From: NTI Wildlife & Environment

Subject: Appendix 1 - Harvest Simulations (Sanikiluaq)

Date: January 10th, 2020

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1 General Assumptions

a. The seasonal distribution of the skin samples collected in Sanikiluaq represents the seasonal distribution of the entire Sanikiluaq Beluga harvest.

b. 84% of the Belugas harvested in Sanikiluaq are landed between April 1 and July 14. This represents the period of exposure of EHB Beluga.

c. The proportion of Eastern Hudson Bay (EHB) Beluga in the harvest is assumed to be 4.4% during this period (DFO 2018).

2 Methods

The bootstrap is a computer-based method for assigning measures of accuracy to sample estimates (Efron and Tibshirani 1994). We used the bootstrap (boot) package (version 1.3-18) in the R (version 3.3.1) language and enviornment for statistical computing and graphics to generate bootstrap replicates of a statistic (mean and median). One of the most important functions in the package is the boot function which implements resampling methods for independent and identically distributed observations. The boot function () can generate both nonparametric and parametric resampling. Nonparametic sampling was used. For the nonparametric bootstrap, resampling methods include ordinary, balanced, antithetic and permutation. The package was originally written as an S-Plus library (Angelo Canty). Subsequently the library was ported to R by Brian Ripley. The basic bootstrap in such cases works by fitting a distribution function $\hat{F}$ to the unknown population distribution F. The Monte Carlo bootstrap method then proceeds by taking R samples, of the same size as the original sample, from $\hat{F}$.

The boot.ci ( ) function in R takes a bootobject and generates 5 different types of two-sided nonparametric confidence intervals. These include the first order normal approximation, the basic bootstrap interval, the studentized bootstrap interval, the bootstrap percentile interval, and the adjusted bootstrap percentile (BCa) interval. The bias-corrected and accelerated bootstrap (BCa) by Efron (1987) is considered an improvement over previously suggested methods, which results in second-order correctness in a wide variety of problems. We report this interval.

Simulations were conducted for three harvest scenarios for the community of Sanikiluaq, NU. The first harvest scenario included harvest data from 1999–2018. The second harvest scenario included harvest data from 2010–2018. The third harvest scenario included harvest data from 2016–2018. For each scenario, we resampled from the harvest data with replacement. The number of resamples was set at 10,000. Confidence intervals were generated for each statistic. The measures of central tendency were then used to estimate the number of EHB Beluga landed in Sanikiluaq based on the assumptions as described in section 1 and by Fisheries and Oceans (DFO 2016, 2018).

3 Scenarios

3.1 Scenario 1

Table 1: Annual Beluga Harvest for 1999–2018 (data provided by DFO)

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Harvest	32	23	.	15	80	94	53	22	35	33

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Harvest	34	47	32	61	76	26	170	43	30	50

3.2 Scenario 2

Table 2: Annual Beluga Harvest for 2010–2018 (data provided by DFO)

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Harvest	47	32	61	76	26	170	43	30	50

3.3 Scenario 3

Table 3: Annual Beluga Harvest for 2016–2018 (data provided by DFO)

Year	2016	2017	2018
Harvest	43	30	50

4 Results

4.1 Bootstrap Mean

Table 4: Mean and 95% Confidence Intervals for Scenarios 1–3

Scenario	Simulation Type	Bootstrap replicates	Mean	95% Confidence Interval (BCa)
1 – (1999–2018)	Ordinary	10,000	50.32	38.84, 67.37
2 – (2010–2018)	Ordinary	10,000	59.44	41.11, 103.67
3 – (2016–2018)	Ordinary	10,000	41.00	30.00, 47.67

4.2 Bootstrap Median

Table 5: Median and 95% Confidence Intervals for Scenarios 1–3

Scenario	Simulation Type	Bootstrap replicates	Median	95% Confidence Interval (Norm)
1 – (1999–2018)	Ordinary	10,000	35.00	16.87, 45.20
2 – (2010–2018)	Ordinary	10,000	47.00	25.92, 67.90
3 – (2016–2018)	Ordinary	10,000	43.00	30.21, 58.71

4.3 Estimated Annual Number of EHB Beluga Landed in Sanikiluaq for Three Harvest Scenarios — Mean

Table 6: Estimated Annual Number of EHB Beluga Landed in Sanikiluaq for Three Harvest Scenarios

	Scenario 1	Scenario 2	Scenario 3
April 1–July 15	N=50.32	N = 59.44	N = 41.00
Seasonal distribution of harvest (proportion)	0.84	0.84	0.84
Total harvest by season	42.27	49.93	34.44
Proportion EHB	0.044	0.044	0.044
Total EHB	1.86	2.20	1.52
Rounded total	2	2	2

4.4 Estimated Annual Number of EHB Beluga Landed in Sanikiluaq for Three Harvest Scenarios — Median

Table 7: Estimated Annual Number of EHB Beluga Landed in Sanikiluaq for Three Harvest Scenarios

