APPENDIX P

TERRESTRIAL RESOURCES TECHNICAL SUPPORT DOCUMENTS

P-1 Baseline Terrestrial Report
P-2.1 GHD Category 2 and Category 3 Updated Modelling Report (Ferrit 2024)
P-2.2 Resource Selection Probability Modelling of Calving Areas using Recent Satellite Telemetry Data (Minnow 2024)
P-2.3 Resource Selection Probability Modelling of Calving Areas Using GHD Spring & Summer and MECP Category 1 Areas (Ferrit 2024)
P-2.4 Report on Caribou Sustainability Metrics for the Springpole Project Current and Future Condition Scenarios with Assessments at LSA and RSA Scales (Ferrit 2024)

Report on Caribou Sustainability Metrics (λ) for the Springpole Project

Current and Future Condition Scenarios with Assessments at RSA, RSA-Habitat, and LSA Analysis scales

Sept 4th, 2024

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The purpose of this study is to support the evaluation of the effect of disturbing caribou nursery sites in the Churchill range on the long-term sustainability of caribou. There are two parts to the report. Section 1 deals with assessing alternative sustainability metrics under current condition, and Section 2 deals with comparing sustainability metrics under current versus future conditions. Assessments are conducted at 3 scales of analysis, RSA-Population, RSA-Habitat, and LSA.

Summary: The analysis of caribou sustainability metrics for current condition in Section1 reveals remarkable consistency in the estimates of long-term sustainability (λ), regardless of method used. Empirical methods based on survey data regression, analytical methods and Leslie matrix methods all produced estimates of λ ranging from about 0.937 to 0.9490, regardless of analysis scale. All these estimates suggest caribou are in a state of long-term decline if habitat is assessed across the entire Churchill range (RSA-Habitat level) or combination of regional ranges (RSA-Population level). The highest estimate resulted from analysis of new recruitment data from aerial surveys, with λ increasing to 0.977. Most of these estimates were within the range of λ given in IRA reports. The Leslie Matrix eigen value estimate of λ is particularly useful as it integrates long-term trends and age-specific survivorship and provides a more robust perspective on λ for assessing effects of disturbance.

The scenario analysis of the Springpole Project footprint on λ also revealed consistencies among methods, especially for the RSA-Population and RSA-Habitat scales. These are the scales most ecologically meaningful to caribou given their home range size. The LSA scale was included mainly for completion but does not estimate the effect of disturbance at the level of the caribou herd as a whole. At the RSA-Population and RSA-Habitat scales, the % change in λ decreased by less than 1%, with decreases ranging from a low of 0.011% to a high of 0.061%. Change was generally lower when assessed at the RSA-Population scale versus the RSA-Habitat scale. Of course, change was much higher when assessed at the local LSA scale of a 10 km buffer around the Project footprint, with a % decrease in λ of between 0.44% to 1.34%, but even for the LSA level the % change in λ was small.

The assessed impacts to sustainability varied depending on the scale of analysis. At RSA-Population level with 31.92 % total disturbance, under future condition the probability of maintaining a self-sustaining population was 68.85%, resulting in a moderate-low risk to sustainability (Figure 7,

Table 14). For the RSA-Habitat and LSA scales with 42% total disturbance, probabilities of maintaining a self-sustaining population of 52.5% and 52.3% translate to moderate risk to sustainability. Springpole Project adds marginally to the impact, with a decrease in λ of less than 1% caused by disturbance resulting from the overall Project footprint, and a decrease in probability of maintaining a self-sustaining population of -0.39% at the RSA-POP level. Note, however, that when using the new caribouMetrics package for estimates, this estimate decreases the sustainability estimate by -3.74% at the RSA-POP level.

Contents

Section 1: Sustainability Metrics under Current Conditions

Issues and approaches

There are several approaches to assess long-term sustainability and risk to the population, including the EEC approach of relating level of disturbance to recruitment rate and probability of sustainability, mapping changes in GHD category 2/3 habitat, changes to breeding and nursery habitat, and calculating changes to the expected population trend. Each of these approaches offer slightly different perspectives on the impact of disturbance resulting from the proposed mining activity. In Section 1 of this report, I will evaluate the approach of assessing changes to the finite rate of population increase, lambda (λ), and potential impacts of the Project footprint on these metrics of sustainability under current conditions. This section includes assessment of both existing metrics from Integrated Range Assessment (IRA) reports, plus new analysis conducted for the Project.

New analysis included population dynamic modelling of λ to explore net effects of calving area disturbance using the following 3 approaches:

1. Empirical modelling of λ based on 3 years of recent population monitoring (2021-2023).
2. Vital rate analytical modelling of λ based on survivorship and changes to overall recruitment.
3. Leslie matrix approach to simulate λ and net effects over time.

