participants then discussed how many samples have already been collected. Bowhead samples have been collected in Greenland (n=346) up to 2010 and in Canada (n=262) up to 2007. Greenland samples were collected in Disko Bay and Canadian samples in Admiralty Inlet, Cumberland Sound, Foxe Basin, Kugaaruk, and Repulse Bay. No genetic differences have been detected between the two countries and three whales were recaptured in Cumberland Sound (two samples were originally obtained in Repulse Bay and one in Foxe Basin). About 100 samples have been collected in Canada in every year since 2007 so the total number of samples would be about 1,000. All tagged whales in Greenland and Canada had genetic samples taken which adds to the information attached to the genetic samples. Combining the tagging and genetic results may provide a better understanding of age-sex structuring of the population and biopsies samples can also be used to assess feeding and habitat. It was suggested that because there are already many samples, it may be possible to get a precise estimate but it may biased (at least one set of samples would have to be a random sample of the population). It may be possible to use existing samples and collect random samples in the next year or two to meet the 2015 timeline. A feasibility study needs to be done to determine if there are enough samples covering all important areas and if at least some samples have been collected randomly to do a reliable population estimate in a relatively short amount of time. It was suggested that this assessment should be done by someone who knows about bowheads, including their movements. Participants noted that samples collected to date have not been randomly sampled to include adult males, but it may be possible to estimate the number of females and extrapolate to the entire population. This approach has been done in the past.

A participant asked about the use of open models to deal with low coverage in some areas. The response was that open models are meant to deal more with immigration and emigration rather than site fidelity and migration. For bowheads, whales of similar size tend to be found in the same areas (telemetry supports this) and they appear to return to areas where they previously found food. If no food is available, they move to another area. Some migration routes are known but it is not known if the same ones are used year to year.

A participant asked if the two populations (B-C-B and EC-WG) are well defined genetically. The response was that there are significant genetic differences but it is not possible to determine which population an individual whale belongs to. It may be possible to do genetic mark-recapture using first-order relatives because there is enough genetic variation that close relatives could be picked out but obtaining a sufficiently large sample size of close-order relatives is unlikely.

Comparison of methods

A participant mentioned that is important to consider future needs when deciding on a method to use. If the goal is to track population trajectory using periodic estimates, but the first estimate is negatively biased and subsequent estimates increase, then the resulting conclusions about population trend may not be correct. Some methods make it possible to re-analyze old data once new analysis methods are developed. For Bering-Chukchi-Beaufort estimates, population trend analysis has been done by retroactively applying correction factors to historical data thought to be negatively biased; this allows for comparisons to future data.

The first objective is to obtain a population estimate by 2015. If a survey is to be conducted next year, a decision on the method is needed (aerial survey versus photographic mark-recapture study). Aerial surveys would benefit from improved sampling methods (e.g., bubble windows, track-line monitoring, and adaptive sampling) and would need to be informed by past tracking data to identify areas to survey. Participants also agreed that analyzing the structure of bowhead aggregations in the existing data would inform the adaptive sampling design. Tagging should be done in the same year as the survey to provide a better availability correction, possibly estimate the fraction of the population outside the survey area, and guide future surveys. Deploying additional tags in Canadian waters would actually be helpful for all methods. This may not feasible in Canada because 20-30 tags would be required to cover the entire range. However, some participants agreed that if this is what is required for an unbiased sample, it should be put forward for funding and compromises made if necessary. Summer aerial surveys of known aggregation areas are preferred to winter surveys and could also be used to capture photographs for photo-identification.

With sufficient effort, because it would be mostly starting from scratch, and multi-year funding, photographic mark-recapture could provide relatively precise estimates of abundance at low cost. Other advantages to this method are that it is not as dependant on weather as aerial surveys and less crew is needed so the potential for cost overrun is lower. Genetic mark-recapture can provide a low cost and relatively precise estimate. There has been considerable past effort in Canada and Greenland but numerous samples in a genetic archive should be analyzed to determine the cost effectiveness and feasibility of future genetic mark-recapture studies. Analysis could be started in the short term but an estimate is not likely to be ready by 2015. Photographic and genetic mark-recapture methods also provide more information than just an abundance estimate.