	Scenario 1	Scenario 2	Scenario 3
April 1–July 15	N=35.00	N = 47.00	N = 43.00
Seasonal distribution of harvest (proportion)	0.84	0.84	0.84
Total harvest by season	29.40	39.48	36.12
Proportion EHB	0.044	0.044	0.044
Total EHB	1.29	1.74	1.59
Rounded total	1	2	2

5 Summary

Bootstrapping was used to enable inference on the statistic of interest (mean and median) when the true distribution of the statistic is unknown. Confidence intervals were generated for the bootstrapped statistics (see tables 4 and 5). Figures 1 and 2 are plots of the sampling distribution of the means. The mean annual number of EHB beluga landed in Sanikiluaq for Scenarios 1–3 was between 1 and 3 and the rounded total average was 2. The mean annual median of EHB beluga landed in Sanikiluaq for all three scenarios was between 1 and 2 and the rounded total average was 2.

6 Figures

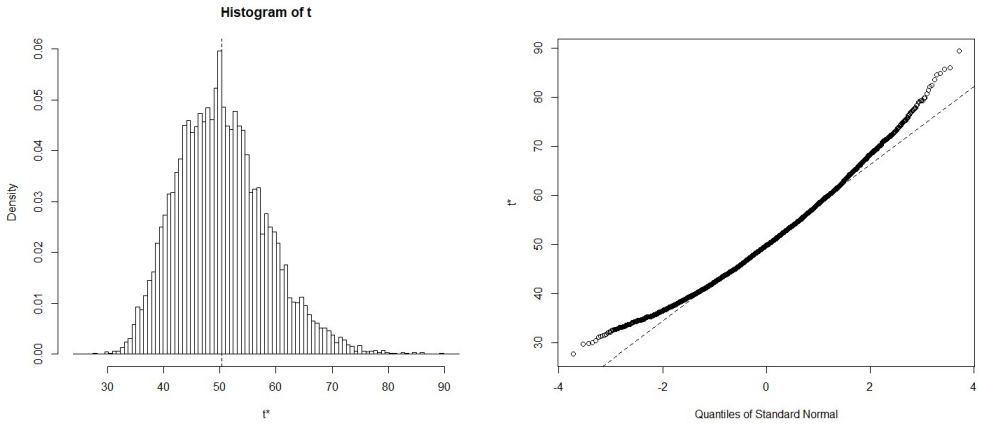

Figure 1: Scenario 1 — Plot of 10,000 resamples of harvest data (1999-2018) and Q-Q plot (Mean)

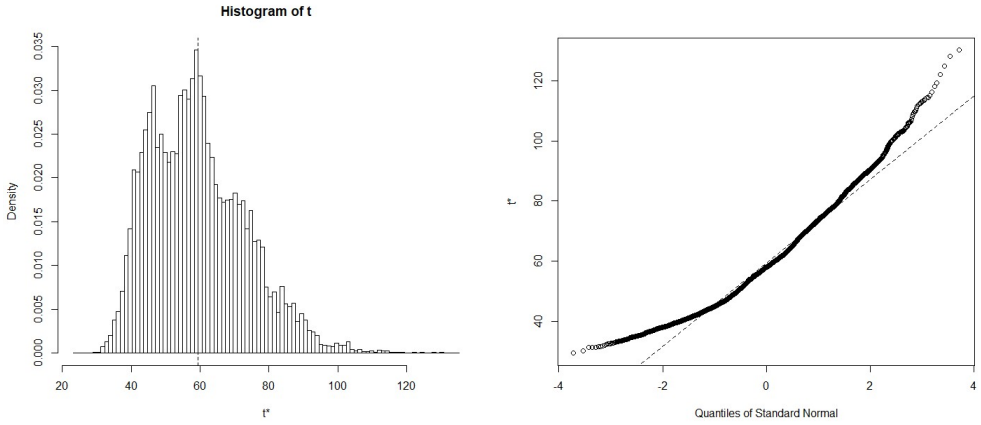

Figure 2: Scenario 2 — Plot of 10,000 resamples of harvest data (2010-2018) and Q-Q plot (Mean)

7 References

1. Davison, A. C. and Hinkley, D. V. Bootstrap Methods and Their Application. Cambridge, England: Cambridge University Press, 1997.

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3. DFO. 2018. Harvest advice for eastern and western Hudson Bay Beluga (*Delphinapterus leucas*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/008.

4. Doniol-Valcroze, T., Hammill, M.O., Turgeon, S. & Postma, L.D. 2016. Updated analysis of genetic mixing among Nunavik beluga summer stocks to inform population models and harvest allocation. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/008. iv + 13 p.

5. Efron, B. 1987. Better Bootstrap Confidence Intervals. Journal of the American Statistical Association, Vol.82, No. 397: 171–185.

6. Efron, B. and Tibshirani, R. J. An Introduction to the Bootstrap. Boca Raton, FL: CRC Press, 1994.