Appendix A

Integrated Population Model Analysis of the Bluenose-East Barren-Ground Caribou Herd

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Introduction

This report summarizes Integrated Population Model (IPM) analyses conducted on the Bluenose-East barren-ground caribou herd following the 2025 calving ground survey. These analyses will be included in the upcoming 2025 Bluenose-East barren-ground caribou herd calving ground survey report or in a stand-alone report. This draft report provides information on the IPMs prior to the upcoming calving ground survey report, for recipients to review and as input for the development of management actions for the Bluenose-East herd.

Methods

Rationale Behind the Use of Demographic Models

Trends in herd abundance (whether a herd is increasing, decreasing, or stable) can be characterized by comparing herd abundance estimates, which are primarily based on calving ground surveys to count the number of adult (2 year+ old) females in the herd, with the number of bulls estimated from sex ratio surveys during the fall breeding season. However, other valuable data is gathered during field surveys at other times of year and in years without calving ground surveys. IPMs provide a way to estimate the herd trend (and other parameters, e.g., calf survival) using all these pieces of information, and can provide a more robust understanding of herd dynamics as a result.

One of the most important questions for the Bluenose-East herd was whether the adult female segment of the population had changed since the last population estimate survey in 2023. The most direct measure that indicates the status of adult females is their survival rate, which is the proportion of females that survive from one year to the next. This metric, along with recruitment of calves to adult females determines the overall trend in adult female abundance. For example, if adult female survival is high then productivity in previous years can be relatively low and the overall trend in breeding females can be stable. Alternatively, if productivity is consistently high, then slight reductions in adult survival rate can be tolerated. However, increases in productivity (in birth rate, calf survival, or survival of yearlings to 2-year-olds) will not result in a change in adult female abundance until calves mature to adults which creates a 2-year time lag in how adult female estimates on the calving ground reflect potential changes in productivity. A population model can help increase understanding of how these various indicators work together to affect herd demography.

General IPM Methods

We used a Bayesian state space IPM (Buckland et al. 2004, Kery and Schaub 2012, Schaub and Kery 2022) based upon the original (OLS) model (White and Lubow 2002) developed for the Bathurst barren-ground caribou herd (Boulanger et al. 2011) to further explore demographic trends for the Bluenose-East herd. A state space model is basically a model that allows separate modeling of field sampling estimates and demographic processes.

The IPM is a stage-based model that divides caribou into three age-classes, with survival rates determining the proportion of each age class that makes it into the next age class (Figure 1-A). The life history model is based upon a "caribou year" that starts in June when calves are born and ends at the end of May when caribou have arrived or are close to arriving on the calving ground. In recent model runs, a "twoling" age class was considered to understand the relative abundance of this class as well as test assumptions on assumed pregnancy rates of younger caribou. There is insufficient data to estimate yearling survival and therefore it is set to equal adult female survival.

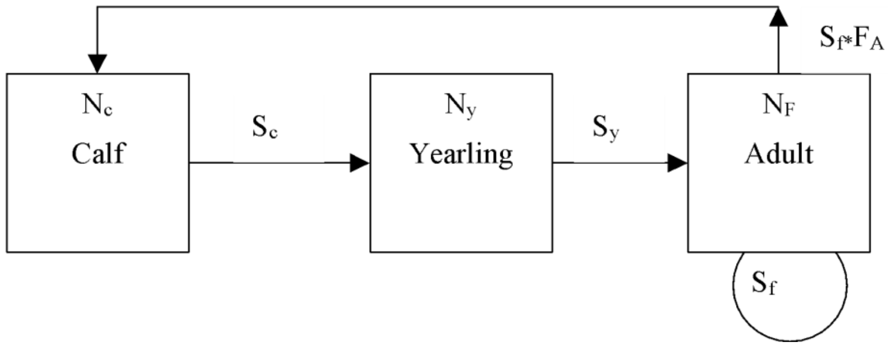

Figure 1-A. The stage matrix life history diagram for the caribou demographic model used for Bluenose-East barren-ground caribou herd in 2025. This diagram pertains to the female segment of the population. Nodes are population sizes of calves (N_c), yearlings (N_y), and adult females (N_F). Each node is connected by survival rates of calves (S_c), yearlings (S_y) and adult females (S_f). Adult females reproduce dependent on fecundity (F_A) and whether a pregnant female survives to produce a calf (S_f). The male life history diagram was similar, with no reproductive nodes.

"Field estimates" are observed data collected from collared caribou and surveys that are used to inform the IPM. These include the breeding and adult female estimates in June, calf:cow ratios in October and March, bull:cow ratios in October, estimates of the proportion of breeding females in June, and adult female and male survival rates from collared caribou and estimated harvest values. The IPM basically iteratively estimates IPM demographic parameters (i.e., abundance, survival and fecundity values as defined in Figure 1-A) that provide the best fit to the field estimates.

For harvest levels, we used reported values but allowed variation around these values to reflect levels of uncertainty. The IPM used information from the collar survival rates, herd size (and related trend), as well as productivity to estimate harvest for bulls and cows. Harvest was assumed to occur in January and was additive to natural mortality.

Models used in this analysis do not estimate emigration or immigration into or out of the Bluenose-East herd under the assumption that movement into equals movement out of the Bluenose-East herd. We provide a summary of emigration and immigration based on collars to allow further evaluation of the assumption of equal immigration and emigration. More advanced emigration and immigration models will be run in the future. Random effect models were used to model yearly variation in demographic parameters. A random effect model can be conceptualized as sampling a distribution of values with a mean central value. In the context of the demographic analysis, it basically assumes a mean value of a demographic parameter (i.e. adult survival rate) with annual yearly variation.

This work was in collaboration with a Bayesian statistician/modeller (Joe Thorley-Poisson Consulting; Thorley 2017, Ramey et al. 2018, Thorley and Boulanger 2019). Details on the IPM approach follow here.

IPM Details

The cow and bull harvest, fecundity, breeding cow abundance, cow survival, bull survival, fall bull cow, fall calf cow and spring calf cow ratio data complete with standard errors were analysed using a stage-based state-space population model similar to Boulanger et al. (2011). Key assumptions of the female stage-based state-space population model include:

- Calving occurs on the 11th of June (with a year running from calving to calving);
- Cow natural survival from calving to the following year varies continually and randomly by year;
- Bull natural survival from calving to the following year varies randomly by year;
- Cow and bull natural survival is constant throughout the year in any given year;
- Harvest of cows and bulls occurs on the 15th of January;
- Harvest rate varies by harvest period (the second harvest period occurs from 2001-2009) and continually by year by harvest period for cows and bull;
- Yearling survival to the following year is the same as cow natural survival;
- Calf survival varies between the summer and winter seasons and randomly by year;
- The calf sex ratio is 1:1;
- Fecundity varies randomly by year;
- In an average year two year old cows have a fecundity of 0.25;
- Female yearlings are indistinguishable from cows in the fall and spring surveys;
- The uncertainty in the number of cows in the initial year is described by a positively truncated normal distribution; and
- The uncertainty in each data point is normally distributed with a standard deviation equal to the provided standard error.