There are three study areas used for to assess impacts to caribou from the Springpole Project; 1) a population level regional study areas (RSA-population) , which is the combined Berens, Kinloch, and Churchill ranges; 2) a habitat based regional study area (RSA- habitat) which consists solely of the Churchill Range; and, 3) a local study area (LSA) which a 10 km buffer around the Project footprint. For the RSA-Population average values were used to estimate the current condition of this "regional" population, wherever possible. For Section 2 of the report, analysis included RSA-Population, RSA-Habitat, and LSA analysis units.

Empirical modelling of λ

Population monitoring within the caribou RSAs (Figure 1) was conducted over the years 2021-2024. An estimate of λ can be obtained through log-linear regression of $\ln(N_t)$ versus t, where N is the observed number of caribou at time t. The survey area (number of plots) differed among the 3 years, so to make the estimate of N consistent across years, maximum animal count (MAC) was first transformed to density (N/survey area), and then scaled to a common survey area by multiplying density * maximum survey area (16276 km^2) over the 3 years (Table 1). The intercept of the regression will be affected slightly by the survey area used in the calculation, but the slope will be unaffected. From the slope of the regression, λ is estimated as:

$$\lambda = e^{(\text{slope})}$$

From density estimates given in Table 1Table 1, λ in the RSA-Habitat is estimated as $e^{(-0.05235)}$, = 0.9490, indicating that caribou population in the areas is in a downward trend.

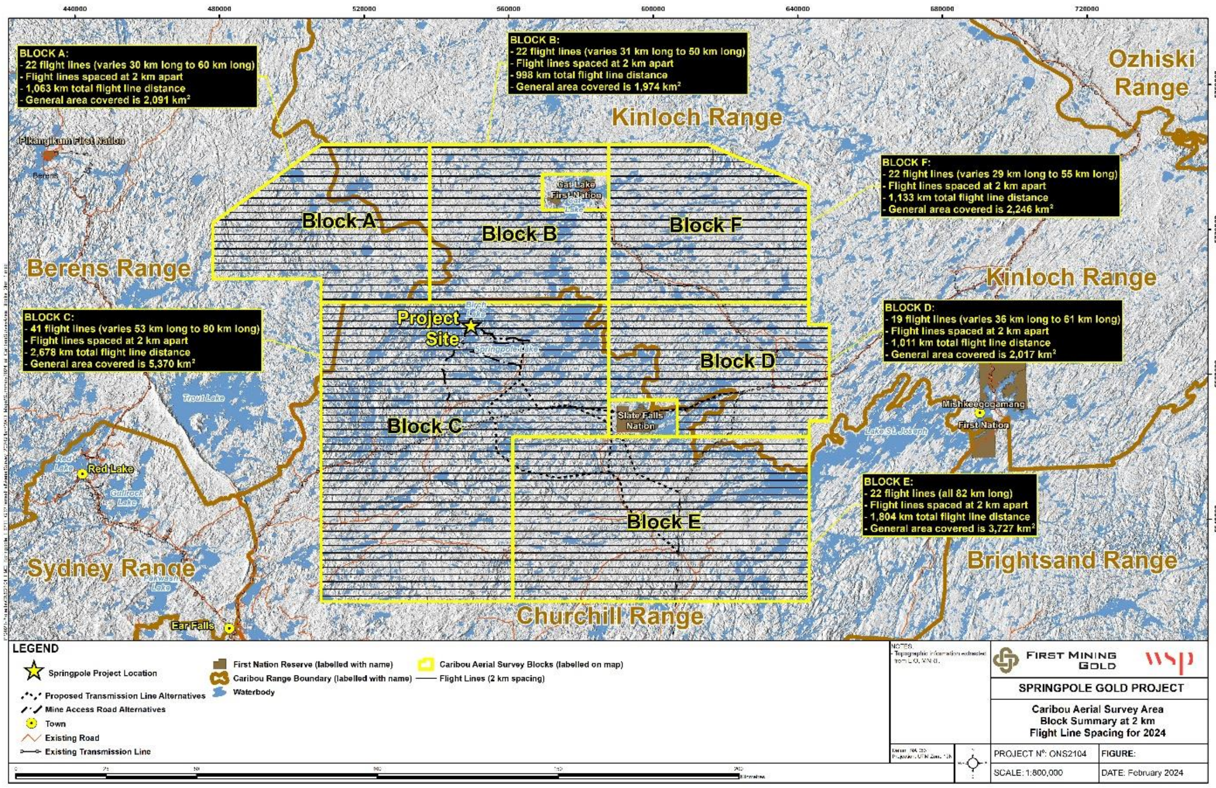

Figure 1. Caribou aerial survey flight lines

Table 1. Caribou minimum animal counts and density from recent surveys used to estimate λ from slope of population trend.