A participant mentioned that proper sampling is important to consider for all techniques to get an unbiased estimate given the structure and movements of bowheads. Because of changing ice conditions, bowhead movements may result in future aerial surveys missing aggregations. Therefore, aerial surveys may be more susceptible to weather-related sampling issues than genetic and photographic mark-recapture methods which would allow samples to be collected over many years.

A participant asked if there was any possibility to do opportunistic reconnaissance flights with Transport Canada or the Department of National Defense prior to the survey. Transport Canada has provided video and photographs along the east coast. For example, they provided photographs of identifiable killer whales taken from an altitude of 9,000 feet at a distance of 2 miles. Participants were not sure this would be feasible for the North.

Longer-term research plan

Participants briefly discussed the second objective, longer-term research. They asked for clarification on what is meant by “reference points”. This refers to a term associated with the Precautionary Approach Framework that is used for making management decisions about data-rich species. The goal is to move bowheads from being considered a data-poor species to a data-rich species, which requires three or more population estimates within ten years and population data on survival and reproduction. The discussion focused around what could be done in the next 5+ years to address reference points. Several life history characteristics are important in population/stock assessment: calf production, body condition (an indication of reproductive success) which can be obtained using photographs, mortality rate and age structure. The latter is mostly assumed by size and markings that together give a good indication of age in bowheads. Seasonal distribution is also needed to assess critical habitat and guide future surveys. It was suggested that population structure should be rated as second in importance after estimation of population abundance. Understanding where bowheads are harvested and how that relates to the overall population is important in making good management decisions.

It was suggested that the most cost effective approach would be an annual community-based study which includes tissue biopsy, satellite tagging and photo-identification methods, combined with a focused aerial survey every four years to estimate N_{min}. The community-based program would provide stock structure and distribution data to inform the stratified aerial survey. The aerial survey will give a defensible estimate of N_{min}.

It was mentioned that in addition to a good abundance estimate, an assessment of risks is also needed by Fisheries Management. These risks include levels of harvest and killer whale predation. The current level of harvest in Canada is three bowheads per year in the Nunavut Settlement Area; one bowhead was harvest by Nunavik Inuit in each of 2009 and 2010. More information would be required to advise on potential increase in harvest for the EC-WG population. A participant also suggested that level of harvest may play a role in deciding which method(s) to use and how much effort and funding is needed if the harvest is not affecting the sustainability of the population.

It was asked if and how the level of killer whale predation can be measured. Interviews with Inuit have been conducted to develop an estimate for Hudson Bay and Foxe Basin. Scarring can give an indication of encounter rates with killer whales and could be compared between the B-C-B and EC-WG populations.

It was asked if an R_{max} of 0.04 and a recovery factor of 1 would be used for calculating PBR. Last time, DFO used recovery factors of 0.1 (showing 0.5 as another option). At that time, COSEWIC had assessed the EC-WG bowhead population status as Threatened but it has since been downgraded to Special Concern. This may change which recovery factor is used for future calculations of PBR. If not much is known about stock structure and without a good estimate of R_{max}, a recovery factor of 0.5 is used.

The following list of desirables was identified for longer term research:

- a production model with catch history
- abundance trend
- population structure
- calf production
- body condition
- mortality rate (predation from killer whales)
- age/stage structure
- seasonal distribution
- habitat use

It was suggested that this list should also play a part in the selection of abundance estimation methods. Some methods (e.g. photographic mark-recapture) provide additional information pertinent to the list.

In summary, the choice of approach to estimate population abundance in the short term should consider the longer-term research goals identified, however the method(s) suitable for the former may not be the best for the latter. The longer-term research plan could draw on things done in the past and what will be done in the short term to determine which method(s) are most profitable to collect appropriate information.

