EASTERN CANADA-WEST GREENLAND BOWHEAD WHALE POPULATION ABUNDANCE AND LIMIT REFERENCE POINT

CONTEXT

Fisheries and Ocean Canada's (DFO) Sustainable Fisheries Framework requires the development of Limit Reference Points (LRPs) for key regional fisheries. DFO Science Advice concerning LRP development for the Eastern Canada-West Greenland (ECWG) bowhead whale population is requested.

Aerial surveys cannot cover Canada's vast geographic range of ECWG bowhead whales. The most recent management advice for the ECWG stock originates from aerial surveys conducted in 2013 that indicated an abundant population (DFO 2015). The aerial survey produced a partial population abundance estimate of 6,446 whales (CV = 26%) and results suggested that the population can support a total human-induced mortality of 52 whales annually (DFO 2015). More recent literature includes updated abundance estimates developed from genetic mark-recapture data (Frasier et al. 2020, Biddlecombe et al. 2023, 2025), and a proposed precautionary management approach for ECWG bowheads (Ferguson et al. 2021).

Canada's subsistence ECWG bowhead whale fishery operates under various agreements and regulations. Presently, the management approach lacks a precautionary framework that guides Reference Points (LRP and Upper Stock Reference point (USR) estimates) (DFO 2009). This information is crucial for DFO Resource Managers and Inuit wildlife co-management organizations in Nunavut and Nunavik. This Science Response Report is to aid in achieving departmental priorities, establishing sustainable harvest levels, and incorporate a precautionary approach within the Sustainable Fisheries Framework. The requested science review will serve as a foundation for co-management discussions, particularly focusing on including LRPs in Canada's subsistence ECWG bowhead whale fishery and considerations for the Integrated Fishery Management Plan. The Science Response Report comprehensively reviews published literature on ECWG abundance estimates and precautionary approaches, specifically examining LRPs.

This Science Response Report results from the Canadian Science Advisory Secretariat (CSAS) regional peer review held on January 27, 2025, on the Eastern Canada-West Greenland Bowhead Whale Population Abundance and Limit Reference Points.

Objectives

1. Review the following peer-reviewed publications on ECWG bowhead whale population with respect to sustainable management harvest strategies:
    - Frasier, T.R., Petersen, S.D., Postma, L., Johnson, L., Heide-Jørgensen, M.P., and Ferguson, S.H. 2020. Abundance estimation from genetic mark-recapture data when not all sites are sampled: an example with the bowhead whale. Global Ecol. Conserv. 22: e00903.

- o Biddlecombe, B.A., Ferguson, S.H., Heide-Jørgensen, M.P., Gillis, D.M., and Watt, C.A. 2023. Estimating abundance of Eastern Canada-West Greenland bowhead whales using genetic mark-recapture analyses. Global Ecol. Conserv. 45: e02524.
- o Biddlecombe, B., Heide-Jørgensen, M., Ferguson, S.H., Gillis, D., and Watt, C. 2025. Combining multiple data sources to model population dynamics of Eastern Canada-West Greenland bowhead whales. J. Environ. Manage. 389(2025): 126183.
- o Ferguson, S.H., Higdon, J.W., Hall, P.A., Hansen, R., and Doniol-Valcroze. T. 2021. Developing a precautionary management approach for the Eastern Canada-West Greenland population of bowhead whales (*Balaena mysticetus*). Front. Mar. Sci. 8: 709989.

2. Provide recommendations and conclusions related to LRP and management approach.

BACKGROUND

Bowhead whales (*Balaena mysticetus* L., 1758) in the ECWG population have been hunted by Inuit communities for centuries (NWMB 2000), spanning from the central Canadian Arctic Archipelago to the west coast of Greenland (Figure 1). Following a commercial whaling era that ended around 1915 due to economic extinction, a co-managed subsistence harvest has occurred sporadically since 1996 in Canada and from 2009 to 2017 in Greenland. The population rebounded after near extirpation, prompting the need for a harvest management framework that integrates abundance trends, population dynamics, and environmental relationships.

The ECWG bowhead whale population is traditionally harvested by Inuit communities in Canada (Nunavut, Nunavik) and Greenland. Over time, the allocation of licenses for Canadian bowhead whale hunts has increased with improved stock assessment information, with the Nunavut quota rising from one every 2–3 years before 2007 to five per year in 2015, distributed across different regions. These decisions accounted for two possible takes by Nunavik whalers (maximum four strikes) and two in West Greenland. However, not every allocated license has been utilized, highlighting a need for more effective management strategies (Higdon et al. 2023). For example, the existing co-management framework in Canada lacks a specific management scenario incorporating an LRP for ECWG bowhead whales.

To address this gap, DFO has sought Science Advice to evaluate the feasibility and sustainability of implementing an LRP-based management plan for Inuit subsistence harvests in Nunavut and Nunavik. This summary focuses on recent peer-reviewed publications articulating such a management plan, providing an overview and critical assessment of the relevant information. DFO remains committed to establishing an evidence-based approach to evaluate co-management measures, including precautionary strategies defining LRP or threshold abundance estimates to regulate anthropogenic mortality (DFO 2006), ensuring the conservation and protection of the ECWG bowhead whale population.

The analysis of current anthropogenic mortality sources, including harvest, struck and lost incidents, fishing gear entanglements, and vessel strikes (see Ferguson et al. 2021; detailed in Table 2), indicates that between 1996 and 2020, a total of 50 bowhead whales were killed, with 11 in West Greenland and 39 in Canada, including three bycatch incidents from crab traps and four struck and lost whales. Harvest levels in recent years averaged 3.3 whales per year between 2008 and 2019, lower than the recommended human-induced mortality of 52 based on the Potential Biological Removal (PBR; Wade 1998, DFO 2015).

