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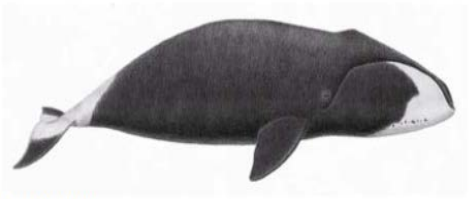
Central and Arctic Region

Canadian Science Advisory Secretariat
Science Advisory Report 2015/052

UPDATED ABUNDANCE ESTIMATE AND HARVEST ADVICE FOR THE EASTERN CANADA-WEST GREENLAND BOWHEAD WHALE POPULATION



G. Kuehl

*Bowhead whale (*Balaena mysticetus*).*

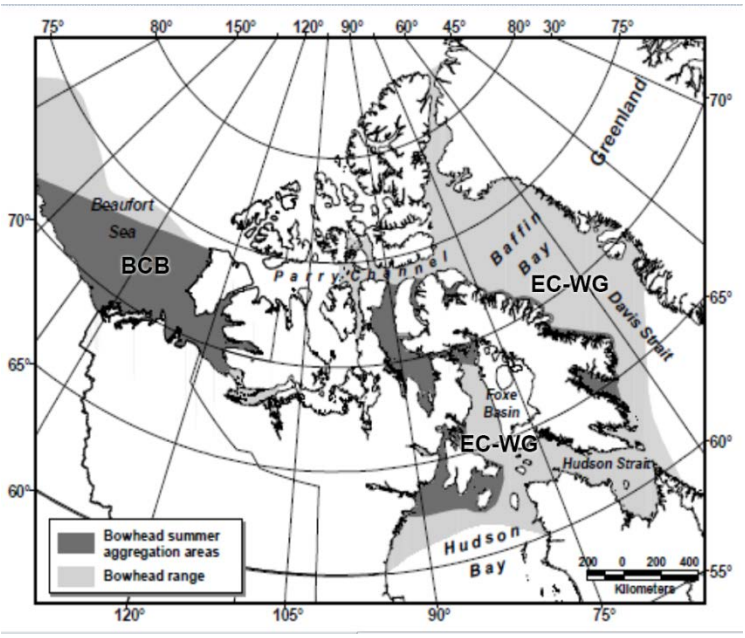


Figure 1. Range and main summer distribution of the Bering-Chukchi-Beaufort (BCB) and Eastern Canada-West Greenland (EC-WG) bowhead whale populations in Canada.

Context:

*Bowhead whales (*Balaena mysticetus*) distributed in the Eastern Canadian Arctic and West Greenland (EC-WG) are now considered to be a single population. This population is shared within Canada (Nunavut and Nunavik) and with Greenland. The population appears to be segregated within its range by age and sex; higher proportions of females and juveniles are observed in the Northern Hudson Bay-Foxe Basin area and also within Prince Regent Inlet.*

Subsistence Inuit hunts for EC-WG bowhead whales in Canada resumed in 1996. Each of these subsistence bowhead hunts is authorized by a Fisheries and Oceans Canada (DFO) license. Greenlandic harvests from this population resumed in 2008, subject to conditions established by the International Whaling Commission.

*No previous aerial surveys have covered the full extent of bowhead whale summer distribution in the Eastern Canadian Arctic in a single year. In August 2013 DFO planned to conduct the High Arctic Cetacean Survey (HACS) to update abundance estimates for known stocks of Baffin Bay narwhal (*Monodon monoceros*). The 2013 survey area was expanded to achieve complete coverage of the summer range of EC-WG bowhead whales, because it overlaps to a great extent with summer distributions of Baffin Bay narwhals and because the survey methodology is similar for both species. This Science Advisory Report (SAR) presents an updated abundance estimate for the EC-WG bowhead whale population, obtained from analysis of the HACS results and from a preliminary genetic capture-mark-recapture approach. Management advice, i.e. an updated Potential Biological Removal (PBR) estimate, is calculated only from the 2013 HACS results. This SAR is from the October 20-24, 2014 Annual Meeting of the National Marine Mammal Peer Review Committee (NMMPRC). Additional publications from this meeting will be posted on the DFO Science Advisory Schedule as they become available.*