Participants agreed the working paper would be updated based on discussions from this meeting and then presented at the annual National Marine Mammal Peer Review Committee meeting (October 2011). The approved document will be published as a CSAS Research Document. An advisory document would not be a product of this meeting because without more information, such as the feasibility of genetic mark-recapture and a plan comparing collection of photographs versus an aerial survey, advice cannot be given.

APPENDIX 1. Terms of Reference

Evaluation of bowhead whale survey methods to determine population abundance

Central and Arctic Regional Science Peer Review Meeting

9:30 a.m. to 3:30 p.m. (Central Daylight Time) on 28 and 29 September 2011

Winnipeg / Teleconference & WebEx

Chair: Don Bowen

Context

Eastern Canada-West Greenland (EC-WG) bowhead whales are a key ecosystem component in the Central and Arctic (C&A) Region within Fisheries and Oceans Canada (DFO). The EC-WG bowhead population is shared with Greenland and is an important subsistence fishery in both countries. C&A Fisheries Management (FM) and Science staff are developing a multi-year plan to address management and stock assessment needs for this fishery. However, there are significant outstanding information needs from Science. FM has requested advice on (1) a current abundance estimate to inform decisions on levels of harvest and (2) improved data quality with respect to knowledge of minimum population size necessary to determine Potential Biological Removal thresholds and Total Allowable Harvest recommendations. The first step in the process for providing this advice is to determine the most appropriate method(s) for assessing EC-WG bowhead whale population abundance.

Objectives

The objective of the meeting is to evaluate bowhead whale stock assessment techniques used to determine abundance including aerial surveys (e.g., winter or summer range) and mark-recapture methods (e.g., photo-id, genetics).

Expected publications

This regional Science peer review meeting will generate a proceedings report that summarizes the discussions of the participants. It will be published in the proceedings series on the Canadian Science Advisory Secretariat (CSAS) website. A working paper describing the advantages and disadvantages of various methods for assessing EC-WG bowhead whale abundance will be reviewed at the meeting. Following the meeting the working paper will be revised, if necessary, to reflect the meeting discussions. The working paper will then be presented for review by the National Marine Mammal Peer Review Committee (NMMPRC) at the NMMPRC annual meeting and later published as a CSAS research document.

Participation

DFO Science and FM sectors, the Nunavut Wildlife Management Board, Nunavut Tunngavik Inc. and academia are invited to this meeting.

APPENDIX 2: Meeting Participants

Name/Nom	Region	Affiliation
Natalie Asselin		University of Manitoba
Marie Auger-Methe		University of Alberta
Don Bowen (Chair)	MAR	Fisheries and Oceans Canada – Science
Elly Chmelnitsky (rapporteur)	C&A	Fisheries and Oceans Canada –Science
Holly Cleator (rapporteur)	C&A	Fisheries and Oceans Canada –Science
Thomas Doniol-Valcroze	QC	Fisheries and Oceans Canada –Science
Steve Ferguson	C&A	Fisheries and Oceans Canada –Science
Tim Frasier		Saint Mary's University
Jean-Francois Gosselin	QC	Fisheries and Oceans Canada –Science
Rikke Guldborg Hansen		Greenland Institute of Natural Resources
Patt Hall	C&A	Fisheries and Oceans Canada – Fisheries Management
Rod Hobbs		U.S. National Oceanic and Atmospheric Administration - National Marine Fisheries Service
Bill Koski		LGL Limited
Jack Lawson	NL	Fisheries and Oceans Canada – Science
Bernard LeBlanc	C&A	Fisheries and Oceans Canada –Science
David Lee		Nunavut Tunngavik Inc.
Kathleen Martin	C&A	Fisheries and Oceans Canada – Science
Stephen Petersen		Assiniboine Park Zoo
Lianne Postma	C&A	Fisheries and Oceans Canada –Science
Pierre Richard	C&A	Fisheries and Oceans Canada –Science
Gary Stenson	NL	Fisheries and Oceans Canada – Science
Glenn Williams		Nunavut Tunngavik Inc.
Robert Young	C&A	Fisheries and Oceans Canada –Science