Various factors, including habitat alterations, changes in prey availability, and increased natural mortality, can significantly impact bowhead whale abundance, distribution, and stock structure

(COSEWIC 2009). The loss of Arctic sea ice is expected to result in heightened marine vessel activity, associated with tourism, industrial development, commercial fishing, mining, and hydrocarbon exploration. This increase in vessel traffic introduces growing threats to bowhead whales, including acoustic disturbances, potential harm to critical habitat areas, and an elevated risk of vessel strikes in key migration corridors such as Hudson Strait, Lancaster Sound, Davis Strait, and Baffin Bay (Halliday et al. 2022).

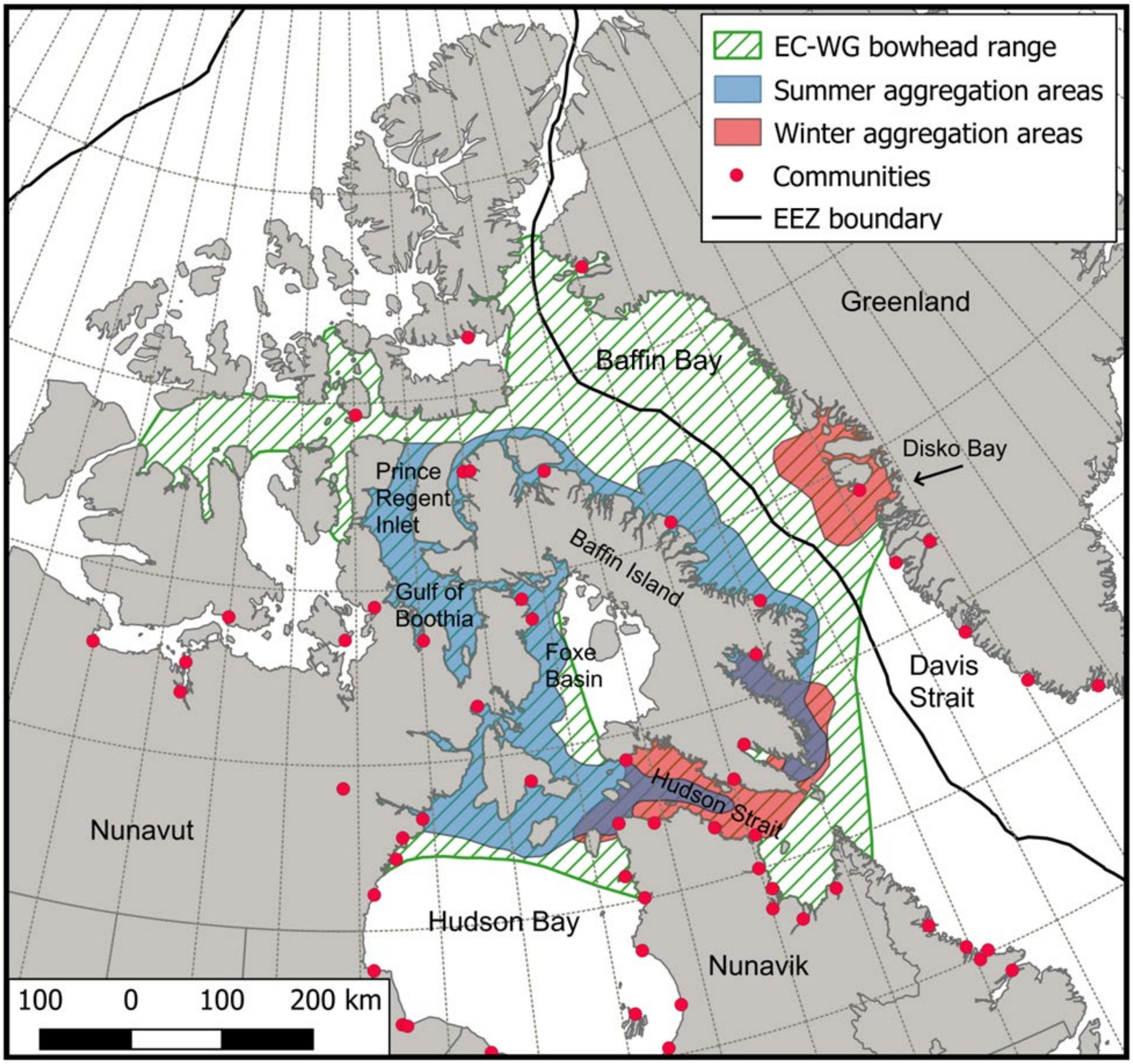

Figure 1. Approximate geographic range of the Eastern Canada-West (EC-WG) Greenland bowhead whale population, with important aggregation areas during the open-water ("summer") and ice- covered ("winter") seasons (from Ferguson et al. 2021). EEZ boundary is the Exclusive Economic Zone boundary prescribed by the United Nations Convention on the Law of the Sea.

As specialized filter feeders, bowhead whales face potential physiological risks such as fouling of baleen plates by fuel oil or entanglement in nets or debris. Additionally, the warming of the Arctic is anticipated to alter the food web, favoring smaller and leaner zooplankton species. This shift may require bowhead whales, which specialize in zooplankton, to adapt to changes in food quality and availability.

