Notes on the analysis of the photo data for the Bluenose East herd calving ground survey 2018

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This report was originally circulated in November 9, 2018 immediately after the photo sightability analysis was completed. Subsequent to the initial analyses, the confidence limits on the estimates were updated (in February 2019) as a result of more recent analyses. The estimates themselves have not changed. The updated confidence intervals have been included in this report to ensure the most up to date information is available for management decisions.

This document contains initial notes on the Bluenose East photo data analysis and estimates from the entire survey. The estimates now account for photo sightability and supersede previous estimates.

Data summary

The basic statistics for the photo strata are given below. Strip width and coverage was based upon distances measured from ortho-photos rather than GSD levels. Interestingly, strip width was lower than that suggested by GSD (1.38km) and as a result coverage was slightly lower.

Table 1: Photo strata dimensions for the BNE survey

Strata	area	transects	Ave Transect length	baseline	Average Strip width	Area Surveyed (km^2)	Coverage
North Photo	3787.76	22	49.36	78.20	1.31	1402.4	37.0%
South Photo	2051.45	16	30.40	69.20	1.28	621.3	30.3%

The base count data is given in the table below. Overall, 5,297 caribou were counted on photos

Table 2: Raw photo counts including estimated strip widths and transect lengths

Line	Strata	lengthkm	strip_width	caribou	calves
1	NorthPhoto	14.35	1.6565	42	1
2	NorthPhoto	27.01	1.492	115	3
3	NorthPhoto	36.61	1.444	147	1
4	NorthPhoto	45.68	1.3845	154	0
5	NorthPhoto	54.04	1.3375	251	0
6	NorthPhoto	60.44	1.3205	230	0
7	NorthPhoto	63.92	1.3315	171	2
8	NorthPhoto	62.98	1.312	458	0
9	NorthPhoto	60.96	1.3085	318	0
10	NorthPhoto	58.76	1.319	283	2
11	NorthPhoto	58.85	1.292	228	1
12	NorthPhoto	58.74	1.263	254	0
13	NorthPhoto	58.68	1.333	146	0
14	NorthPhoto	58.66	1.2475	69	0
15	NorthPhoto	57.31	1.247	144	4
16	NorthPhoto	54.91	1.2015	76	1
17	NorthPhoto	50.95	1.201	27	0
18	NorthPhoto	50.16	1.199	85	0
19	NorthPhoto	43.40	1.2015	171	4
20	NorthPhoto	39.89	1.203	155	2
21	NorthPhoto	36.52	1.195	62	3
22	NorthPhoto	33.05	1.238	66	0
23	SouthPhoto	30.27	1.2205	105	5
24	SouthPhoto	30.15	1.2265	182	8
25	SouthPhoto	30.13	1.2255	136	0
26	SouthPhoto	29.96	1.2565	156	3
27	SouthPhoto	30.22	1.2695	278	13
28	SouthPhoto	30.67	1.2675	193	7
29	SouthPhoto	30.90	1.292	144	1
30	SouthPhoto	31.29	1.2905	82	0
31	SouthPhoto	31.40	1.327	61	0
32	SouthPhoto	32.03	1.301	63	0
33	SouthPhoto	33.27	1.254	46	0
34	SouthPhoto	34.90	1.254	44	0
35	SouthPhoto	31.87	1.2535	37	1
36	SouthPhoto	29.21	1.3265	23	0
37	SouthPhoto	26.42	1.3255	52	0
38	SouthPhoto	23.78	1.376	43	0
				5297	

A plot of counted caribou on each transect line suggests that distribution of caribou counted on photos was also indicated by collar locations.