t	Survey MAC	Survey Area	Density (/km²)	*N*[1]	$\log_e(N)$
2021	196	6681.4	0.029335	344.31	5.841535
2022	320	12253.5	0.026115	306.51	5.725254
2023	430	16276.0	0.026419	310.08	5.736835

1. *N* coded as density * maximum survey area (16276)

Vital rate (simple analytical) modelling of λ

Population trend (λ) can also be estimated based on vital rates. The IRA reports present recruitment as calves per 100 adjusted adult females, where adult female (cow) adjustments are estimated from unknown adults based on survey estimated sex ratio. Calculation of λ, however, requires recruitment expressed as calves per adult, or female calves per total females. The IRA reports use the female-only equation (Hatter and Bergerud 1991):

$$\lambda = {}^{s}/_{(1 - R_f)}, \qquad \text{equation 1}$$

where s = adult female survivorship; R_f = female only recruitment ((calves per 100 adult females/2)/(100 + (calves per 100 adult females/2)).

Earlier IRA estimates of λ from 2009 onwards were calculated for Churchill, Berens, and Kinloch ranges as 0.96, 0.93, and 0.95, respectively, with an average value of 0.953 from the IRA reports (Figure 2). Using survival and recruitment estimates from those same IRA reports, λ was calculated as 0.931, as both Berens and Kinloch had λ estimates lower than those in the reports (Table 2).

Population monitoring between 2021 and 2023 also produced new estimates of *R* for those years, and assuming the same survival rate of 0.87, resulted in an average λ of 0.964 (Table 3). This represents a more optimistic perspective on population persistence than regression-based estimate of λ (0.949), as recruitment estimates appear to have increased slightly, or at least levelled off in recent years. However, multiple lines of evidence continue to suggest that λ remains below a sustainable value of 1.0, at between 0.93 and 0.96 within the caribou RSA-Population.

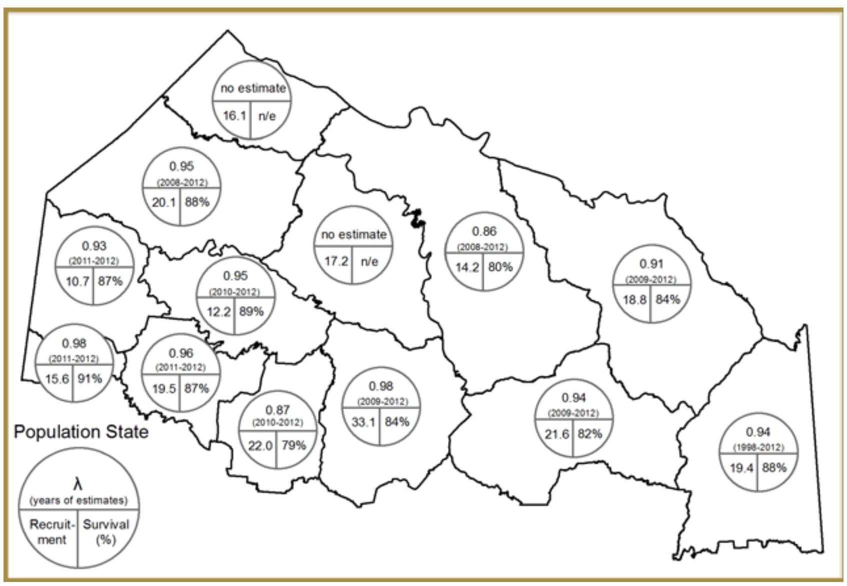

Figure 2. Recruitment, survival, and lambda estimates from IRA reports (taken from figure 2.5, (Ontario Ministry of Natural Resources and Forestry [MNRF] 2014)).

Table 2. Estimates of λ based on values taken from IRA reports, for surveys between 2008 and 2013.

Range	Calves per 100 cows	R_f	Survival (s)	λ[1]	IRA λ[2]
Churchill	19.5	0.0888	0.87	0.955	0.96
Berens	10.7	0.0508	0.87	0.917	0.95
Kinloch	12.2	0.0575	0.87	0.923	0.95

Average	14.13	0.0707	0.87	0.931	0.953

1. Calculated using reported *R* and *s*.
2. Values provided in IRA reports.

Table 3. Estimates of λ based on recruitment estimates (calves:100 cows) from recent population monitoring (2021-2023).

t	Calves per 100 cows	R_f	Survival	λ
2021	16.67	0.0769	0.87	0.943
2022	28.38	0.1243	0.87	0.993
2023	20.12	0.0914	0.87	0.958
Average	21.72	0.10	0.87	0.964

Leslie matrix approach to simulate λ

The Leslie matrix approach can be used to simulate population dynamics over longer time periods, allowing for more detailed and realistic analysis of population trends using age specific vital rates (, thus the Leslie matrix is producing results similar to that expected using the Equation 1 approach.