ANALYSIS AND RESPONSE

The ECWG bowhead whale population has substantially increased since its near extirpation, necessitating a robust harvest management framework that safeguards the population while providing subsistence value to Inuit communities. The current PBR calculation is based on a single abundance estimate from the 2013 aerial survey, and suggests that the ECWG bowhead whale population can sustain a total human-induced mortality of 52 whales annually while reaching or remaining at maximum productivity. However, relying on a single abundance estimate for PBR threshold calculation has limitations. To address uncertainties and varying management objectives, a Precautionary Approach framework providing sustainable harvest advice for the ECWG bowhead population was developed, integrating knowledge of abundance trends, population dynamics, and carrying capacity (Ferguson et al. 2021). Historical catch data and modeling were employed to estimate a pre-commercial exploitation or carrying capacity, providing reference points and stock status zones within the Precautionary Approach framework for formal decision-making in population management in Canada. We review this information below:

Genetic Mark-Recapture Analyses

Estimating population abundance typically relies on two primary methods: distance sampling or mark-recapture analysis (Rekdal et al. 2015). Mark-recapture studies employ various individual identification techniques, and the use of genetic data for this purpose has become increasingly common. Genetic mark-recapture analyses can sometimes surpass traditional methods, such as aerial surveys, in efficiency for monitoring populations (Koski and Ferguson 2012).

Mark-recapture analysis is a method employed to estimate population abundance by marking individuals in an initial capture event and then recording the proportion of recaptured animals in subsequent events (Koski and Ferguson 2012). The total population size is estimated by comparing the proportion of recaptures to the number of initially marked individuals (Jolly 1965, Seber 1965). The challenge lies in ensuring that all individuals have an equal probability of capture, especially in populations with a large geographic distribution. While sampling throughout the distribution can address this, individual and species-wide traits may still present challenges or biases in sampling. In situations where the entire range cannot be sampled or populations are large, the Cormack-Jolly-Seber method (Cormack 1964) becomes useful, addressing the fact that sampling occurs only in a relatively small portion of the population's range, while still assuming equal probability of capture (Schwarz and Arnason 2009).

Genetic data, often using microsatellite genotypes, aids in identifying individuals for mark-recapture analyses. Microsatellites are short sections of repeating base pairs with a high mutation rate, leading to high genetic diversity. This allows for the identification of distinct individuals within the same species using multiple microsatellite loci. While using microsatellite markers for mark-recapture analyses provides the benefit of remote capture, it comes with potential errors in identifying unique individuals. To overcome this, a certain number of mismatches are typically allowed when determining if multiple samples are from a single individual (Frasier et al. 2015).

Recent genetic mark-recapture analyses of the ECWG bowhead whale population were conducted to estimate annual abundance from 1995 to 2013 (Frasier et al. 2020) and from 2012 to 2021 (Biddlecombe et al. 2023). These analyses used an analytical technique that accounted for unsampled locations, providing a more accurate abundance estimate when sampling all sites was not possible, and are reviewed below.

Bayesian Analysis of Genetic Mark-Recapture to Estimate ECWG Bowhead Whale Abundance (Frasier et al. 2020)

A key challenge in mark-recapture studies is the need to effectively sample all individuals within a population. Many populations, however, are unevenly and widely distributed, making comprehensive sampling logistically unfeasible. To address this, Frasier et al. (2020) developed a Bayesian analytical technique that accounts for unsampled locations and infers the presence of "missing" individuals, enabling more accurate abundance estimates.

The method was validated using simulations to estimate abundance of the ECWG bowhead whale population based on microsatellite data from 1,177 samples collected over 19 years (1995-2013) (Figure 2). Bayesian methods were employed to analyze genetic mark-recapture data. The approach combined location-specific abundance estimates with knowledge of movement rates from telemetry data to infer sighting histories, including for unsampled locations. The analysis estimated this population to comprise 11,747 individuals during the sampling period (1995-2013), with a 95% highest density interval of 8,169–20,043 (Table 1).

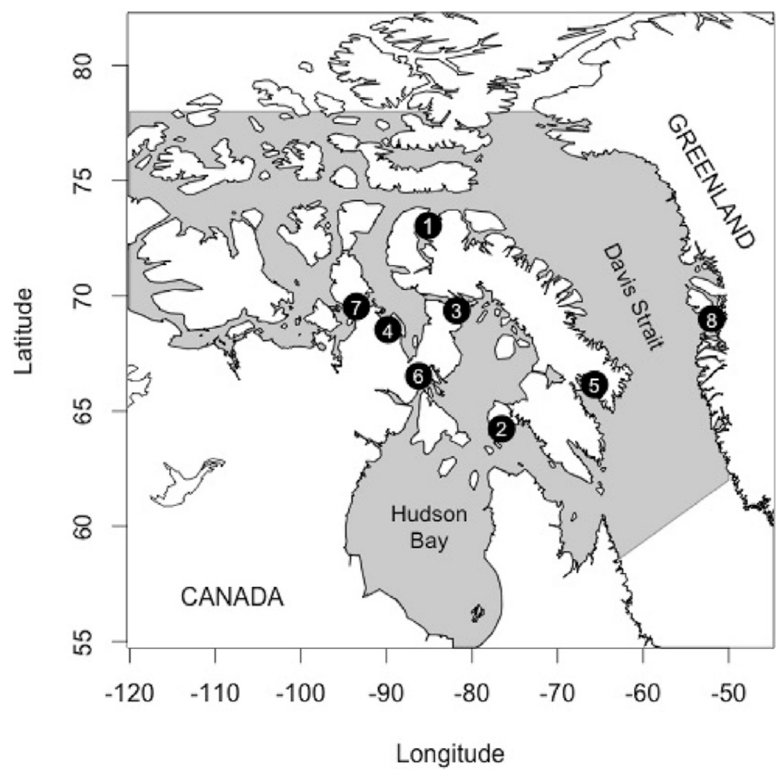

Figure 2. Distribution and sampling locations used to estimate abundance of the eastern Arctic bowhead population via genetic capture-recapture analysis. Sampling locations are numbered as follows: 1) Arctic Bay, 2) Cape Dorset, 3) Igloolik, 4) Kugaaruk, 5) Pangnirtung, 6) Repulse Bay, 7) Taloyoak, and 8) Disko Bay (from Frasier et al. 2020).