Canada

SUMMARY

- Bowhead whales from the Eastern Canada-West Greenland (EC-WG) population range widely around Baffin Island in the summer and aggregate in Prince Regent Inlet, Gulf of Boothia, Foxe Basin, Cumberland Sound, Isabella Bay and Repulse Bay in August. This population was historically overharvested by commercial whalers. Current evidence indicates that the EC-WG bowhead whale population has increased considerably since the end of commercial whaling.
- No previous aerial surveys covered the entire summer range of the EC-WG bowhead population. A winter survey took place in Hudson Strait in March 1981 and a summer survey was conducted over Eclipse Sound, Prince Regent Inlet and Gulf of Boothia in August 2002. The partial abundance estimate obtained from the 2002 survey was imprecise due to the small number of whales observed and the large uncertainty associated with the estimate.
- In August 2013, a large scale aerial survey was conducted over all the major aggregation areas of the EC-WG bowhead whale population, with the exception of Foxe Basin, Repulse Bay and Lancaster Sound. To account for bowhead whales that were diving and not visible to aerial survey observers, survey results were adjusted using dive data from August 2012 and 2013 obtained from 22 bowhead whales fitted with satellite-linked time depth recorders near Igloolik and Pangnirtung, Nunavut. Depending on the area and time of month, bowhead whales were visible for detection by observers from 17.6% to 29.1% of the time. Applying this correction to the August 2013 survey resulted in an updated abundance estimate of 6,446 bowhead whales (Coefficient of Variation, CV = 26%).
- Population abundance of EC-WG bowhead whales was also estimated using a genetic capture-mark-recapture approach. Analysis of 1,177 biopsy samples from nine locations within the population's range produced a best estimate of population abundance of 7,660 individuals (range of uncertainty: 4,500-11,100).
- The genetic capture-mark-recapture approach, while promising, relies on several assumptions. The effects of violating these assumptions require more thorough exploration. For this reason, we recommend using only the 2013 aerial survey abundance estimate to calculate sustainable harvest levels for EC-WG bowhead whales.
- Given that our knowledge of current population size is based on only a few incomplete surveys over a 34 year period, and given uncertainty about the size of the EC-WG bowhead whale population prior to commercial whaling, we recommend a recovery factor (F_R) of 0.5 for use in the potential biological removal (PBR) calculation of sustainable harvest.
- Using the 2013 aerial survey estimate and a recovery factor of 0.5, the EC-WG bowhead whale population can support a total human-induced mortality of 52 whales annually resulting from all sources of anthropogenic mortality (e.g., harvest, struck and loss, net entanglements, ship collisions).

BACKGROUND

Bowhead whales (*Balaena mysticetus*) have a near circumpolar distribution in the northern hemisphere. Bowhead whales in the eastern Arctic travel widely (Figure 1). Satellite tagging results indicate that EC-WG bowhead whales winter in Hudson Strait and off Frobisher Bay and Cumberland Sound. As the ice breaks up, bowhead whales found in northern Foxe Basin in spring likely move through Fury and Hecla Strait to summer in the Gulf of Boothia and Prince

Regent Inlet. Whales from southeastern Baffin Island move to summering areas in Prince Regent Inlet and Gulf of Boothia, following either a southern route via Hudson Strait or a northern route via Lancaster Sound. Bowhead whales tagged in west Greenland move across Baffin Bay in spring into Canadian waters. In the summer, some tagged bowhead whales enter the Canadian Arctic archipelago and travel as far west as Prince Regent Inlet; others remain along the eastern Baffin Island. The main summer aggregation areas are Foxe Basin, Prince Regent Inlet, Gulf of Boothia, Cumberland Sound, and Isabella Bay.