The Leslie (female-only) matrix results in an average year-to-year λ of 0.9390 over the periods 5 to 40, which is consistent with both the empirical and vital rate estimates of λ. A more elegant and robust solution is the eigenvalue of the matrix, which results in a λ of 0.9365. As noted above, this value integrates the age structure and fecundity schedule, and provides a similar, but more precise long-term estimate of λ, and will be used for assessing the effect of disturbance on λ (population sustainability). At this level of λ, the population is in long-term decline (Figure 3).

Table 4). The Leslie matrix incorporates both age-specific fecundity and survivorship rates, structured across multiple age classes (Table 5). This approach takes into account the entire age structure of the population and the transitions between age classes. The matrix method explicitly models how individuals move through different age classes over time, reflecting the true reproductive and survival potential at each stage. λ can be calculated as the dominant eigenvalue of the Leslie matrix. This eigenvalue represents the long-term growth rate of the population, considering the stable age distribution that the population eventually reaches. The eigenvalue method inherently accounts for the compounding effects of survival and reproduction over multiple generations.

In contrast, the simple method given in Equation 1 does not consider the age structure or the specific transitions between age classes. This method treats survivorship and fecundity as independent averages, which does not precisely capture the dynamics of population growth over time in that it ignores the age structure and assumes a homogeneous population, leading to an oversimplified view of population dynamics. Finally, It assumes a single time point and does not account for the cumulative effects over multiple generations.

As noted above, the Leslie matrix method adds a complication in that it considers the entire age-structures, and thus uses fecundity or live births, rather than recruitment, which is measured through aerial surveys sometime after live-births. Therefore, *R* must be expressed as live-birth rate, and then adjusted by reducing survival for the young of year (YOY) age class, which includes neonates. In Ontario, the pregnancy rate of caribou is generally between 0.8 and 0.89, and pregnancy rate, (State of Woodland Caribou Resource – Part 3), average *Rf* in the 3 ranges (RSA-Population) of 0.0707 (Table 2), and survival is 0.87. Expressing *R* as an average live birth rate of 0.8 (0.4 for females only), with a YOY survival rate of 0.35, results in an average simulated *Rf* of 0.0686. This recruitment level is associated with an average λ of ca. 0.93 (Table 2), thus the Leslie matrix is producing results similar to that expected using the Equation 1 approach.

The Leslie (female-only) matrix results in an average year-to-year λ of 0.9390 over the periods 5 to 40, which is consistent with both the empirical and vital rate estimates of λ. A more elegant and robust solution is the eigenvalue of the matrix, which results in a λ of 0.9365. As noted above, this value integrates the age structure and fecundity schedule, and provides a similar, but more precise long-term estimate of λ, and will be used for assessing the effect of disturbance on λ (population sustainability). At this level of λ, the population is in long-term decline (Figure 3).

Table 4. Leslie Matrix with fecundity/2 (females only) on top row, and survivorship on sub-diagonal.

YOY	Yearling	Young Adult	Young Adult	Mature Adult	Mature Adult	Mature Adult	Mature Adult	Old Adult	Old Adult	Oldest age class
0	0	0.39	0.39	0.41	0.41	0.41	0.41	0.39	0.39	0.39
0.35	0	0	0	0	0	0	0	0	0	0
0	0.85	0	0	0	0	0	0	0	0	0
0	0	0.88	0	0	0	0	0	0	0	0
0	0	0	0.88	0	0	0	0	0	0	0
0	0	0	0	0.87	0	0	0	0	0	0
0	0	0	0	0	0.87	0	0	0	0	0
0	0	0	0	0	0	0.87	0	0	0	0
0	0	0	0	0	0	0	0.87	0	0	0
0	0	0	0	0	0	0	0	0.87	0	0
0	0	0	0	0	0	0	0	0	0.82	0

Table 5. Leslie-matrix vital rate schedule for females only in the caribou RSA-Population. Similar to how recruitment was adjusted for female only model (equation 1), fecundity is also adjusted for female only model.

AGE CLASSES	Sex / Age	Average Fecundity	Fecundity Female only	Natural Mortality	Survival	Year 1
YOY	Female 0	0	0	0.65	0.35	60
Yearling	Female 1	0	0	0.15	0.85	40

Young Adult	Female 2	0.78	0.39	0.12	0.88	20
Young Adult	Female 3	0.78	0.39	0.12	0.88	18
Mature Adult	Female 4	0.82	0.41	0.13	0.87	14
Mature Adult	Female 5	0.82	0.41	0.13	0.87	12
Mature Adult	Female 6	0.82	0.41	0.13	0.87	10
Mature Adult	Female 7	0.82	0.41	0.13	0.87	8
Old Adult	Female 8	0.78	0.39	0.13	0.87	6
Old Adult	Female 9	0.78	0.39	0.18	0.82	4
Oldest age class	Female 10	0.78	0.39	0.18	0.82	2
Total Female Population	All	0.80[1]	0.4	0.14[2]	0.86[2]	194