Simulations demonstrated the model's robust performance across a range of population sizes and sampling efforts, recovering accurate total abundance estimates even when one or more locations were unsampled. Simulation results suggest that sampling approximately 15% of individuals at each location is optimal, as further intensive sampling yields diminishing returns.

However, the model's performance declined when abundances and/or movement rates among sampled locations were not representative of unsampled ones based on simulation results.

When applied to the bowhead whale data, the method performed well despite low recapture rates, which resulted from sampling a widely distributed population. Location-specific estimates for sampled areas were consistent with previously published aerial survey estimates. Overall, this approach offers a potentially more accurate and efficient means for assessing and monitoring the ECWG bowhead whale population, and potentially other populations, compared to aerial surveys.

Table 1. Abundance estimates (modes of the posterior probabilities) and 95% highest density intervals (HDI) for major sample locations and the total population. Total-LS refers to the abundance estimate for the total population based on inference from the location-specific analyses and Total-LI refers to estimates based on the location-independent analyses (from Frasier et al. 2020).

	Full Data Set		5 Years of Data	
Location	**Estimate**	**95% HDI**	**Estimate**	**95% HDI**
Greenland	2,615	1,353–6,114	2,089	928–5,748
Igloolik	4,201	2,952–6,252	2,571	1,698–4,024
Pangnirtung	2,378	1,491–4,203	2,852	1,210–7,868
Repulse Bay	35	20–90	NA	NA
“Missing”	449	0–8,297	4,111	179–19,721
Total-LS	11,747	8,169–20,043	13,899	7,782–30,602
Total-LI	11,682	8,620–16,014	6,877	4,828–11,477

Recent Genetic Mark Recapture Population Abundance Estimates (Biddlecombe et al. 2023)

Biddlecombe et al. (2023) used genetic samples of ECWG bowhead whales in mark-recapture models to estimate population abundance from 2012–2021, approximately 100 years after the end of commercial bowhead whaling. Capture histories were analyzed using the Cormack-Jolly-Seber model (CJS) to estimate year-specific values for survival and capture probabilities, which were then used to estimate annual population abundance. The Jolly-Seber (JS) model was used to estimate a single abundance estimate for the entire period and test model structure and results by regions (e.g., Pangnirtung) to assess model consistency and determine whether sampling location potentially affected model estimates. Models incorporating location-specific and combined data were compared, with the top model selected based on Akaike’s Information Criterion scores. The best models suggested limited change in population abundance during the study, supporting the conclusion that growth may have plateaued.

Overall, 1,165 unique genetic samples were used in the analyses, with 92 recaptures. The preferred JS model provided a 2017 estimated (midpoint of 2012–2022) total abundance of

5,173 individuals (95% confidence interval, CI: 3,436–7,788), suggesting population growth may plateau below pre-whaling carrying capacity.

Movement data from satellite telemetry indicated whales traveled widely across their range, supporting the assumption of equal capture probability, though estimates may be slightly low due to juvenile capture bias. Juvenile-biased captures near Pangnirtung and Igloolik raised concerns about age-related sampling biases that may be associated with population substructure. Body length data were analyzed to differentiate juveniles (< 10 m) from sub-adults and adults (≥ 10 m), but resolution limitations prevented finer age classification. A bias towards juveniles was quantified within genetic samples, and behaviourally, there may be some distinction between groups in the ECWG bowhead population, which may also lead to sampling bias. Notably, using only the Pangnirtung samples collected from 2012 to 2021 yielded an abundance estimate of 4,227 whales (CI: 2,771 to 6,447), reflecting the significant contribution of these samples (n = 877; 75.3%) to the overall population abundance estimate. However, for mark-recapture analyses, the large-scale interannual movement of sampled individuals and the presence of all age classes in captures allows the population to be analyzed as a whole. The divisions of sex and age in captures suggest that, although an awareness of biases in model estimates is necessary, the sample collection does not restrict model results to a single demographic group of the ECWG bowhead whale population.

Bayesian Stock Production Model combining aerial survey and genetic mark-recapture data (Biddlecombe et al. 2025)

Accurately estimating the abundance of bowhead whales in expansive areas through aerial surveys is complex (Doniol-Valcroze et al. 2020). To overcome this challenge, a Brownian bridge movement model (BBMM) was applied, using data from satellite-tagged bowhead whales (Biddlecombe et al. 2025). The BBMM enabled the calculation of the probability of occupancy within and outside areas surveyed during aerial surveys conducted in 1981, 2002, and 2013 (Figure 3). By establishing a relationship between the probability of occupancy and abundance in surveyed areas through Quasi-Poisson regression, this relationship was then used to extrapolate survey estimates into unsurveyed regions. Combining these extrapolated estimates with genetic mark-recapture abundance data from 2013 and 2017, and harvest history, a Bayesian stock production model provided a more developed approach.