Model parameters were estimated using Bayesian methods. The estimates were produced using JAGS (Plummer 2003). For additional information on Bayesian estimation the reader is referred to McElreath (2016).

Unless stated otherwise, the Bayesian analyses used weakly informative normal and half-normal prior distributions (Gelman et al. 2017). The posterior distributions were estimated from 1500 Markov Chain Monte Carlo (MCMC) samples thinned from the second halves of 3 chains (Kery and Schaub 2011, 38–40). Model convergence was confirmed by ensuring that the potential scale reduction factor $\hat{R} \leq 1.05$ (Kery and Schaub 2011, 40) and the effective sample size (Brooks et al. 2011) $ESS \geq 150$ for each of the monitored parameters (Kery and Schaub 2011, 61).

The parameters are summarised in terms of the point *estimate*, *lower* and *upper* 95% credible limits (CLs) and the surprisal *s-value* (Greenland 2019). The estimate is the median (50th percentile) of the MCMC samples while the 95% CLs are the 2.5th and 97.5th percentiles. The s-value can be considered a test of directionality. More specifically it indicates how surprising (in bits) it would be to discover that the true value of the parameter is in the opposite direction to the estimate. An s-value (Chow and Greenland 2019) is the Shannon transform (-log to base 2) of the corresponding p-value (Kery and Schaub 2011; Greenland and Poole 2013). A surprisal value of 4.3 bits, which is equivalent to a p-value of 0.05 indicates that the surprise would be equivalent to throwing 4.3 heads in a row. The condition that non-essential explanatory variables have s-values ≥ 4.3 bits provides a useful model selection heuristic (Kery and Schaub 2011).

The sensitivity of the estimates to the choice of priors was examined by doubling the standard deviations of the normal priors and using the split $\hat{R}$ (after collapsing the chains) to compare the posterior distributions (Thorley and Andrusak 2017). A split $\hat{R} \leq 1.1$ was taken to indicate low sensitivity.

The results are displayed graphically by plotting the modeled relationships between particular variables and the response(s) with the remaining variables held constant. In general, continuous and discrete fixed variables are held constant at their mean and first level values, respectively, while random variables are held constant at their typical values (expected values of the underlying hyperdistributions) (Kery and Schaub 2011, 77–82). When informative the influence of particular variables is expressed in terms of the *effect size* (i.e., percent or n-fold change in the response variable) with 95% credible intervals (CIs, Bradford et al. 2005). Data are indicated by points (with lower and upper bounds indicated by vertical bars) and estimates are indicated by solid lines (with CIs indicated by dotted lines).

The analyses were implemented using R version 4.5.1 (R Core Team 2024) and the `mbr` family of packages. The data were analysed using a state-space population model (Newman et al. 2014).

Table 1-A. IPM parameter description.

Parameter	Description
Annual	The year as an integer starting at 1
BreedingCowsSE[i]	The standard error for **BreedingCows[i]**
BreedingCows[i]	The data point for the number of breeding cows in the i^{th} year
BreedingProportionSE[i]	The standard error for **BreedingProportionSE[i]**
BreedingProportion[i]	The data point for the logistic proportion of cows breeding in the i^{th} year
BullSurvivalSE[i]	The standard error for **BullSurvival[i]**
BullSurvival[i]	The data point for logistic bull survival from the $i\text{-}1^{th}$ year to the i^{th} year
CollarsFidelity[i]	The total number of collared cows remaining with the herd in the spring of the i^{th} year
CollarsTotal[i]	The total number of collared cows in the spring of the i^{th} year
CowSurvivalSE[i]	The standard error for **CowSurvival[i]**
CowSurvival[i]	The data point for logistic cow survival from the $i\text{-}1^{th}$ year to the i^{th} year
FallBullCowSE[i]	The standard error for **FallBullCow[i]**
FallBullCow[i]	The data point for the bull cow ratio in the fall of the i^{th} year
FallCalfCowSE[i]	The standard error for **FallCalfCow[i]**
FallCalfCow[i]	The data point for the calf cow ratio in the fall of the i^{th} year
HarvestedBullsSE[i]	The standard error for **HarvestedBulls[i]**
HarvestedBulls[i]	The data point for the number of bulls harvested in January of the i^{th} year
HarvestedCowsSE[i]	The standard error for **HarvestedCows[i]**
HarvestedCows[i]	The data point for the number of cows harvested in January of the i^{th} year
SpringCalfCowSE[i]	The standard error for **SpringCalfCow[i]**
SpringCalfCow[i]	The data point for the calf cow ratio in the spring of the i^{th} year
bBreedingCows1	The number of breeding cows in the initial year
bBullsCows1	The bull to cow ratio in the initial year
bFecundityAnnual[i]	The random effect of the i^{th} **Annual** on **bFecundity**
bFecundity	The log-odds probability of a cow breeding in a typical year
bFidelityAnnual[i]	The random effect of the i^{th} **Annual** on **bFidelity**
bFidelity[i]	The log-odds probability of a cow remaining with the herd in a typical year in the i^{th} **FidelityPeriod**
bHarvestRateBullYear[i]	The change in **bbHarvestRateBull** by year for the i^{th} **HarvestPeriod**
bHarvestRateBull[i]	The log-odds probability of a bull being harvested in year 0 for the i^{th} **HarvestPeriod**

Parameter	Description
bHarvestRateCowYear[i]	The change in **bbHarvestRateCow** by year for the i[th] **HarvestPeriod**
bHarvestRateCow[i]	The log-odds probability of a cow being harvested in year 0 for the i[th] **HarvestPeriod**
bSurvivalBullAnnual[i]	The random effect of the i[th] **Annual** on **bSurvivalBull**
bSurvivalBull	The log-odds bull survival in a typical year
bSurvivalCalfAnnual[i]	The random effect of the i[th] **Annual** on **bSurvivalCalfSummerAnnual** and **bSurvivalCalfWinterAnnual**
bSurvivalCalfSummerAnnual	The log-odds summer calf survival if extended for one year
bSurvivalCalfWinterAnnual	The log-odds winter calf survival if extended for one year
bSurvivalCowAnnual[i]	The random effect of the i[th] **Annual** on **bSurvivalCow**
bSurvivalCow	The log-odds cow (and yearling) survival in a typical year
sFecundityAnnual	The SD of **bFecundityAnnual**
sFidelityAnnual	The SD of **bFidelityAnnual**
sSurvivalBullAnnual	The SD of **bSurvivalBullAnnual**
sSurvivalCalfAnnual	The SD of **bSurvivalCalfAnnual**
sSurvivalCowAnnual	The SD of **bSurvivalCowAnnual**

Table 2-A. Bluenose-East barren-ground caribou herd IPM parameter estimates. Estimates are on the log or logistic scale. Confidence limits (lower and upper) are given along with s-values. An s “surprisal” value is the number of successive head flips of a coin that would create the given estimates. A s-value of 4.5 is equivalent to a p-value of 0.05.