1. Average fecundity for females >= 2. In the model this translates to a recruitment *R* of ca. 0.14
2. Average mortality and survival for females >= 1

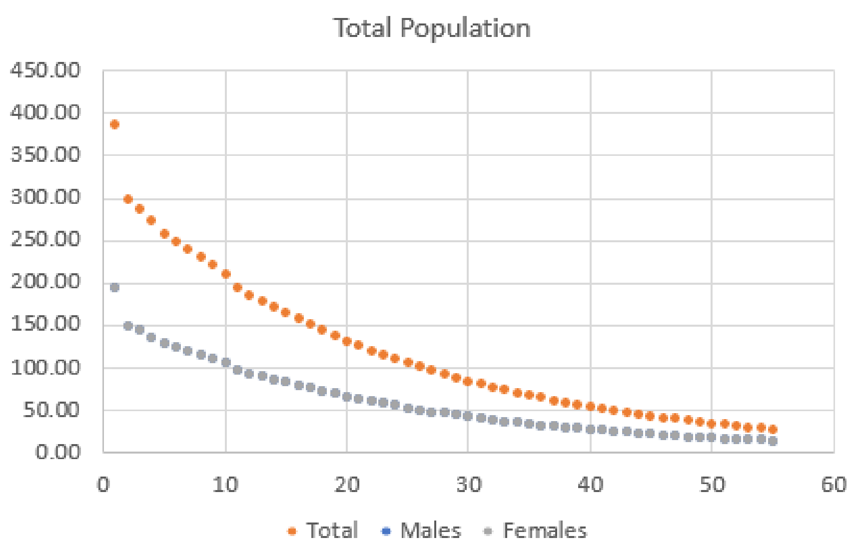

Figure 3. Change in population level over 55 years as estimated from the Leslie Matrix model.

Section 2 – Scenario Analysis of Sustainability Metrics under Current vs. Future Conditions

Assessing Disturbance Effects on Sustainability

The effect of disturbance on the long-term sustainability of the caribou population was assessed at 3 analysis scales, RSA- Population, RSA-Habitat, and LSA. The RSA-population included the 3 contiguous ranges, Berens, Kinloch, and Churchill. Habitat (RSA-Habitat) included only the Churchill range, and local (LSA) was a 10-km buffer around the Springpole Project. To assess future condition, the buffered (500 m) Project footprint was added to the current disturbance signature (Figure 4).

Three approaches were used to assess the effect of the Springpole Project on long-term sustainability:

1) **Federal ECCC statistical relationships between disturbance and recruitment.**
    a. Map and calculate % disturbance using Provincial/Federal mapping standards for current and future conditions for the 3 analysis scales (RSA-Population, RSA-Habitat, and LSA). See mapping method below.
    b. Apply the ECCC statistical relationships between % disturbance and recruitment and survival rates (Johnson et al. 2020) to estimate % change in sustainability (λ) as a consequence of adding additional disturbance from the Springpole Project.
2) **Leslie Matrix model of to assess effects of change in disturbance and recruitment rates.**
    a. Apply the above estimated % change in recruitment and survival rates to lower these vital rates in the Leslie matrix model for the 3 analysis scales.
    b. Estimate % change in sustainability (λ) as a consequence of adding additional disturbance from the Springpole Project.
3) **Predictive model of calving and nursing habitat**
    a. Predict change in category 1 habitat (calving and nursing area) for current and future conditions for the 3 analysis scales (see Row (2024) report).
    b. Directly apply the % change in category 1 habitat to lower fecundity rate for the Lesli Matrix model, and use the estimated survival rate from the ECCC statistical relationship with disturbance to lower survival rate.
    c. Estimated % change in sustainability (λ) as a consequence of adding additional disturbance from the Springpole Project.

Federal/Provincial Method to Map and Calculate % Disturbance.

1. Initial procedure follows that used in the Woodland Caribou Integrated Range Assessments (Province of Ontario) whereby vector layers representing existing infrastructure, industrial, recreational and resource extraction features were buffered by 500 m, then combined and dissolved into a single anthropogenic disturbance layer. Based on earlier discussion, mining lease and patent lands were excluded as disturbance layers (Figure 5A)
2. Burns from PIAMM database that were <= 37 years old were added to the anthropogenic disturbance layers (Figure 5B). This follows Provincial protocol.
3. Additional recent harvest that was not included in some of the 7 FMU shapefiles were then added from the PIAMM database (buffered by 500 m). Only a few areas were added, and these were generally 2023/2024 harvest records (Figure 5B).
4. The resulting buffered anthropogenic and unbuffered burn disturbance layer for current condition is shown in Figure 5C.
5. The Springpole Siteplan 24 PDA footprint was then added to the current condition map to create the future condition disturbance layer (Figure 4).
6. Percent disturbance was calculated using the Federal method, where % disturbance = area of disturbance/total area of the range, including water (but not reservoirs). Buffered anthropogenic and fire disturbance calculated separately.