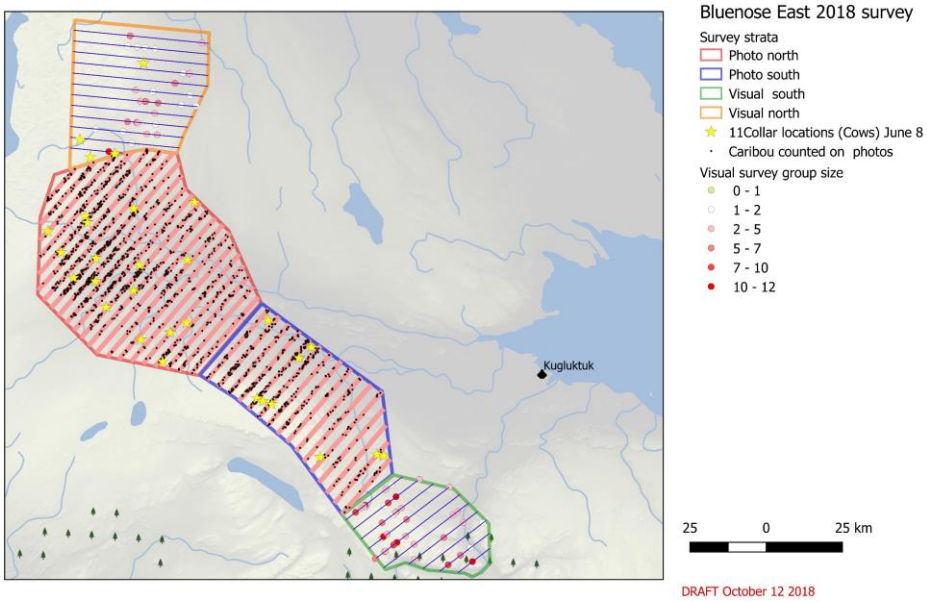

Figure 1: A plot of the photo data counts and visual survey results with collar locations on June 8 when surveys occurred.

Photo sightability estimation

Sightability of caribou on photos was estimated by having a 2nd party independently recount caribou on a subset of photos. The photo survey transect lines were resampled systematically using transects perpendicular to the original photo-plane transects. The second phase design from the Bathurst, which sampled the closest photo to the transect line in which at least one caribou was detected, was used to select photos for resampling. Using this approach still allowed a systematic sampling approach while ensuring an adequate sample size of useful photos (that had caribou on them) for resampling. The figure below shows the photo resampling design.

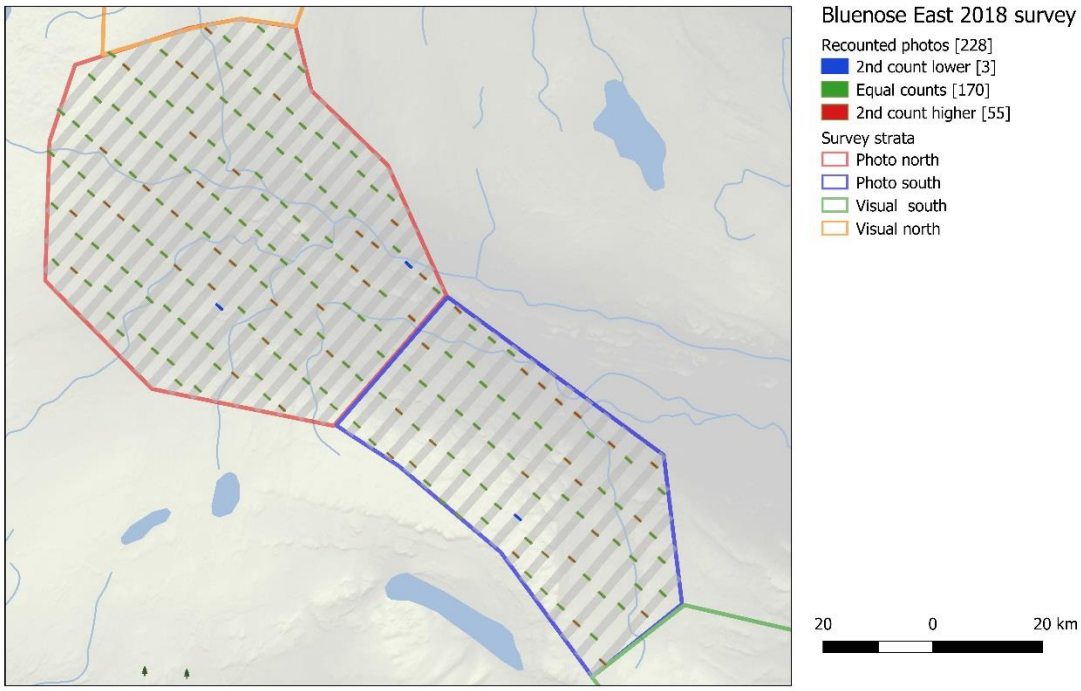

Figure 2: Systematic sampling design for cross validation of photos for the Bluenose East calving ground survey.