Bowhead whales from the EC-WG population are genetically distinct from the more westerly Bering-Chukchi-Beaufort population. Current evidence from molecular genetics and satellite tagging does not support a two-stock hypothesis for the EC-WG bowhead whale population. The higher proportions of female and juvenile bowhead whales observed in the Northern Hudson Bay-Foxe Basin area and within Prince Regent Inlet suggest some degree of age/sex segregation in this population.

No previous surveys have covered the entire summer range of the EC-WG bowhead whale population. A winter survey of Hudson Strait occurred in March 1981, and subsequently a multi-year (2002, 2003 and 2004) survey of known bowhead whale aggregation was conducted (two separate stocks were still recognized at the time). After eastern Arctic bowhead whales were re-assessed as a single population in 2006, it was no longer possible to estimate population size by adding the results of surveys conducted in different areas in different years. A partial abundance estimate obtained from the 2002 aerial survey of Eclipse Sound, Prince Regent Inlet and Gulf of Boothia was imprecise due to the small number of whales observed. All subsequent re-analyses of the 2002 aerial survey data indicated that the EC-WG population has increased significantly since bowhead whales were protected from commercial whaling.

A limited subsistence hunt for the EC-WG bowhead whale population resumed in the Nunavut Settlement Area (NSA) in 1996 and in the Nunavik Marine Region (NMR) in 2008 (Table 1). These hunts are co-managed by the Nunavut Wildlife Management Board (NWMB), the Nunavik Marine Region Wildlife Board (NMRWB) and Fisheries and Oceans Canada (DFO). The current level of total allowable harvest is five bowhead whales per year in the NSA, and two bowhead whales per year in the NMR. In both Settlement Areas, a DFO License is issued for approved subsistence bowhead harvest. The hunt license prohibits hunting of bowhead calves (<7.6 m) or whales accompanied by calves. Hunting regulations are implemented under the *Fisheries Act* and the Marine Mammal Regulations by DFO. In 2014, the International Whaling Commission (IWC) re-approved the two strikes per year for West Greenland with the requirement for an annual review by the IWC Scientific Committee.

Table 1. Subsistence hunts for bowhead in Nunavut and Nunavik.

YEAR	COMMUNITY	HARVESTED	SEX	LENGTH (m)
1996	Repulse Bay, NWT†	15-Aug-96	M	14.91
1998	Pangnirtung, NWT†	21-Jul-98	M	12.75
2000	Coral Harbour, NU	16-Aug-00	M	11.65
2002	Igloolik, NU	10-Aug-02	F	14.19
2005	Repulse Bay, NU	18-Aug-05	F	16.40
2008	Hall Beach, NU	18-Aug-08	M	13.43
2008	Kugaaruk, NU	04-Sep-08	M	10.51
2008	Kangiqsujuaq, QC	09-Aug-08	M	14.88
2009	Rankin Inlet, NU	28-Aug-09	F	16.15
2009	Cape Dorset, NU	29-Sep-09	M	15.77
2009	Kangiqsujuaq, QC	22-Aug-09	F	17.29
2010	Pond Inlet, NU	05-Aug-10	M	12.80
2010	Repulse Bay, NU	28-Aug-10	F	14.32
2011	Coral Harbour, NU	20-Sep-11	F	16.38
2011	Iqaluit, NU	15-Aug-11	M	14.33
2011	Kugaaruk, NU	20-Aug-11	F	9.04
2012	Arctic Bay, NU	11-Aug-12	M	8.99
2012	Repulse Bay, NU	13-Aug-12	M	8.10
2012	Taloyoak, NU	06-Sep-12	F	9.60
2013	Pangnirtung, NU	06-Aug-13	M	12.80
2013	Repulse Bay, NU	31-Aug-13	F	15.72
2013	Gjoa Haven, NU	14-Sep-13	M	9.75
2014	Clyde River, NU	03-Aug-14	F	16.00
2014	Kugaaruk, NU	31-Aug-14	M	13.10

†prior to 1999 when Nunavut separated from the Northwest Terrirtories.