7. At the RSA-Population level, the ECCC 2020 disturbance layers (Environment and Climate Change Canada 2024) for the 3 ranges (Berens, Far North, and Churchill) were merged and clipped to the RSA-Population boundary (Figure 6A). The project footprint (Site Plan 24 PDA) was then added (Figure 6B).

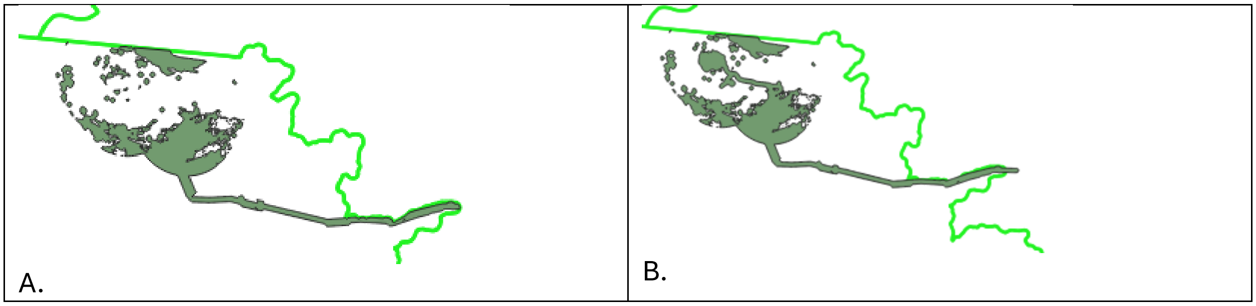

Figure 4. Buffered Project disturbance. A. Current condition; B. Future condition with proposed Siteplan 24 PDA (buffered 500 m) added.