Overall, 228 photos were resampled in the North and South photo strata. Ratios of 2nd to original count suggested higher photo sightability in the North stratum. One assumption in this comparison is that the first and 2nd counter were counting the same caribou on a given photo. To test this assumption the distances between points of counted caribou in the first and 2nd count was measured in GIS to identify any counted caribou that were further distance from the original counts. This process did not identify any new caribou.

Table 3: Summary of photo cross validation data set. The ratio of the original count to 2nd count is an estimate of photo sightability

Strata	Photos resampled	Original count	2nd count	New caribou counted in 2nd count	Caribou not detected in 2nd count	Original count/2nd count
North	158	447	490	43	2	0.91
South	70	257	301	44	1	0.85

This cross-validation process can be modelled as a 2 sample mark-recapture sample with caribou being "marked" in the original count and then be "re-marked" in the 2nd count. Using this approach avoids the assumption that the 2nd counter detects all the caribou on the photo. The Huggins closed N model (Huggins 1991) in program MARK (White and Burnham 1999) was then used to estimate sightability. This approach was also used to test potential differences in sightability in the north and south stratum. Non-independence of caribou most likely caused overdispersion of binomial variances. The

overdispersion parameter (c-hat) was estimated as the ratio of the bootstrapped (photo-based) and simple binomial variance with a resulting value of 2.2. Bootstrap estimates (Manly 1997), which use the photo as the sample unit (therefore assuming photos are independent), are most likely a better indication of variance than binomial estimate (which assume independence of caribou counted on photos).

Model selection suggested that the difference in sightability between strata was supported even when overdispersion was accounted for. Therefore, strata-specific sightability estimates were used for subsequent estimates.

Table 4: Model selection of photo sightability cross validation data set using Huggins closed models in program MARK. Quasi Akaike Information Criterion ($QAIC_c$), the difference in $QAIC_c$ between the most supported model and given model $\Delta QAIC_c$, the model weight (wi), number of parameters (K) and quasi-Deviance (QDeviance) is given

Model		**Model selection**				
First count	**2nd count**	**$QAIC_c$**	**$\Delta QAIC_c$**	**w_i**	**K**	**QDeviance**
Strata	Constant	269.90	0.00	0.50	3	3609.0
Constant	Constant	270.77	0.87	0.32	2	3611.9
Strata	Strata	271.91	2.00	0.18	4	3609.0

The estimates of sightability are given below along the bootstrap-based estimates of standard error, CV and confidence limits. The bootstrap estimates, which conditions on the photo as a sample unit, were used for subsequent variance estimates.

Table 5: Estimates of sightability from the most supported Huggins model

Count-stratum	**Estimate**	**Binomial SE**	**Binomial CV**	**Bootstrap SE**	**Bootstrap CV**	**Bootstrap confidence limit**	
1st count-North stratum	0.912	0.013	0.014	0.015	0.016	0.884	0.941
1st count -South stratum	0.853	0.020	0.024	0.035	0.040	0.782	0.919
2nd count-Both stratum	0.996	0.002	0.002				

The standard Jolly estimator was used to obtain estimates of caribou on the calving ground from the transect data. As with the 2015 Bluenose East survey (Boulanger et al. 2016), transect densities were weighted to ensure equal representation of transects with varying strip widths. The initial estimate was divided by photo sightability to obtain the photo-sightability abundance estimate. Overall, sightability-corrected estimates were 12% higher than initial estimates.

Table 6: Initial estimates of abundance in survey strata, estimated photo sightability and estimates of abundance with photo sightability.