term	estimate	lower	upper	svalue
bBullsCows1	4.723e-01	2.860e-01	6.853e-01	10.55
bCalvesCows1	8.820e-01	7.400e-01	9.697e-01	10.55
bCows1	8.440e+04	5.979e+04	1.147e+05	10.55
bFecundityCow	3.622	2.290	5.480	10.55
bHarvestRateBull[1]	-3.045	-3.874	-2.221	10.55
bHarvestRateBull[2]	-1.888	-3.400	-6.060e-01	6.464
bHarvestRateBullYear[1]	1.283e-03	-1.216e-01	1.097e-01	0.0213
bHarvestRateBullYear[2]	-1.562e-01	-2.433e-01	-6.531e-02	10.55
bHarvestRateCow[1]	-3.671	-4.758	-2.788	10.55
bHarvestRateCow[2]	-2.382	-3.666	-1.083	10.55
bHarvestRateCowYear[1]	8.373e-03	-1.707e-01	1.930e-01	0.09947
bHarvestRateCowYear[2]	-2.355e-01	-3.332e-01	-1.506e-01	10.55
bSurvivalBull	4.794e-01	5.790e-02	9.577e-01	5.422
bSurvivalCalfSummerAnnual	-1.049	-1.403	-7.057e-01	10.55
bSurvivalCalfWinterAnnual	3.700e-01	-3.272e-02	8.186e-01	3.757
bSurvivalCow	1.424	1.157	1.718	10.55
bTwolingsCows1	1.269e-01	2.910e-02	3.084e-01	10.55
bYearlingsCows1	4.823e-01	2.976e-01	6.873e-01	10.55
sFecundityAnnual	2.465	1.483	4.120	10.55
sSurvivalBullAnnual	8.796e-01	5.875e-01	1.387	10.55

term	estimate	lower	upper	svalue
sSurvivalCalfAnnual	6.025e-01	4.088e-01	9.244e-01	10.55
sSurvivalCowAnnual	5.511e-01	3.515e-01	8.765e-01	10.55

Table 3-A. Model summary.

n	K	nchains	niters	nthin	ess	rhat	converged
19	22	3	500	100	171	1.03	TRUE

Results

Overall Model Fit

Figure 2-A displays the fit of the IPM to the main demographic indicators. As described earlier, the IPM estimates demographic parameters (i.e., abundance, survival and fecundity rates) as well as predicted “true” values of field observations. Figure 2-A shows the modelled values (blue line with hashed confidence limits) relative to the observed field estimates (red points with confidence limits as vertical bars). Each component is discussed in a separate section in the report.

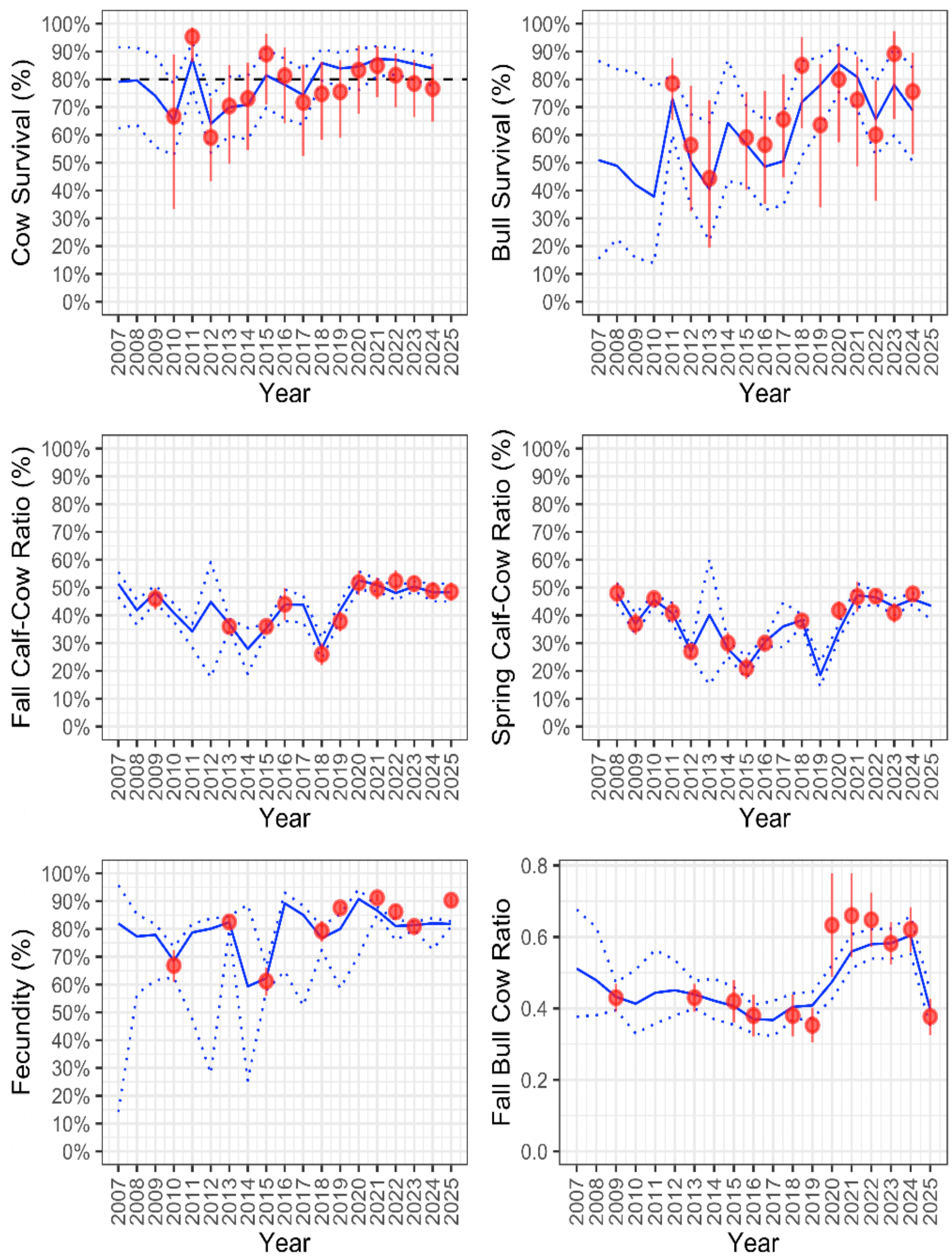

Figure 2-A. IPM predictions (blue line with hashed confidence limits) in comparison to observed field estimates (red dots with confidence limits) for the base Bluenose-East barren-ground caribou herd IPM.

Adult Female and Male Survival

Estimates of IPM survival were higher than observed collar-based estimates for adult females from 2017 to 2024. The IPM estimate of adult cow survival for the 2024 caribou year (i.e., from June 2024 to May 2025) is 0.84 (CI 0.78-0.89) compared to the observed collar-based estimate of 0.77 (CI 0.65-0.85). The IPM estimates of adult female survival are consistently higher than observed estimates for 6 of the past 8 years suggesting a potential negative bias in collar survival rates as suggested by other studies (Haskell and Ballard 2007, Rasiulis et al. 2014). Causes of negative bias could be uncertainty in determination of collar fate, premature collar release (assumed to be mortality), or other factors.