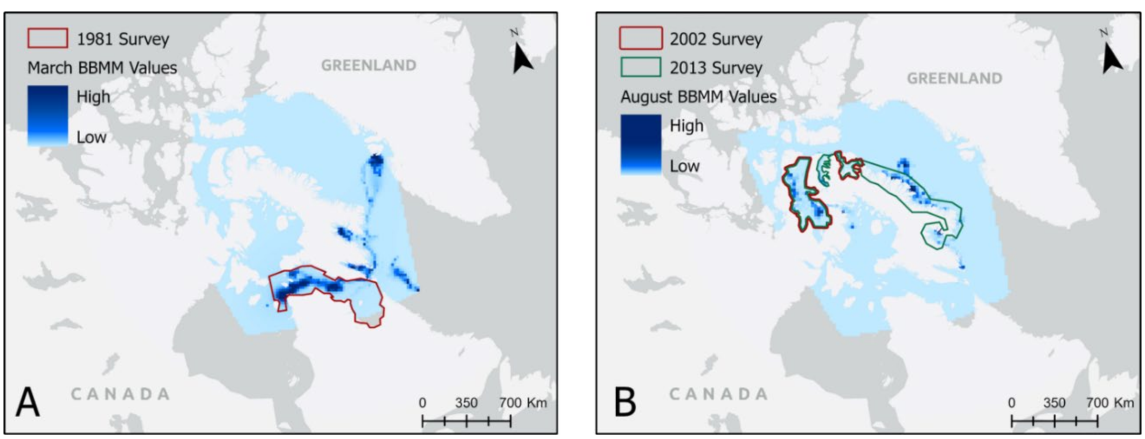

Figure 3. Relative probability density of occupancy for Eastern Canada-West Greenland bowhead whales based on telemetry in A) March with 1981 (red) aerial survey coverage and B) August with 2002 (red) and 2013 (green) aerial survey coverage (from Biddlecombe et al. 2025). Brownian bridge movement model (BBMM; blue gradient) values are the relative probability density of occupancy values, presented as relative high and low probabilities.

During the March 1981 survey (Koski et al. 2006), approximately 32% of high-occupancy regions were covered, with the highest BBMM values observed within the surveyed areas. The August 2002 survey covered approximately 33% of high-occupancy regions, and the August 2013 survey covered approximately 77% of high-occupancy regions, including those with the highest BBMM values. Using the regression equation, extrapolation of aerial survey estimates led to adjustments in the 1981 estimate from 1,549 to 2,898 individuals, the 2002 estimate from 6,344 to 7,822 individuals, and the 2013 estimate from 6,446 to 7,592 individuals.

The ECWG bowhead whale stock production model reconstructed the population trajectory from 1915 to 2022 (Figure 4). Using adjusted aerial survey estimates from 1981, 2002, and 2013, along with genetic mark-recapture estimates from 2013 and 2017, the model produced results with Bayesian Credible Intervals (BCI). Unlike frequentist confidence intervals, which describe the behavior of intervals over repeated sampling, BCIs directly state the probability that the parameter lies within a given range. The prior for θ (shape parameter) was set as a uniform distribution ranging from 1-5 following Ferguson et al. (2021), as values from 1-5 represent a range in density dependence that results in maximum sustainable yield levels assumed for baleen whales (Witting 2013). All model diagnostics indicated a suitable fit and the posterior for θ was 2.86 (standard error = 1.18). The starting population in 1915 was estimated at 816 whales (95% credible interval; BCI 225–4,206), and the estimate for 2022 was 8,150 whales (95% BCI 6,150–10,823). Carrying capacity (K) was estimated as 10,202 (95% BCI 6,367–23,013), and the estimated maximum growth rate (R_{max}) was 0.028 (95% BCI 0.020–0.044) or 2.8%. The model's outcomes suggest that the ECWG bowhead whales have been consistently recovering since the cessation of commercial whaling and have surpassed the point of maximum productivity, leading to a slowdown in recent years.