Strata	**Initial estimate of N**			**Photo sightability**			**Photo-sightability N estimate**		
	N	**SE**	**CV**	**p**	**SE**	**CV**	**N**	**SE**	**CV**
North	9887.0	849.5	0.086	0.912	0.015	0.016	10841.0	948.4	0.087
South	5487.6	837.0	0.154	0.854	0.035	0.041	6425.8	1014.8	0.158

The photo data was combined with visual data (from 2x observer surveys) to obtain a total estimate of caribou on the calving ground of 19,161. Recon-based strata will be included to this total in the future. This total applies to strata with corresponding composition survey data.

Table 7: Estimates of abundance on all survey strata including visual surveys

Strata	N	SE	Conf. Limit		CV.N
North Photo	10,841	948.4	9,041	13,000	8.7%
South Photo	6,426	1014.8	4,599	8,979	15.8%
North Visual	788	140.4	541	1,149	17.8%
South Visual	1,106	173.5	778	1,571	15.7%
Total	**19,161**	**1406.8**	**16,512**	**22,233**	**7.3%**

Estimates of breeding females (from the composition data described in previous reports) is given below (11,675).

Table 8: Estimates of breeding females based upon initial abundance estimates and composition surveys.

Strata	Caribou		Proportion breeders		Breeding females				
	N	CV.N	pb	CV	N	SE	Conf. Limit		CV
NorthPhoto	10,841	0.087	0.816	0.025	8,846	803.7	7,326	10,681	9.1%
SouthPhoto	6,426	0.158	0.330	0.100	2,121	396.4	1,429	3,148	18.7%
NorthVisual	788	0.178	0.845	0.032	666	120.5	454	976	18.1%
SouthVisual	1,106	0.157	0.038	0.421	42	18.9	16	110	45.0%
Total	**19,161**				**11,675**	**904.4**	**9,971**	**13,670**	**7.7%**

Estimates of adult females are given below (13,988).

Table 9: Estimates of adult females based upon initial abundance estimates and composition surveys.

Strata	Caribou		Prop. Adult females		Adult females				
	N	CV.N	pf	CV	N	SE	Conf. Limit		CV
NorthPhoto	10,841	0.087	0.875	0.018	9,486	847.7	7,880	11,419	8.9%
SouthPhoto	6,426	0.158	0.540	0.050	3,470	574.8	2,444	4,928	16.6%
NorthVisual	788	0.178	0.908	0.026	716	128.9	489	1,048	18.0%
SouthVisual	1,106	0.157	0.286	0.147	316	68.0	196	510	21.5%
Total	**19,161**				**13,988**	**1034.6**	**12,042**	**16,249**	**7.4%**

The ratio of breeding females to adult females suggests a higher proportion of pregnant females of 83%.

Comparison with previous estimates

Comparison with previous estimates suggests a gross change of 51% in adult females with translates into an annual rate of change 80% in the 2015-8 interval. In contrast, breeding females had a gross change of 67% which translates to an annual rate of change of 88% in the interval since 2015. I note that the annual rate of decline of adult females from 2010 to 2013 was 0.80 and from 2013 to 2015 was 79%, and therefore in this context the Bluenose East herd is exhibiting a roughly constant rate of decline since 2010. More detailed trend analyses will be undertaken later.

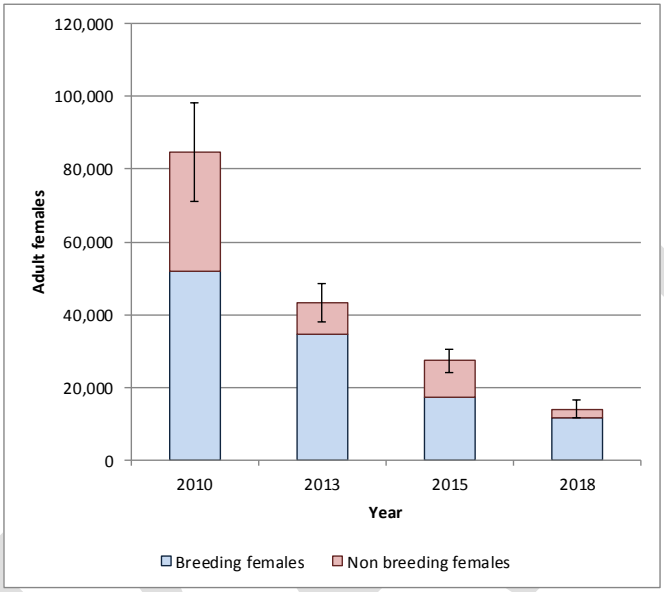

Figure 3: Comparison of estimates of breeding and adult females from previous surveys.