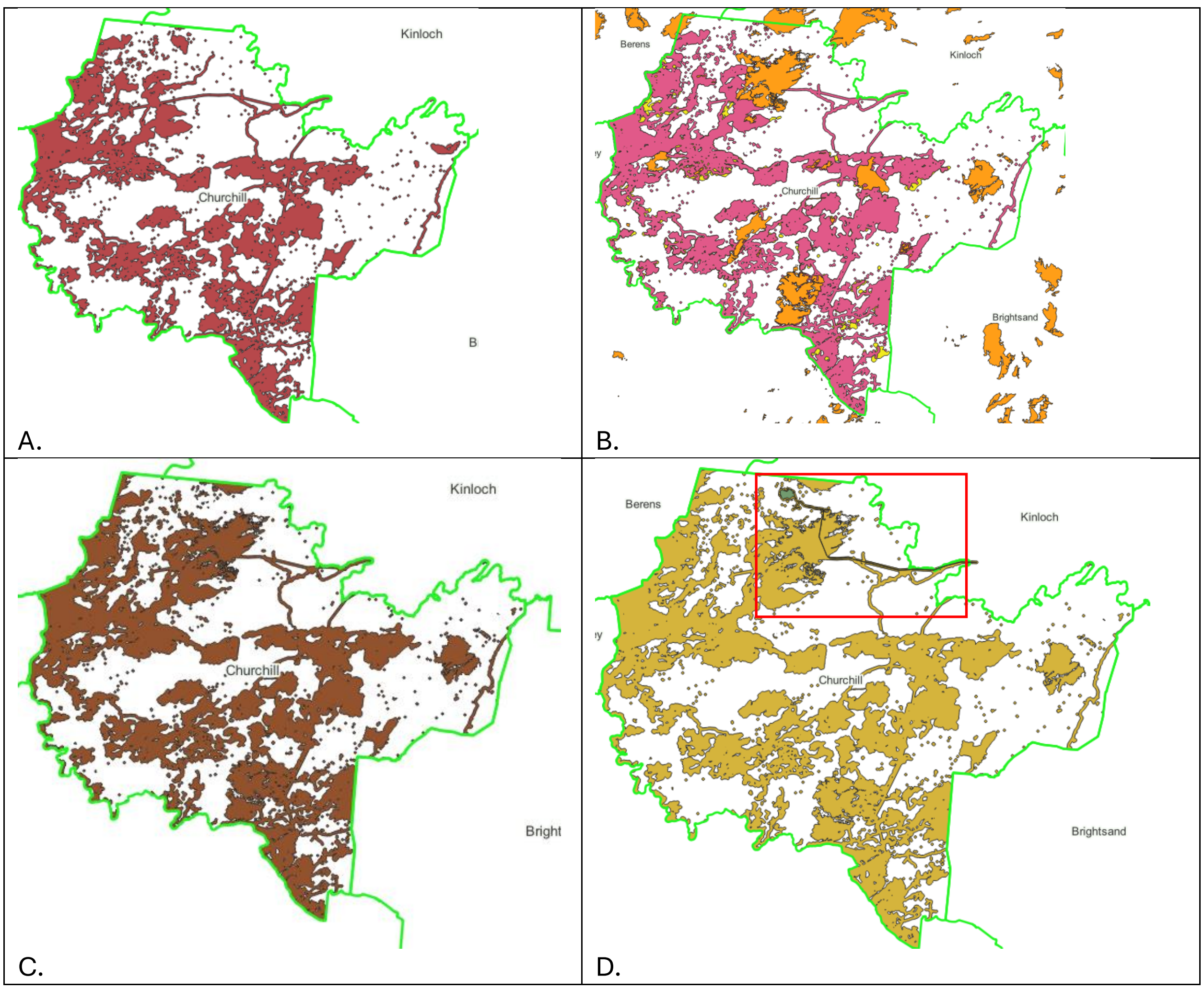

Figure 5. Disturbance analysis for RSA-Habitat scale. A. Buffered anthropogenic disturbance (initial); B. Burns <40 years old (from PIAMM database) added to anthropogenic disturbance (orange) and additional buffered harvest from PIAMM

database added (yellow); C. Final updated disturbance area, current condition; D. Final updated disturbance, future condition, with proposed Siteplan 24 PDA (buffered 500 m) added (area in red outline).

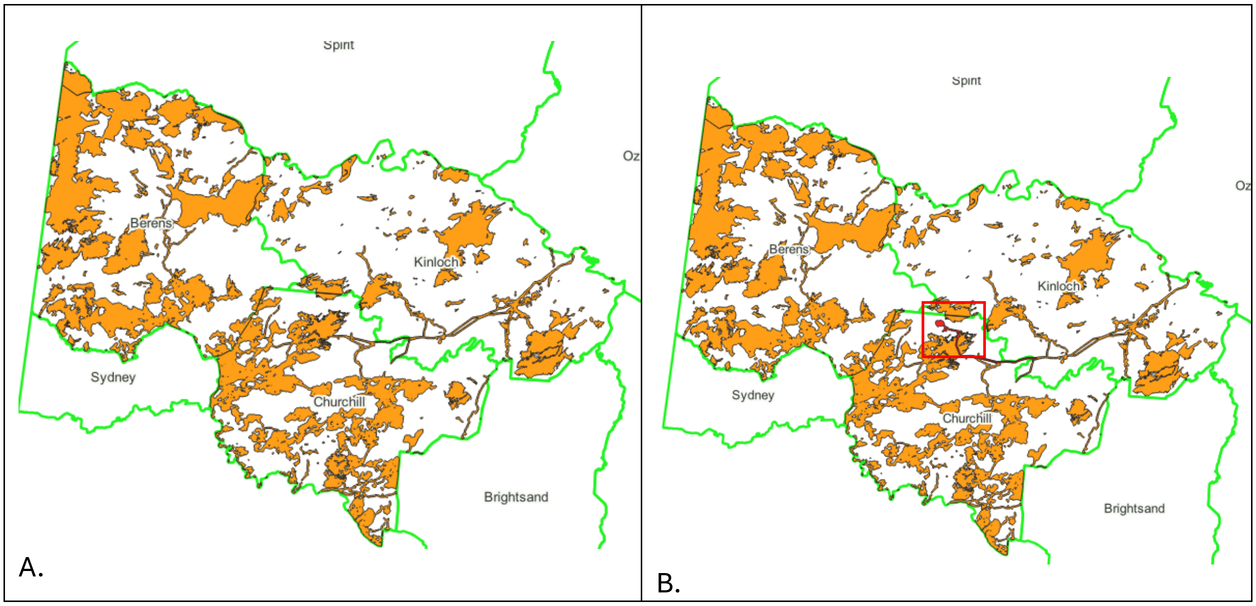

Figure 6. Disturbance analysis at RSA-Population scale. A. Compiled disturbance data from ECC (2020). A. Current condition; B. Future condition with proposed Siteplan 24 PDA buffered to 500 m (area outlined in red).

Federal Disturbance Relationships with Recruitment, Survival, and Probability of Maintaining a Self-Sustaining Population.

To relate changes in disturbance to the vital rate statistics or recruitment and survival, I used the re-derived M4 model (buffered anthropogenic disturbance and unbuffered fire) presented by Cheryl Johnson of ECCC (Johnson et al. 2020). The M3 model (total disturbance only) was used in the original 2011 report (Environment and Climate Change Canada 2011) (see figure 8 in the report) but the M4 model performed better for both survival and recruitment under updated data (Johnson et al. 2020). The Johnson et al. (2020) report also provided coefficients from alternative models to estimate the effect of % disturbance on recruitment and survival (see image of table 3 from the report below). The R package caribouMetrics (Matt Dyson et al. 2024) contain the coefficients and models used in the Johnson et al. (2020) report, and coefficients from model M4 were used to estimate the % change in disturbance resulting from the Springpole Project on recruitment and survival (**Error! Reference source not found.**). This % change was then applied to both the analytical equation 1 for λ, and the Leslie Matrix model (described in Section 1 above) by decreasing survival and recruitment by the estimated amount to assess long-term change in sustainability resulting from the additional disturbance.