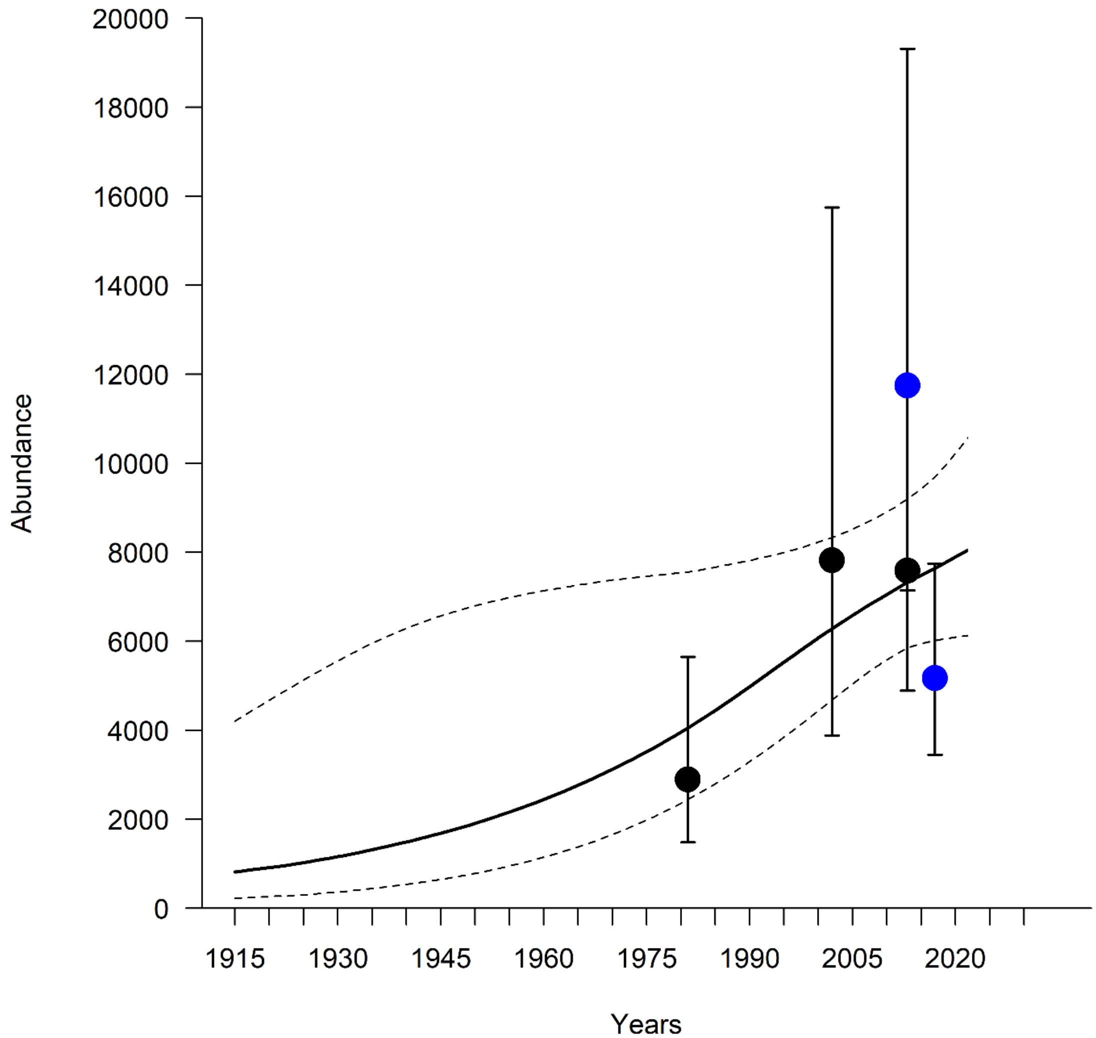

Figure 4. Eastern Canada-West Greenland bowhead whale abundance based on population estimates from a Bayesian stochastic stock production model fitted to extrapolated aerial survey estimates flown in 1981, 2002, and 2013 (black dots ± 95% log-normal Bayesian Credible Interval, BCI), and genetic mark recapture estimates from 2013 and 2017 (blue dots ± 95% log-normal BCI). The solid line indicates the posterior median estimates and dashed lines show 95% credible intervals (from Biddlecombe et al. 2025).

Proposed Precautionary Approach Framework (Ferguson et al. 2021)

The Precautionary Approach serves as a crucial tool for addressing uncertainty in whale management in Canada, aligning with domestic legislation (e.g., *Fisheries Act*). The formal approach provides decision-making rules for managers dealing with scientific uncertainty in fisheries management, highlighting the need for its broader application to guide decisions based on multiple objectives for marine mammal species (Stenson et al. 2012). This ensures species protection from potential threats, fostering international cooperation and collaboration.

The stock assessment conducted by Ferguson et al. (2021) for the ECWG bowhead whale population incorporated historical harvest levels, data from three aerial surveys, genetic mark-recapture analysis, and information on fecundity and/or survival from a genetically similar population. Indigenous and commercial harvest data were used to estimate a plausible historical population size, forming the basis for establishing reference levels consistent with Canadian practices for marine mammals (Stenson et al. 2012).

Over the past four decades, varying survey approaches have complicated comparisons and trend assessments (Figure 5). Aerial surveys in 1981, 2002, and 2013 yielded abundance estimates ranging from 1,549 to 6,446 whales. A genetic mark-recapture analysis estimated a total population abundance of 11,747 whales in 2013 (final year of the full dataset, 1995–2013), incorporating unsampled locations.

The trend in abundance estimated by the deterministic model, with R_{max} ranging from 0.038 to 0.040 and the struck and lost factor between 1.10 and 1.15, aligned with historical catch data, providing a reasonable pre-commercial whaling estimate of approximately 18,500 whales. This estimate formed the basis for developing a Precautionary Approach.

To establish a Precautionary Approach framework for the ECWG bowhead whale population, historical carrying capacity served as a basis ($N_{k,}$ estimated by Higdon and Ferguson 2016), with reference points proposed for the LRP (30% of N_k or N_{30}) and USR (50% of N_k or N_{50}) delineating Healthy, Cautious, and Critical stock status zones, as well as a Target Reference Point (N_{70}).

Figure 5. Eastern Canada-West Greenland bowhead whale population trajectory from a logistic population growth model estimated using historical catch data, paired with more recent estimates. Model results with a modified density-dependent shape parameter (γ) constrained between 1.8 and 1.9 and with R_{max} (maximum growth rate) constrained between 3.8-4.0 (Higdon and Ferguson 2016). Black circles represent aerial survey estimates and blue triangle represents the genetic mark-recapture method (reproduced from Ferguson et al. 2021). Dash lines represent the 95% confidence intervals and the dotted line is the estimated abundance trajectory, excluding the blue (triangle) genetic model.

Ferguson et al. (2021) assessed past and current trends of the ECWG population using a deterministic logistic growth model to approximate carrying capacity and develop a Precautionary Approach management framework with reference points and corresponding stock status zones (Table 2). This analysis can then guide management advice based on the population's current status relative to established benchmarks. When applied to the abundance estimates available at the time of Ferguson et al. (2021), this framework suggested that the population was likely within their proposed “Healthy Zone”. The Precautionary Approach is endorsed for both environmental and fisheries management, with organizations such as DFO, the North Atlantic Marine Mammal Commission, and the International Whaling Commission advocating its use. The Precautionary Approach concept emphasizes corrective measures in situations of significant risk, considering scientific uncertainty and climate change impact.

Table 2. Stock status zones and reference points proposed for a Precautionary Approach to management of the Eastern Canada-West Greenland bowhead whale population, based on historical (pre-commercial exploitation) population abundance (Higdon and Ferguson 2016). N_k is the carrying capacity.

Stock Status Zone	Reference Point	Abundance (% of historical maximum N_k = 18,500)	Proposed Management Strategy
Healthy	–	9,250 (50% of N_k) to 18,500 (N_k)	Include ecosystem and socio-economic considerations. Anthropogenic removals in line with management objectives.
Cautious	Upper Stock Reference	9,250 (50% of N_k)	Measures required to promote population growth above Upper Stock Reference.
Critical	Limit Reference Point	Below 5,500 (30% of N_k)	Actions must promote stock growth. Rebuilding Plan developed.