ANALYSIS

Aerial Survey Design and Analysis

The High Arctic Cetacean Survey (HACS) was designed to cover the largest possible proportion of the population's summering range and improve on the precision of past surveys. To meet these requirements, the study area was stratified based on geographic boundaries and by expected densities of narwhal and bowhead whales inferred from past surveys of the main summering areas (Figure 2). A combination of parallel line transect and zigzag transect was used to accommodate for small areas with expected high whale densities and large area with expected low densities, respectively. An effort was made to survey each stratum within 1-2 days.

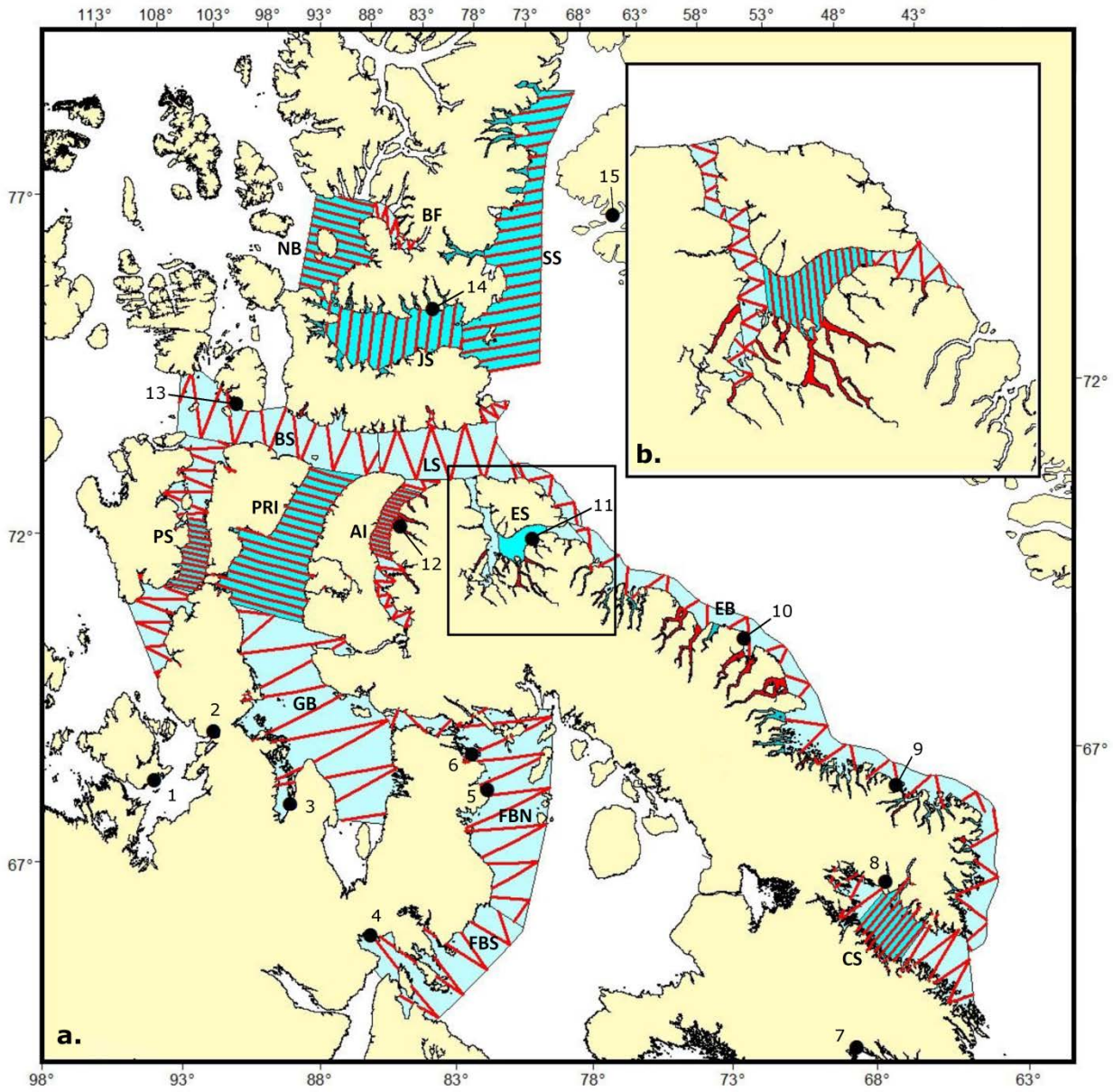


Figure 2. a.) Map of planned survey strata (blue polygons), transect lines (red lines), and fiord strata (red areas). AI: Admiralty Inlet. BF: Baumann Fiord. BS: Barrow Strait. CS: Cumberland Sound. EB: East Baffin Island. ES: Eclipse Sound. FBN: Foxe Basin North. FBS: Foxe Basin South. GB: Gulf of Boothia. JS: Jones Sound. LS: Lancaster Sound. NB: Norwegian Bay. PRI: Prince Regent Inlet. PS: Peel Sound. SS: Smith Sound. Communities (black dots): 1. Gjoa Haven; 2.Taloyoak; 3. Kugaaruk; 4. Repulse Bay; 5. Hall Beach; 6. Igloolik; 7. Iqaluit; 8. Pangnirtung; 9. Qikiqtarjuaq; 10. Clyde River; 11. Pond Inlet; 12. Arctic Bay; 13. Resolute; 14. Grise Fiord; 15. Qaanaaq (Greenland). b.) inset: zoom of the Eclipse Sound stratum (boxed area).

Three aircraft (deHavilland Twin Otter 300) were used simultaneously to cover the vast survey area within a short time frame; each was flown at an altitude of 1,000 feet (305 m) and a target speed of 100 knots (185 km/h). Each aircraft was equipped with cameras mounted in a belly window, and four bubble windows from which the survey observers could view the track line directly beneath. Survey observers were each assigned a specific bubble window for the