IPM bull survival estimates follow collar-based estimates. These will also be influenced by bull:cow ratios and are likely more robust than collar-based estimates which are based on lower sample sizes of collars. The IPM estimate of bull survival for the 2024 caribou year is 0.69 (CI 0.50-0.84) in comparison to the collar-based estimate of 0.76 (CI 0.53-0.89).

An additional factor influencing survival is harvest. The observed collar-based survival estimates include harvest mortality because it is difficult to discern exact mortality caused from collars and there are usually insufficient sample sizes of collars to separate harvest mortality from natural mortality. The IPM used estimates of harvest (Figure 3-A) to also estimate "natural survival" with harvest mortality removed (Figure 4-A). Levels of harvest were relatively low compared to the abundance of bulls and cows and therefore there is minimal difference between observed and natural survival rates (Figure 4-A).

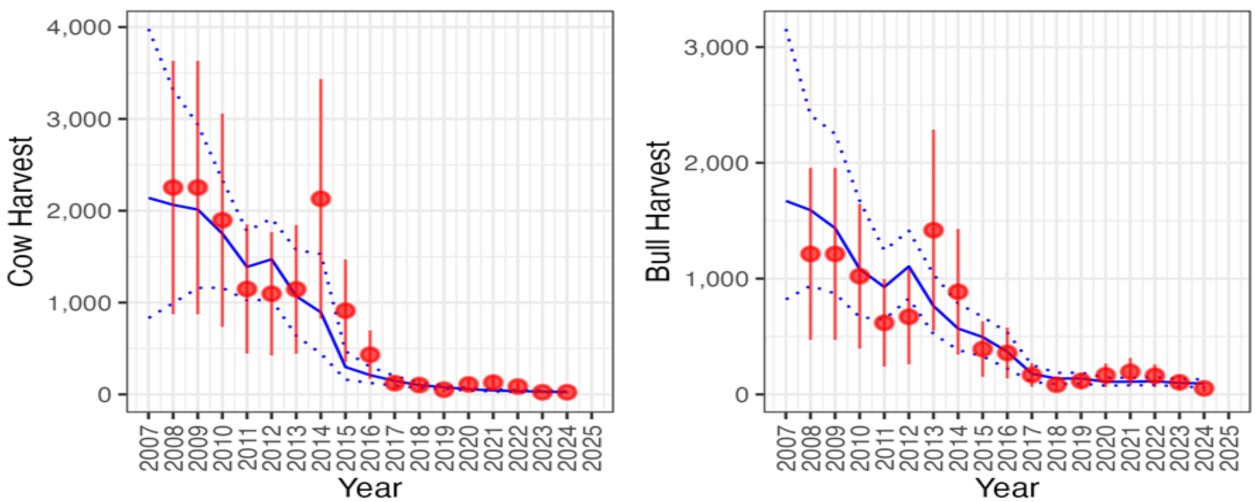

Figure 3-A. Estimated harvest of cows and bulls.

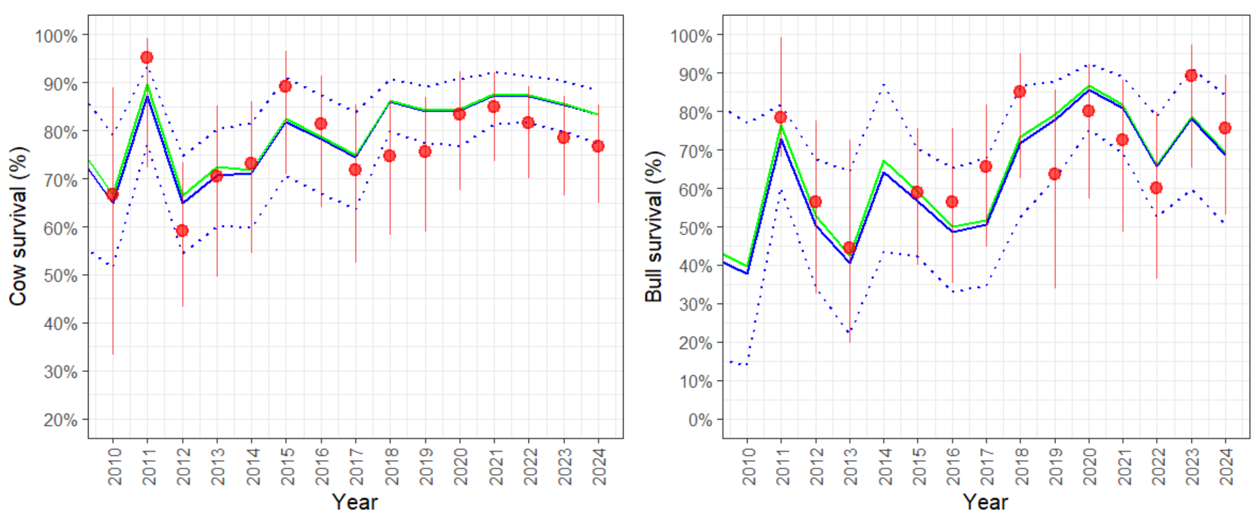

Figure 4-A. Estimates of adult cow and bull survival from IPM (blue line) compare with field estimates (red line). The green line shows "natural survival" with harvest mortality removed. Since harvest was low the difference between the two estimates is negligible.

Bull:Cow Ratios

The IPM estimates for bull:cow ratio in 2025 were close to field values even though the 2025 bull:cow estimate (0.38) was much lower than previous years (Figures 5-A). We suggest that the IPM estimate for bull:cow ratio in 2025 be treated cautiously given that there is minimal current data to provide secondary inference on the ratio of bulls and cows in the herd (such as a future population estimate). However, IPM (and collar) survival rate estimates for bulls have been lower than cows since 2020 (after an increase prior to 2020) which would result in a reduction in the bull:cow ratio. Therefore, a decrease in the bull cow ratio is demographically possible.

We ran the IPM without the observed 2025 bull:cow ratio included to test the overall effect of inclusion or exclusion of the 2025 data point (Figure 5-A). When the observed 2025 bull:cow ratio is excluded the IPM estimate of this parameter does not decrease in 2025 and instead stays at the same level as the previous year. The reason for this is that there are few data points to inform the IPM on the appropriate bull:cow ratio given that it is at the tail end of the data set.