CONCLUSIONS

In establishing reference points for the ECWG bowhead whale population, the historical population size is often crucial, serving as a measure of carrying capacity. The Precautionary Approach framework considers catch statistics and aligns them with a time series of abundance estimates. The 2013 ECWG bowhead population estimate of 6,446 (DFO 2015) falls within the N_{30} to N_{50} Zone, categorizing it as "Cautious" based on Ferguson et al. (2021). Using the updated abundance estimate from Biddlecombe et al. (2025), the 2022 abundance estimate of 8,150 whales also falls within this “Cautious” Zone. This result differs from the conclusion of Ferguson et al. (2021) who had used higher abundance estimates from a deterministic model (10,968 whales; Higdon and Ferguson 2016) and from the genetic mark-recapture (11,747 whales; Frasier et al. 2020) to conclude that the population was in the proposed “Healthy Zone” in Ferguson et al. 2021. Moreover, the possibility that carrying capacity has decreased is discussed in Biddlecombe et al. (2025) and has significant ramifications for the prescribed Precautionary Approach.

The limitations of aerial surveys in estimating total abundance are evident, with over 1,000 whales added to each survey estimate (Biddlecombe et al. 2025). Methodological variations across multiple surveys introduce uncertainties, especially regarding availability bias adjustments for the 1981 survey. The Bayesian stock production population model used by Biddlecombe et al. (2025) is an improvement over past models (Ferguson et al. 2021) because it accommodates survey error and uncertainties from differences in survey design and adjustments.

However, as with all approaches, the genetic mark-recapture approach has its limitations, including possible sampling bias, genotyping errors, violation of the closed population assumption, and temporal variation (Pearse et al. 2001).

Aerial survey and genetic mark-recapture estimates suggest a plateau in population growth from 2002 onwards, aligning with the recent model's estimated trajectory, indicating a leveling off of abundance (Biddlecombe et al. 2025). Recently, reports suggest increased killer whale predation (Young et al. 2020) and possible poor body condition in some years leading to mortality events (Barratclough et al. 2025). Using the Precautionary Approach from the Stock Production Model (Biddlecombe et al. 2025), current Inuit harvest levels have minimal impact on the risk of population decline.

The uncertainties in anthropogenic-caused mortalities and demographic parameters make estimating reference points challenging, emphasizing the need for continued monitoring and adaptive management. The rebound of the ECWG bowhead whale population, while steady since the cessation of commercial whaling, faces potential challenges from climate change, anthropogenic stressors, and other threats, necessitating a comprehensive and adaptive management approach (de Greef et al. 2024).

Management Considerations

Key management considerations for the ECWG bowhead whale population include:

- Population Abundance Estimation: Updated abundance estimates will aid in refining stock production models, thereby increasing the accuracy of population dynamics and projections.
    - It is recommended to update the population abundance estimate for ECWG bowhead whales using the genetic mark-recapture method. A more accurate and recent estimate that includes samples from diverse regions will contribute to well-informed management decisions and sustainable harvest practices. Incorporating recent genetic samples from biopsy sampling programs in Canada and Greenland is advised to enhance the precision of the estimate.
    - Continuing aerial surveys for abundance estimates is useful. However, efforts should be made to improve survey design, such as conducting winter surveys when the whales are concentrated in a smaller region as defined by telemetry. Utilization distribution based on telemetry results can be used to ensure comprehensive coverage of occupied regions.
    - Future analysis of a developing photo-identification catalogue of the ECWG bowhead whale population will provide an additional independent estimation of abundance and should be pursued. Currently, 559 whales are considered marked, and annual surveys have been conducted since 2016 to provide the recaptures necessary to make this calculation possible.

Monitoring the population's stability is crucial, especially as it may have already reached carrying capacity. If the next population abundance estimate continues to support a lack of trend indicating a population near carrying capacity, then the Precautionary Approach outlined here should be amended to account for a possible lower population carrying capacity. This comprehensive approach, combining updated abundance estimates, improved survey methodologies, and international collaboration, aims to contribute to the effective conservation and management of the ECWG bowhead whale population.

Reference Point Recommendations

It is recommended to adopt the LRP and proposed USR, as outlined in Ferguson et al. (2021), based on an estimated pre-commercial whaling carrying capacity of 18,500 whales (Higdon and Ferguson 2016). In addition, we recommend using the most recent abundance estimate from the Bayesian stock production model of 8,150 whales (95% BCI 6,150-10,823) in 2022 (Biddlecombe et al. 2025), which places the population in the “Cautious Zone” (between 5,500 and 9,250 whales). However, the uncertainty around this abundance estimate (credible interval), as well as the possibility that carrying capacity is lower than historical estimates, indicates that the population could be in the “Healthy Zone” (but not in the “Critical Zone”). In the “Cautious Zone”, the recommended management strategy is to promote population growth above the LRP (5,500 whales) towards the proposed USR (9,250 whales).

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SOURCES OF INFORMATION

Barratclough, A., Young, B.G., Thiemann, G.W., Higdon, J.W., Raverty, S., Houde, M., Matthews, C.J.D., Dominguez-Sanchez, C., and Ferguson, S.H. 2025. Bowhead whale mortality event in Nunavut, Canada - Autumn, 2020. J. Cetacean Res. Manage. 26: 21-40.

Biddlecombe, B.A., Ferguson, S.H., Heide-Jørgensen, M.P., Gillis, D.M., and Watt, C.A. 2023 Estimating abundance of Eastern Canada-West Greenland bowhead whales using genetic mark-recapture analyses. Global Ecol. Conserv. 45: e02524.

Biddlecombe, B., Heide-Jørgensen, M., Ferguson, S.H., Gillis, D., and Watt, C. 2025. Combining multiple data sources to model population dynamics of Eastern Canada-West Greenland bowhead whales. J. Environ. Manage. 389: 126183.