duration of the survey. The survey was designed as a double-platform experiment with independent observation platforms at the front (primary) and rear (secondary) of the survey aircraft. The two observers stationed on the same side of the aircraft were visually and acoustically isolated to ensure independence of their detections. Each of the three survey teams included a trained Inuit observer, and when surveys were conducted close to a community, participation of a local hunter was encouraged. Overall, Inuit groups were intimately involved with survey planning and design.

Observers recorded sightings on a hand-held recorder indicating the time at which a bowhead whale was first seen and the time at which the bowhead whale was abeam of the aircraft. Additional information was recorded with the following priority:

1) number of bowhead whales in a group (defined as 2 or more whales within one or a few body lengths of each other and oriented in the same direction),
2) perpendicular distance to sighting, and
3) other variables (direction of movement, presence of young).

The position and altitude of the aircraft was recorded every 2 seconds.

Distance sampling methods were used to estimate detection probability away from the track line. Mark-recapture methods were used to account for the proportion of whales missed by pairs of visual observers on each side of the aircraft. Density spatial modelling was used to account for the complex shape and uneven coverage in Isabella Bay.

An instantaneous correction factor was developed for bowhead whales submerged at time of the survey and not visible to survey observers, using dive data from August 2012 and 2013 obtained from 22 bowhead whales fitted with satellite-linked time depth recorders near Igloolik and Pangnirtung, Nunavut. Depending on the area and time of month, bowhead whales were available for detection by observers from 17.6% to 29.1% of the time. Instantaneous correction factors based on these proportions were applied to the surface abundance estimates of each stratum (Table 2). Due to unfavorable weather conditions, it was not possible to survey all of the planned areas. However, the survey achieved complete coverage of important summer aggregation areas like Prince Regent Inlet, Gulf of Boothia, Admiralty Inlet, Eclipse Sound, Isabella Bay and Cumberland Sound (Figure 3). It was the first time that all of these areas were surveyed in a single year.