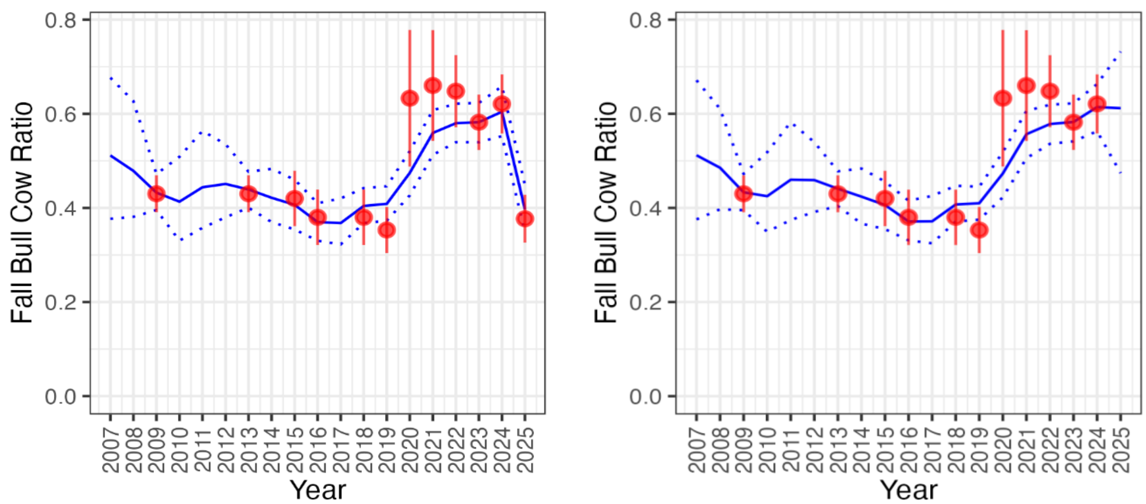

Figure 5-A. IPM model run with (left) and without (right) the 2025 bull:cow ratio.

The main effect of inclusion or exclusion of the 2025 bull:cow ratio was a slight increase in the estimate of bull survival rate which is derived in the model from other survival and productivity parameters (Figure 6-A). Other predictions were minimally affected which was presumably due to the bull:cow ratio being at the tail end of the data set and therefore having minimal influence.

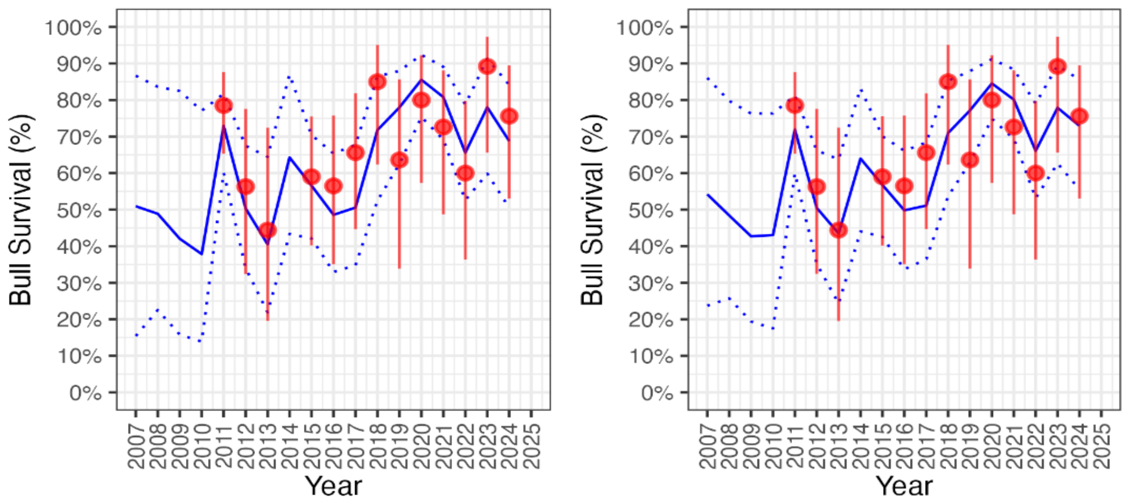

Figure 6-A. IPM model run bull survival estimates with (left) and without (right) the 2025 bull:cow ratio.

Productivity

Estimates of fecundity, derived calf survival, and productivity suggest higher overall productivity (estimated as fecundity X calf survival) from 2019 to 2024 caribou years. The IPM did not meet the observed fecundity estimate of 89% (observed as proportion of adult females breeding on the calving ground) in 2025 (Figure 7-A). As with the bull:cow ratio this was likely due to this data point being at the tail end of the data set.

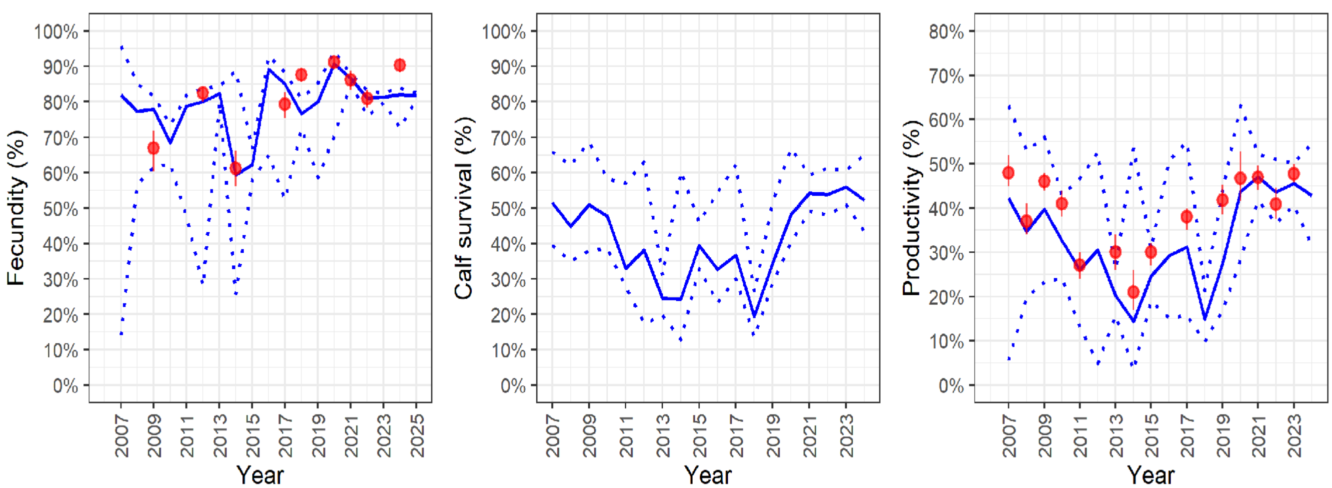

Figure 7-A. Fecundity, calf survival (derived) and productivity (calf survival X fecundity). Also shown are spring calf:cow ratios which inform productivity. The exact fit of IPM predictions to calf:cow ratios is shown in previous figures.

Abundance Estimates

Overall the IPM parameter estimates for breeding females, adult females, and bull abundance follow the observed field estimates with the exception of the IPM not predicting higher abundance estimates in 2023 for herd size and adult females (Figure 8-A).