Extrapolated herd estimates

A composition survey was conducted from 23-25 October 2018 to estimate the bull-cow ratio of the Bluenose East herd. Overall there were 115 observations

Table 10: Summary of observations from fall composition survey

Cows	Bulls	Calves	Observations
1542	586	396	115

Bootstrap methods were used to obtain standard errors on estimates.

Table 11: Estimates of the bull-cow ratio, proportion cows, and calf-cow ratio from the fall composition surveys

Indicator	Estimate	SE	Conf. Limit		CV
Bull cow ratio	0.380	0.027	0.333	0.437	7.0%
Proportion cows	0.725	0.014	0.697	0.750	1.9%
Calf-cow ratio	0.257	0.016	0.229	0.291	6.1%

Comparison of composition estimates with previous years suggest a decreasing bull cow ratio.

Table 12: Estimates of proportion cows and the bull cow ratio from previous surveys

	Proportion cows					Bull-cow ratio			
Year	**Estimate**	**SE**	**Conf. Limit**		**CV**	**Estimate**	**SE**	**Conf. Limit**	
2009	0.700	0.008	0.684	0.716	0.011	0.429	0.017	0.396	0.463
2013	0.701	0.009	0.685	0.720	0.013	0.426	0.019	0.389	0.461
2015	0.706	0.014	0.678	0.734	0.020	0.417	0.029	0.367	0.479
2018	0.725	0.014	0.697	0.750	0.019	0.380	0.026	0.332	0.437

Estimates of herd size are presented in the table below. The assumed pregnancy rate estimate is higher since it assumes a pregnancy rate of 0.72 which is lower than that observed in 2018 (0.83) therefore inflating the estimate. The best estimate uses proportion females, which is simply the estimate of adult females (13,988) divided by proportion cows in the herd (0.725). Log-based confidence limits, which were used for other estimates as well as traditional symmetrical confidence limits (estimate $\pm t$*SE) are given. In most cases log-based limits give better coverage of estimates than traditional symmetrical methods given that often the distribution of estimates has a slight positive skew. However, previous analyses have used the symmetrical method. The actual difference in CI's is relatively minor.

Table 13: Extrapolated herd size estimates for the Bluenose East herd

Method	**N**	**SE**	**Log-based CI**		**Symmetric traditional CI**		**CV**
Proportion females	19,294	1474.7	16,527	22,524	16,303	22,285	7.6%
Assumed pregnancy rate	22,366	2861.8	17,247	29,004	16,530	28,202	12.8%

The graph below shows the trend in estimates from previous surveys using both methods. For proportion females, herd size has declined at a near-constant annual rate of 20-21% since 2010.