Table 2. Surface and correct abundance estimates of bowhead whales in each stratum of the 2013 High Arctic Cetacean Survey. Availability correction factors are based on the proportion of time spent near the surface by 22 bowhead whales fitted with satellite tags and are specific to each region and time of the month (early vs mid-August 2013).

Stratum	Surface abundance	Availability correction	Abundance (corrected)	CV
Admiralty Inlet	21	3.98	82	0.97
Cumberland Sound	475	5.68	2,696	0.45
East Baffin Island (fiords)	284	4.12	1,170	0.72
East Baffin Island (offshore)	231	3.98	920	0.72
Eclipse Sound	8	3.98	32	0.74
Gulf of Boothia	192	3.44	660	0.56
Prince Regent Inlet	219	4.05	886	0.36
Total	**1,429**		**6,446**	**0.26**

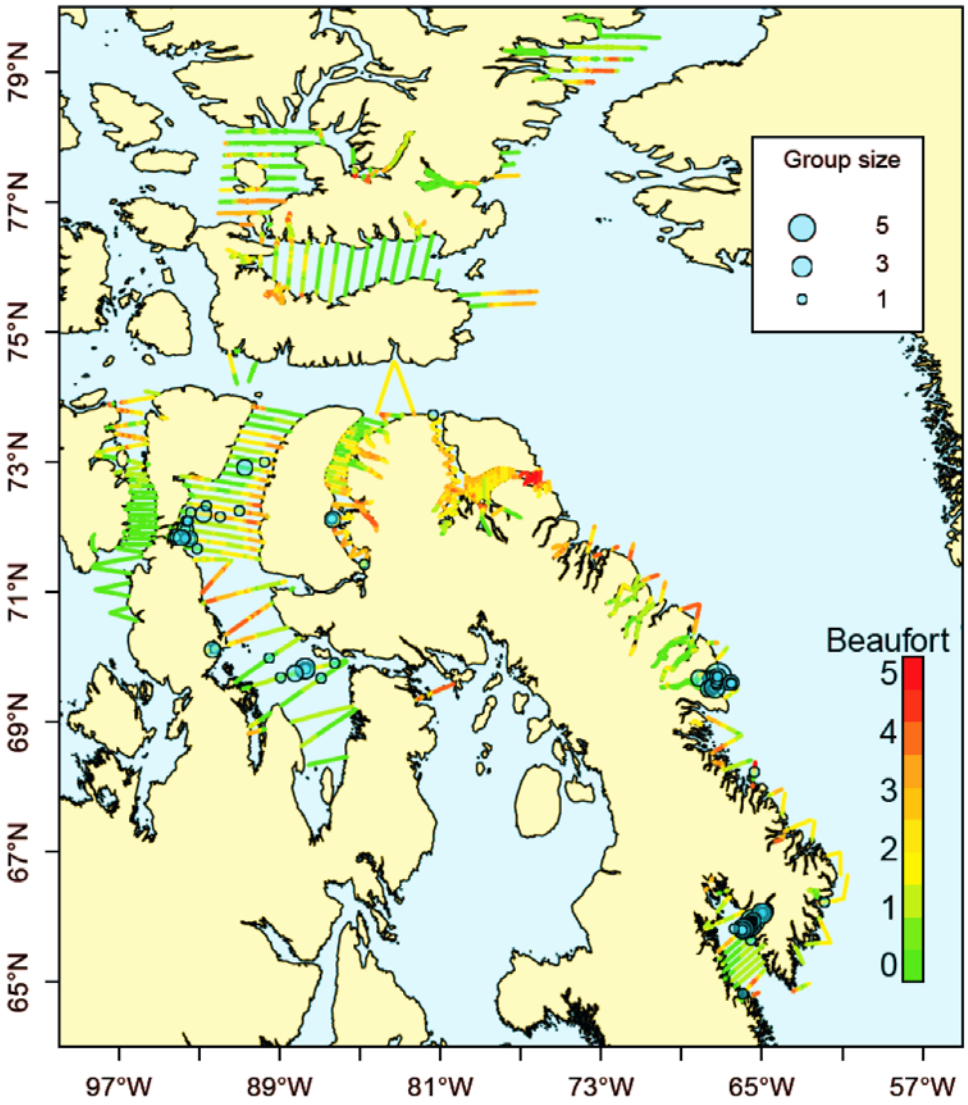


Figure 3. Unique sightings of bowhead whale groups made during the 2013 High Arctic Cetacean Survey (blue circles). Lines represent realized effort with colour scale showing Beaufort conditions.

Applying an instantaneous correction factor for submerged bowhead whales resulted in a corrected abundance estimate of 6,446 bowhead whales (95% Confidence Interval, CI= 3,722–11,200). This population estimate is likely biased negatively because of the incomplete coverage, especially of Foxe Basin, Lancaster Sound and northern Hudson Bay. There were a high number of bowhead sightings owing to greater survey effort than previous surveys, which resulted in a relatively low CV of 26%. Abundance in each stratum is given in Table 2.

Genetic Capture-Mark-Recapture Analysis

EC-WG bowhead whale population abundance was also estimated using a genetic capture-mark-recapture approach. A total of 1,177 biopsy samples, collected from nine locations within the bowhead distribution range, were analyzed. Two different analytical approaches were employed; one treated the entire dataset as one large capture-mark-recapture dataset, and the other used location-specific data to explicitly account for the presence of whales in unsampled

areas. Two subsets of the data were examined under both approaches; one subset included the entire study period (19 years; 1,177 biopsy samples); the other was a 5-year subset of the data (882 biopsy samples).