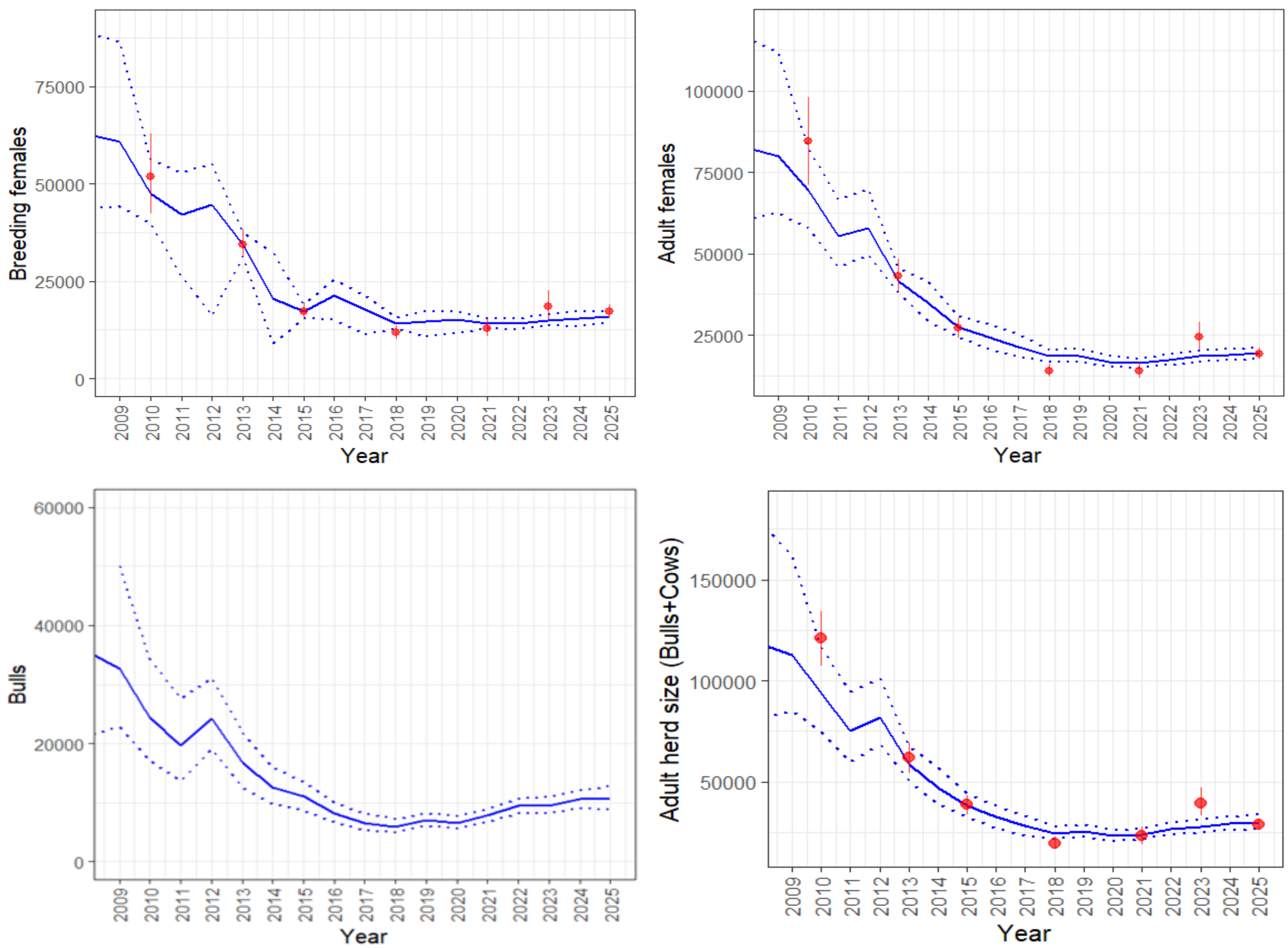

Figure 8-A. Estimates of breeding females, adult females, bulls, and herd size (bulls + cows).

A view of fit of the model to recent data suggests better fit to the breeding cow data in comparison to the adult cow data (Figure 9-A). For breeding cows, the 95% confidence interval of the 2023 field estimate intersects the mean IPM estimate whereas the 95% confidence interval of the 2023 total adult female estimate is beyond the 2023 IPM prediction. The same general pattern occurred for the 2023 Beverly IPM analysis (Campbell et al. 2025) with better model agreement between breeding female IPM and field estimates.

One potential reason for better agreement of IPM predictions with breeding females is that the breeding females likely constitute the core older aged caribou in the herd whereas adult females will include younger aged caribou that are not necessarily breeding. We included a fourth "twoling" age class between yearling and adults to explore this topic further. The IPM estimate of the "twoling cows" (yearlings from the previous year which likely show 0 to lower pregnancy rates) is shown on both graphs. We speculate this class of non-breeding cows, which are roughly 3,000 caribou, may show less fidelity to calving grounds including not necessarily occurring in core breeding areas in compared to adult cows. The challenge here is that the younger cows are not collared and therefore we have little inference on their distribution and movement relative to calving grounds. Currently, the twoling cows are assumed to not breed, however, it is possible/likely that a proportion do breed as explored in previous analyses (Boulanger et al. 2024).

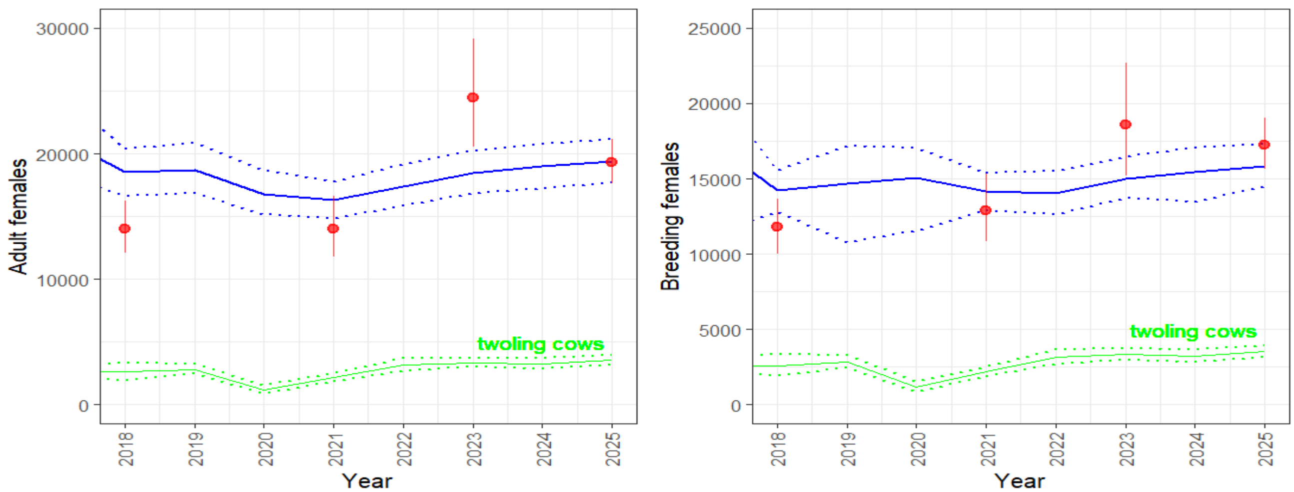

Figure 9-A. Close up of IPM predictions versus field estimates of adult and breeding female estimates from 2018 to 2025. Twoling cows estimates are shown as green lines.