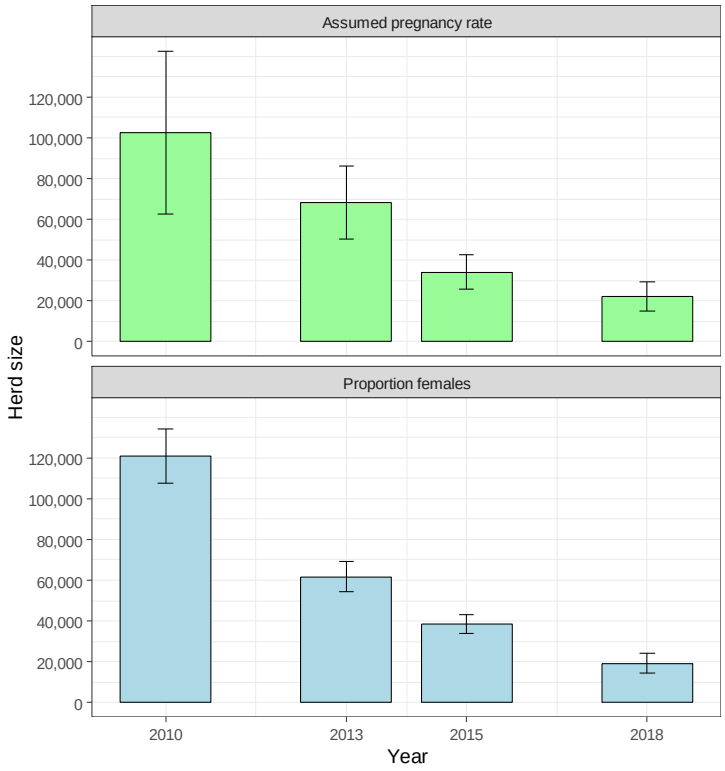

Figure 4: Estimates of Bluenose East herd size using the assumed pregnancy rate and proportion females method from 2010-8.

Discussion

In point form

- Overall densities are quite low. The photo data covered the main congregation of collars and it seems unlikely we would have missed a large enough group of caribou to change estimates substantially.
- Transect densities were lower across all strata compared to 2015 as shown in the two figures below.

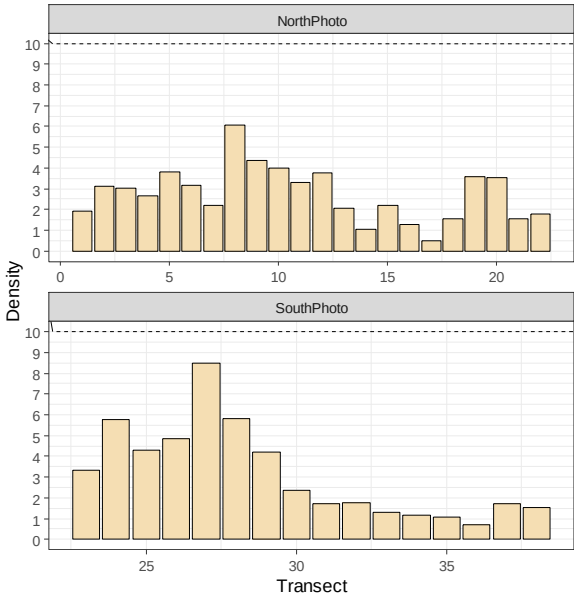

Figure 5: Transect-specific densities for the Bathurst photo block. Transects go from west to east. Sightability was accounted for in density estimates.

In comparison, densities on transect lines was higher in 2015 with some lines have densities above 10 caribou per km^2. This change suggests overall lower counts and densities throughout the surveyed area in 2018.

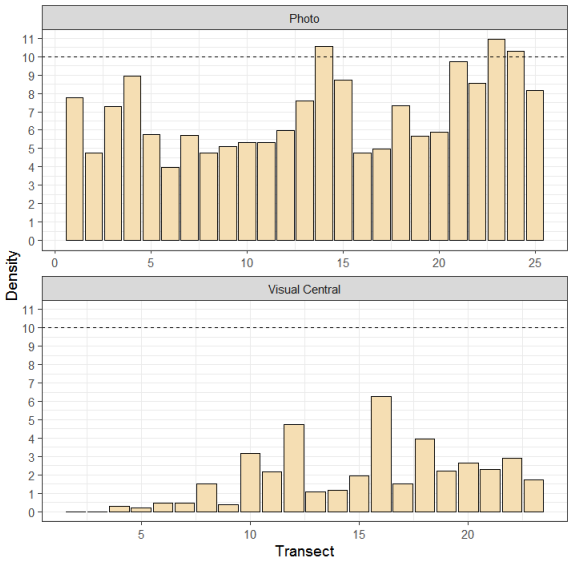

Figure 6: Transect-specific densities for the Bathurst photo block in 2015.