Both estimates for the 5-year data set were smaller than for the 19-year data set, which may be consistent with a population that increased throughout the study period. The best estimate of population abundance, based on a 5-year subset of the data, was 7,660 individuals (95% High Density Interval 4,500-11,100).

Sustainable Harvest Levels

For data-poor populations with few abundance estimates, the potential biological removal (PBR) method provides a conservative approach to estimating sustainable removal rates. The PBR value is estimated as follows:

$$PBR = N_{min} \times \frac{1}{2} R_{max} \times F_R$$

where, N_{min} is the 20th percentile of the confidence range around the abundance estimate, R_{max} is the expected maximum net recruitment rate (4% per year for cetaceans) and F_R is a recovery factor used to account for unknown biases or estimation problems. F_R is set at ≤ 1.0 depending on the level of uncertainty and status of the population.

In previous science advice, DFO has cautioned that, given the high level of uncertainty with the current and historical population estimates, a high level of risk avoidance (i.e., $F_R = 0.1$) should be considered for the management of this population until it could be demonstrated that a higher recovery factor was warranted. Currently, there is accumulating evidence that makes it possible to use a higher recovery factor in the PBR calculation for EC-WG bowhead whale population. Given that our knowledge of current population size is still only based on few surveys over a 34 year period, and that we are uncertain about the size of the EC-WG bowhead whale population prior to commercial whaling, we used a recovery factor of 0.5 in the PBR calculation.

Using the 2013 aerial survey estimate and a recovery factor of 0.5, we estimate that the population can support a maximum human-induced mortality of 52 whales annually resulting from all sources of anthropogenic mortality (e.g., harvest, struck and loss, net entanglements, ship collisions).