Overall Trend

Overall IPM estimates of trend of adult females suggest an increasing trend with an increase starting in 2021 ranging from 1.01 to 1.06. The 3-year geometric mean of adult female λ up to the 2024-25 caribou year was 1.035 (CI 1.0-1.07). The geometric mean of herd (adult males + adult females) λ from 2021 to 2025 was 1.05 with the geometric mean from 2023-2025 being 1.04. These estimates of trend are within the range suggested by comparisons of observed field estimates from 2021 to 2025 (Figure 10-A).

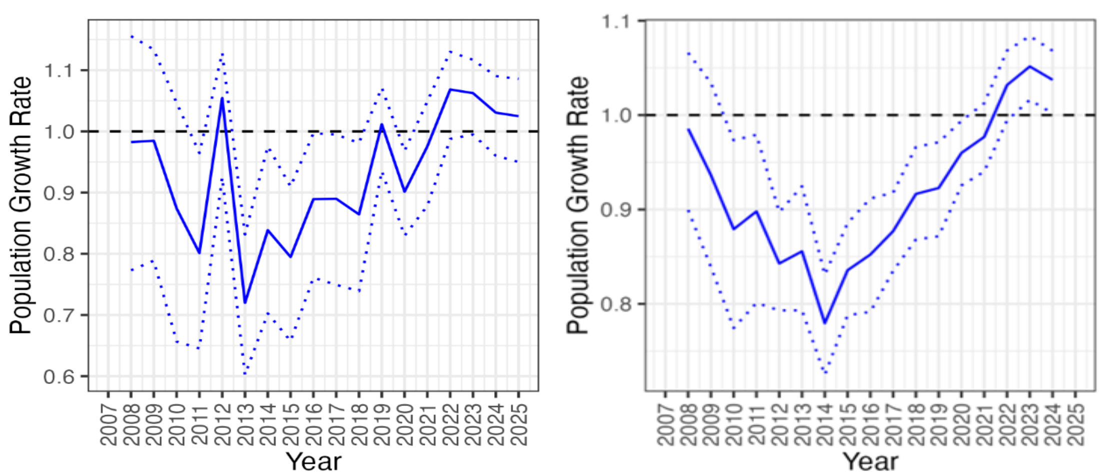

Figure 10-A. Population growth rate for adult females using yearly estimates (left) and geometric means (3-year moving average; right).

Potential emigration or immigration of adult females to the Bluenose-East herd

In the past ten years the average number of collared adult females on the Bluenose-East calving ground in June has been 28 (range 15-43). The average number of collared females on the Bathurst calving ground has been 16 (range 8-29) and the average number of collared adult females on the Beverly calving ground has been 20 (range 11-34). At least 15 collars are needed to detect emigration rates of less than 10% (Boulanger et al 2024). A plot of caribou locations on approximately June 10th for caribou that occurred on calving grounds for more than 1 year shows fidelity as well as movement of caribou between the calving grounds (Figure 11-A). One of the most notable trends is movement from the Bathurst calving ground to both the Bluenose-East and Beverly calving grounds in most years. In addition, some movement from the Bluenose-East calving ground to the Bluenose-West, Bathurst, and Beverly is indicated from 2023-2025.

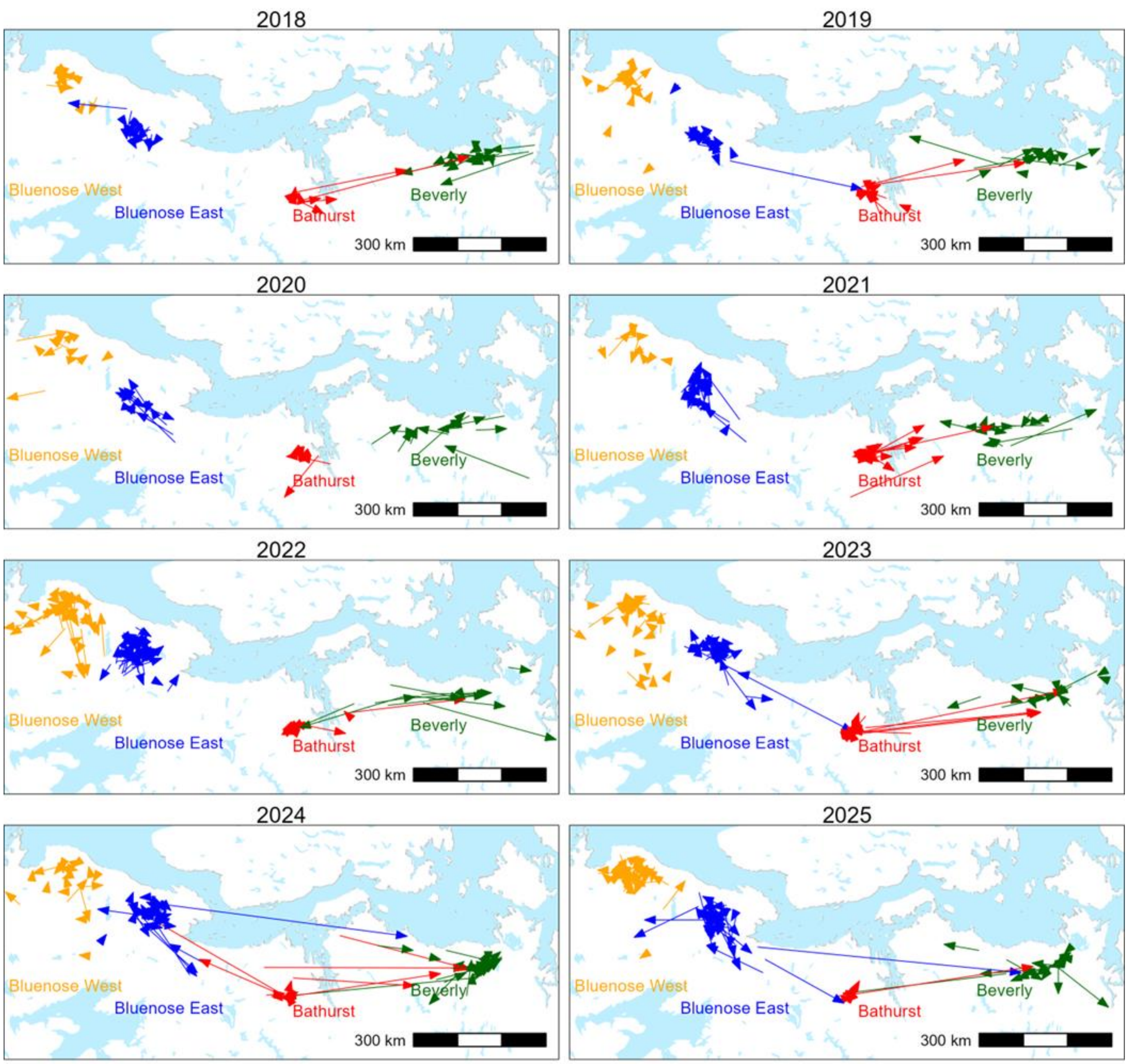

Figure 11-A. Locations of caribou on June 10 for previous (tail of arrow) and current (arrow) year for caribou that occurred on calving grounds for more than 1 year. Color of arrow indicates calving ground from the previous year.