Cormack, R.M. 1964. Estimates of survival from the sighting of marked animals. Biometrika 51(3/4): 429–438.

COSEWIC. 2009. COSEWIC assessment and update status report on the Bowhead Whale *Balaena mysticetus*, Bering–Chukchi–Beaufort population and Eastern Canada-West Greenland population, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 49 pp.

de Greef, E., Müller, C., Thorstensen, M.J., Ferguson, S.H., Watt, C.A., Marcoux, M., Petersen, S.D., and Garroway, C.J. 2024. Unraveling the genetic legacy of commercial whaling and population dynamics in Arctic bowhead whales and narwhals. Global Change Biol. 30(10): e17528.

DFO. 2006. A Harvest Strategy Compliant with the Precautionary Approach. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2006/023.

DFO. 2009. A fishery decision-making framework incorporating the precautionary approach. Fisheries and Oceans Canada, Ottawa, ON. (accessed December 2024).

DFO. 2015. Updated abundance estimate and harvest advice for the Eastern Canada-West Greenland bowhead whale population. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/052.

Doniol-Valcroze, T., Gosselin, J-F., Pike, D.G., Lawson, J.W., Asselin, N.C., Hedges, K.J., and Ferguson, S.H. 2020. Distribution and abundance of the Eastern Canada – West Greenland bowhead whale population based on the 2013 High Arctic cetacean survey. NAMMCO Sci. Publ. 11: 13 p.

Ferguson, S.H., Higdon, J.W., Hall, P.A., Hansen, R.G., and Doniol-Valcroze, T. 2021. Developing a precautionary management approach for the Eastern Canada-West Greenland population of bowhead whales (*Balaena mysticetus*). Front. Mar. Sci. 8: 709989.

Frasier, T.R., Petersen, S.D., Postma, L., Johnson, L., Heide-Jørgensen, M.P., and Ferguson, S.H. 2015. Abundance estimates of the Eastern Canada-West Greenland bowhead whale (*Balaena mysticetus*) population based on genetic capture-mark-recapture analyses. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/008. iv + 21 p.

Frasier, T.R., Petersen, S.D., Postma, L., Johnson, L., Heide-Jørgensen, M.P., and Ferguson, S.H. 2020. Abundance estimation from genetic mark-recapture data when not all sites are sampled: an example with the bowhead whale. Global Ecol. Conserv. 22: e00903.

Halliday, W.D., Le Baron, N., Citta, J.J., Dawson, J., Doniol-Valcroze, T., Ferguson, M., Ferguson, S.H., Fortune, S., Harwood, L.A., Heide-Jørgensen, M.P., Lea, E.V., Quakenbush, L., Young, B.G., Yurkowski, D., and Insley, S.J. 2022. Overlap between bowhead whales (*Balaena mysticetus*) and vessel traffic in the North American Arctic and implications for conservation and management. Bio. Conserv. 276: 109820.

Higdon, J.W., and Ferguson, S.H. 2016. Historical abundance of Eastern Canada - West Greenland (ECWG) bowhead whales (*Balaena mysticetus*) estimated using catch data in a deterministic discrete-time logistic population model. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/023. v + 26 p.

Higdon, J.W., Young, B.G., and Ferguson, S.H. 2023. Evaluation of a Provision to Carry Over Unused Licences for Eastern Canada-West Greenland Bowhead Whales (*Balaena mysticetus*) in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2023/051. iv + 23 p.

Jolly, G.M. 1965. Explicit estimates from capture-recapture data with both death and immigration-stochastic model. Biometrika. 52(1/2): 225–247.

Koski, W.R., and Ferguson, S.H. 2012. Review of Methods for Eastern Canada-Western Greenland Bowhead Whale (*Balaena mysticetus*) Population Abundance Estimation. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/017. iv + 23 p.

NWMB (Nunavut Wildlife Management Board). 2000. Final report of the Inuit bowhead knowledge study, Nunavut, Canada. Nunavut Wildlife Management Board, Iqaluit, NU: 101 p.

Pearse, D.E., Eckerman, C.M., Janzen, F.J., and Avise, J.C. 2001. A genetic analogue of 'mark–recapture' methods for estimating population size: an approach based on molecular parentage assessments. Mol. Ecol. 10(11): 2711-2718.

Rekdal, S.L., Hansen, R.G., Borchers, D., Bachmann, L., Laidre, K.L., Wiig, Ø., Nielsen, N.H., Fossette, S., Tervo, O., and Heide-Jørgensen, M.P. 2015. Trends in bowhead whales in West Greenland: aerial surveys vs. genetic capture-recapture analyses. Mar. Mamm. Sci. 31(1): 133-154.

Seber, G.A. 1965. A note on the multiple-recapture census. Biometrika. 52(1/2): 249–259.

Schwarz, C.J., and Arnason, A.N. 2009. Chapter 12 - Jolly-Seber models in MARK. *In* Program MARK: a gentle introduction (edition 8). Edited by E.G. Cooch and G.C. White. Colorado State University, Fort Collins, CO. pp. 1-55.

Stenson, G.B., Hammill, M., Ferguson, S., Stewart, R., and Doniol-Valcroze, T. 2012. Applying the Precautionary Approach to Marine Mammal Harvests in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/107. ii + 15 p.

Wade, P.R. 1998. Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. Mar. Mamm. Sci. 14(1): 1–37.

Witting, L. 2013. Selection-delayed population dynamics in baleen whales and beyond. Pop. Ecol. 55: 377-401.

Young, B.G., Fortune, S.M., Koski, W.R., Raverty, S.A., Kilabuk, R., and Ferguson, S.H. 2020. Evidence of killer whale predation on a yearling bowhead whale in Cumberland Sound, Nunavut. Arctic Sci. 6(1): 53-61.

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