Sources of Uncertainty

We have attempted to sample the entire area known to be used by EC-WG bowhead whales in summer based on traditional knowledge and telemetry studies. It is likely that the most significant source of negative bias affecting the aerial survey abundance estimate is the lack of coverage of Northern Foxe Basin, Fury and Hecla Strait (considered important aggregation areas in August), and to a lesser extent Repulse Bay and Lancaster Sound. Information from concurrent satellite tracking of 11 individuals suggests that most bowhead whales were within the survey area during August 2013 (particularly in the Gulf of Boothia and Cumberland Sound), and only a small proportion of them were in Northern Foxe Basin, Fury and Hecla Strait.

Another source of bias in our estimate comes from the instantaneous availability correction factor. We have used updated information on diving behaviour from bowhead whales instrumented in areas and at time periods that are representative of the 2013 survey coverage. This increases our confidence in the estimated proportion of time that bowhead whales are presumed available to detection by visual observers. However, there is no experimental evidence to suggest how deep a bowhead whale can be detected from an aircraft. This makes it difficult to determine which depth bins to use to calculate an instantaneous availability bias

correction factor. To account for this uncertainty, we have combined multiple depth bins (0-2, 0-4 and 0-6 m bins), giving equal weight to each possibility.

The use of an instantaneous correction factor is appropriate when sightings are instantaneous (e.g., for photographic surveys). During HACS, visual sightings were not instantaneous and thus the correction factor does not account for the search time available to observers to detect animals, and can positively bias the estimate. Information about the average time bowhead whales are at the surface per dive cycle would be required to correct for the search time of observers during the HACS.

The genetic capture-mark-recapture model made several assumptions about the data that were not met. In particular, it was not possible to sample all age classes in the population, nor was it possible to obtain samples from all main summering locations. Assumptions of equal capture probabilities and of a closed population were not met. The effects of violating these assumptions require more thorough exploration.

CONCLUSIONS AND ADVICE

This assessment provides an updated estimate of EC-WG bowhead whale population abundance obtained from a large-scale aerial survey of all the major summer aggregation areas of the population, except Foxe Basin and Lancaster Sound. Analysis of this survey relied upon concurrent, long-term tagging projects to improve adjustments for availability bias, which resulted in a corrected estimate of 6,446 bowhead whales (CV 26%). The success of this survey was due in no small part to involvement of the Inuit communities and co-management partners, including Inuit participation in the survey as observers and in satellite tagging efforts.

A common source of uncertainty in aerial surveys of bowhead whales arises from estimating the proportion of whales that were available for detection at the surface but were missed by the observers. The 2013 survey results benefitted from a large number of sightings available for distance mark-recapture analysis owing to higher coverage intensity and the synoptic nature of the survey.

A genetic capture-mark-recapture approach estimated population abundance of EC-WG bowhead whales at 7,660 individuals (95% HDI 4,500-11,100). The genetic capture-mark-recapture approach, while promising, relies on several assumptions. The effects of violating these assumptions require more thorough exploration. For this reason, we used the aerial survey abundance estimate to calculate sustainable harvest levels.

The 2013 aerial survey abundance estimate indicated that the EC-WG bowhead whale population can support a maximum human-induced mortality of 52 whales annually across its range from all sources (e.g., Greenland and Canadian harvest, struck and loss, net entanglements, ship collisions).

OTHER CONSIDERATIONS

EC-WG bowhead whales are a migratory species which cross both territorial and international boundaries. These transboundary issues must be considered in the science and management of the population. Within Canada, management of the population is a joint responsibility between DFO and Inuit in Nunavut and Nunavik. There are rights and responsibilities for the management of bowhead whales outlined in the *Fisheries Act*, and several land claim agreements.

SOURCES OF INFORMATION

This Science Advisory Report is from the October 20-24, 2014 Annual Meeting of the National Marine Mammal Peer Review Committee (NMMPRC). Additional publications from this meeting will be posted on the DFO Science Advisory Schedule as they become available.

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Centre for Science Advice (CSA)
Central and Arctic Region
Fisheries and Oceans Canada
501 University Crescent
Winnipeg, MB R3T 2N6

Telephone: 204-983-5131
E-Mail: xcna-csa-cas@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

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