A chart (Figure 12-A) summarizes frequencies of fidelity and movement (below). Each facet displays a calving ground. The column for the herd for the calving ground displays levels of fidelity (caribou returning to the calving ground from the previous year) with movement into or out of the calving ground also indicated. For example, in 2025 for the Bluenose-East herd, 34 caribou returned to the calving ground from the previous year, 2 moved to Bluenose-West, 1 moved to the Bathurst, and 1 moved to the Beverly. One caribou moved into the Bluenose-West, however, inspection of the previous figure suggests this caribou was separate from the main herd so would be a "grey zone" caribou as described previously in the report. General patterns of some increase in movement from the Bluenose-East herd, continued movement out of the Bathurst herd, and movement into the Beverly is suggested.

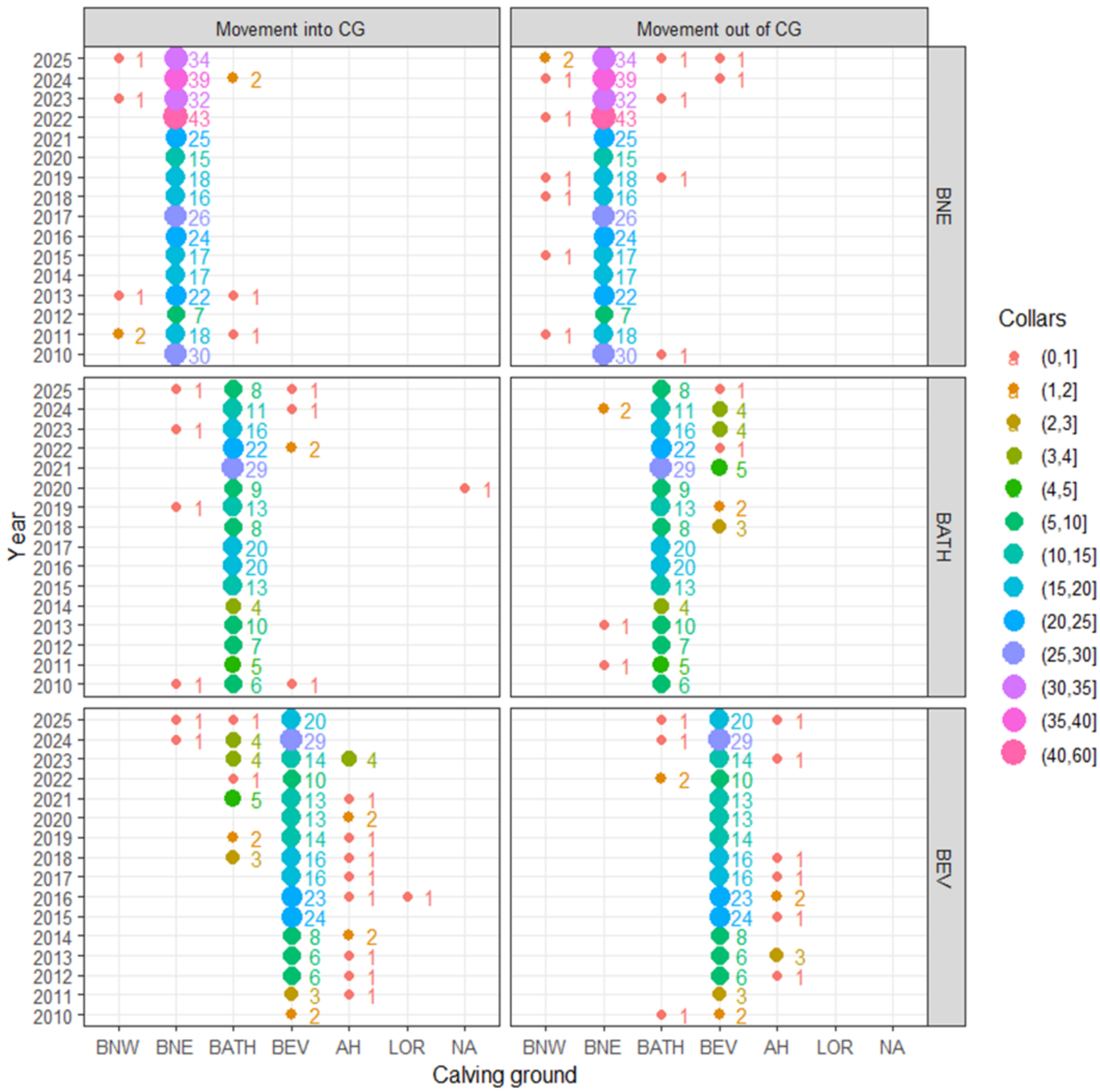

Figure 12-A. Frequencies of collars showing fidelity and movement events from calving ground areas.

The current IPM model did not attempt to model emigration or immigration from the Bluenose-East herd each year and therefore it is assumed that emigration and immigration from the herd are equal. This topic is discussed further in the discussion section of the report.

Discussion

The IPM results incorporating observed field data as of 2025 suggest that the Bluenose-East herd is increasing at an approximate 5% rate per year since 2021. This rate coincides to rates derived from the ratio of 2021 and 2025 adult female and herd size estimates (i.e., if there was a constant rate of increase between the 2021 and 2025 estimates). IPM estimates also suggest that the best estimate of trend is using the ratio of 2021 and 2025 estimates compared to the ratio of 2023 to 2025 estimates which would suggest a decline. Past IPM analyses (Boulanger et al. 2024) considered a variety of hypotheses regarding the potential increase from 2021 to 2023 with the general conclusion of an increase from 2021-2023 with an annual rate (λ) ranging from 3 to 11%. Results from the 2025 survey further affirm this range of increase (estimate of 5%).

As noted previously, the IPM seemed to fit the 2025 lower bull:cow ratio, however, we suggest this fit be interpreted cautiously since it is at the very tail end of the data set. Therefore, there is little data to allow cross-estimation/validation of this estimate. For example, future estimates of survival and abundance will allow the IPM to better assess if the potential decrease in bull abundance is supported by other data sources.

The effect of immigration or emigration into the Bluenose-East herd will be considered in future modelling efforts. Models that considered immigration of caribou from the Beverly herd were considered in analysis of the 2023 calving ground survey in addition to power analyses that assessed the power to detect movement between herds (Boulanger et al. 2024). The general conclusion of these analyses was that undetected immigration, or emigration was likely and power to detect these events was relatively low. We note that modelling emigration from a herd is relatively easy since it can be estimated based on the current herd size X a fidelity rate estimated from collars, although this typically assumes that each collars represents an equal proportion of the females or males in the herd. Modelling movement into the herd is more challenging since it depends on the current yearly size of neighboring herds along with their associated estimates of fidelity and emigration. Emigration or immigration will potentially affect both survival rates as well as fecundity IPM parameters since variation in each parameter will affect herd abundance. To confront this issue a multi-herd IPM is being considered that simultaneously models movement between neighboring herds. This approach would allow both collar and other measures to model demography of each herds. In addition, multi-strata models have (Adamczewski et al. 2015) been used to separate movement events between herds from true mortality events.

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