- There were some caribou to the south of the south visual strata in recon efforts. One hundred and forty two caribou were counted in this strata which leads an approximate estimate of 1,775 caribou (142/0.08). Some of these caribou may have been double counted in the visual surveys given that they occurred after the recons surveys. Composition surveys in the south suggest

low proportion of adult and breeding females (4% breeding females and 29% adult female is Visual south strata). Using these composition estimates there would be an estimated 71 breeding females and 514 adult females. This number is negligible and certainly does not change the overall results of the survey.

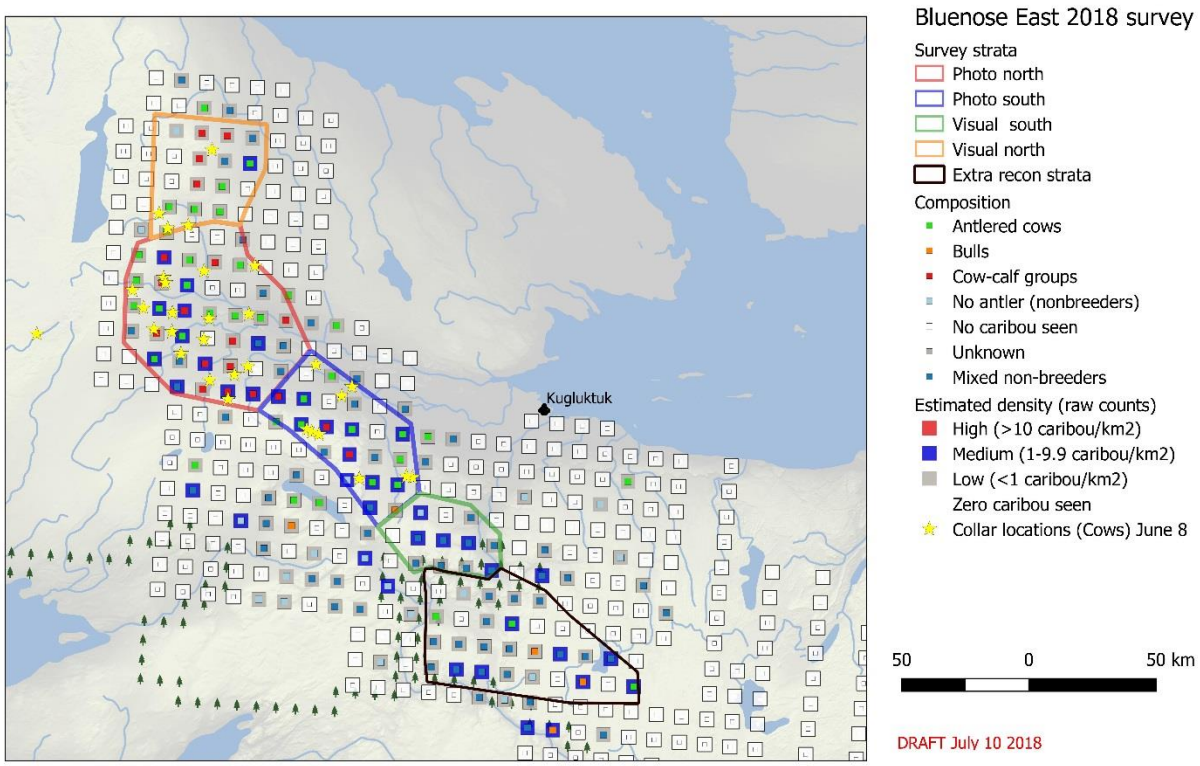

Figure 7: Exploratory southern recon-based strata.

- As with previous surveys the extrapolated estimate of approximately 19,000 will be close if not lower than the total number of caribou on the calving ground once the recon strata is included. This is presumably due to the fact that yearlings are not included in the extrapolated herd estimate but are included in the estimate of total caribou on the calving ground.
- The photo sightability analysis suggests lower sightability. Further analyses will be conducted to determine factors affecting sightability. It is important to demonstrate that 2018 was an anomaly compared to previous years when photo sightability is close to 1 (Appendix in the 2013 survey report).

Literature cited

Boulanger, J., B. Croft, J. Adamczewski, D. Lee, N. C. Larter, and L. M. Leclerc. 2016. An estimate of breeding females and analyses of demographics for the Bluenose-East herd of barren-ground

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