To estimate the probability of maintaining a self-sustaining population where λ is stable, i.e., the proportion of times λ >=0.99, I used the ECCC ensemble model (Environment and Climate Change Canada 2011) (

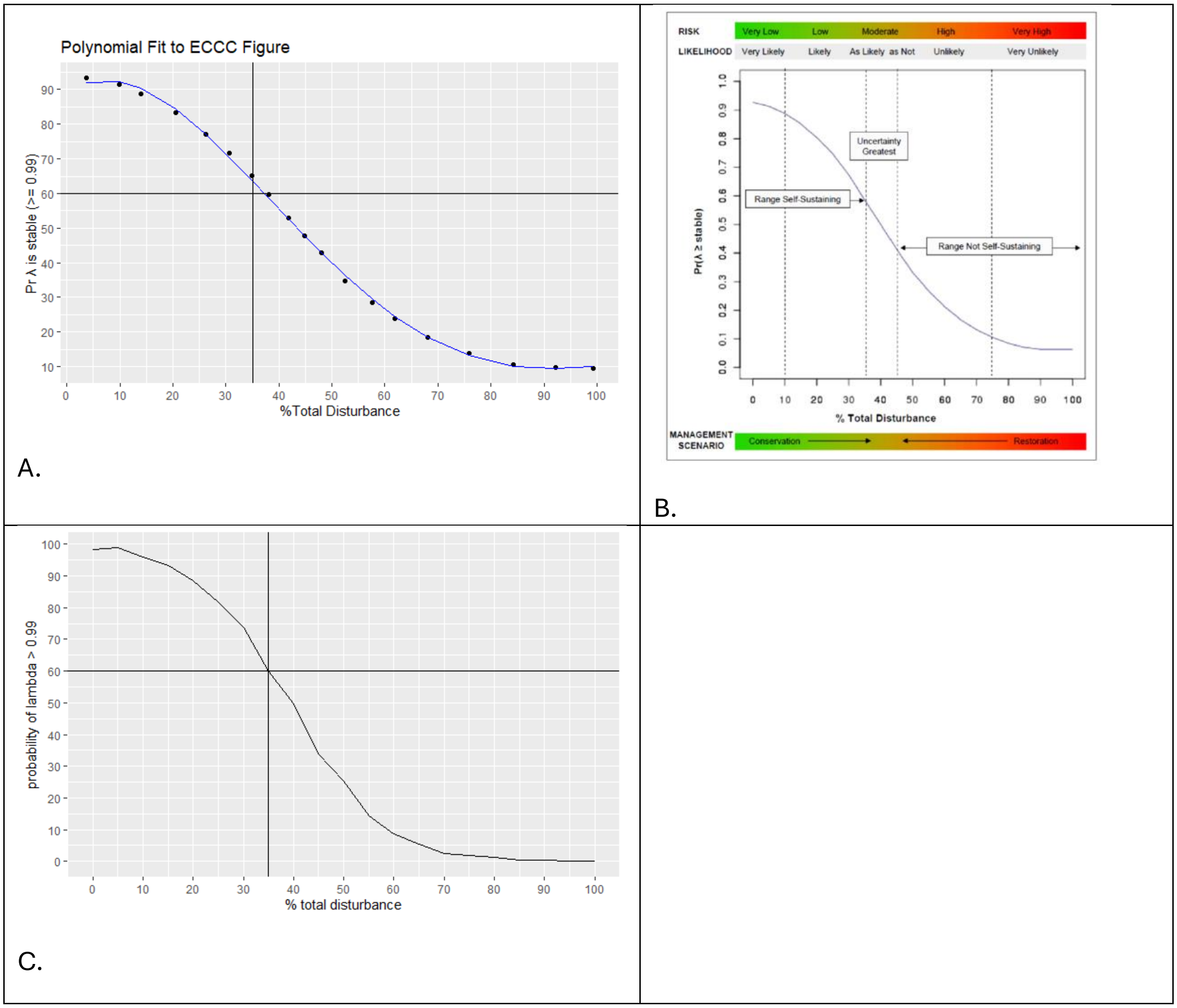

Figure 7BFigure 6). The model uses the M3 relationship between total disturbance and recruitment. A digital form of the model was created to estimate exact amounts (Figure 7A). In addition, I also used the caribouPopGrowth function in the caribouMetrics package to emulate the ECCC model (Figure 7C) using parameter code provided by the authors (Josie Hughes, ECCC, pers. Comm).

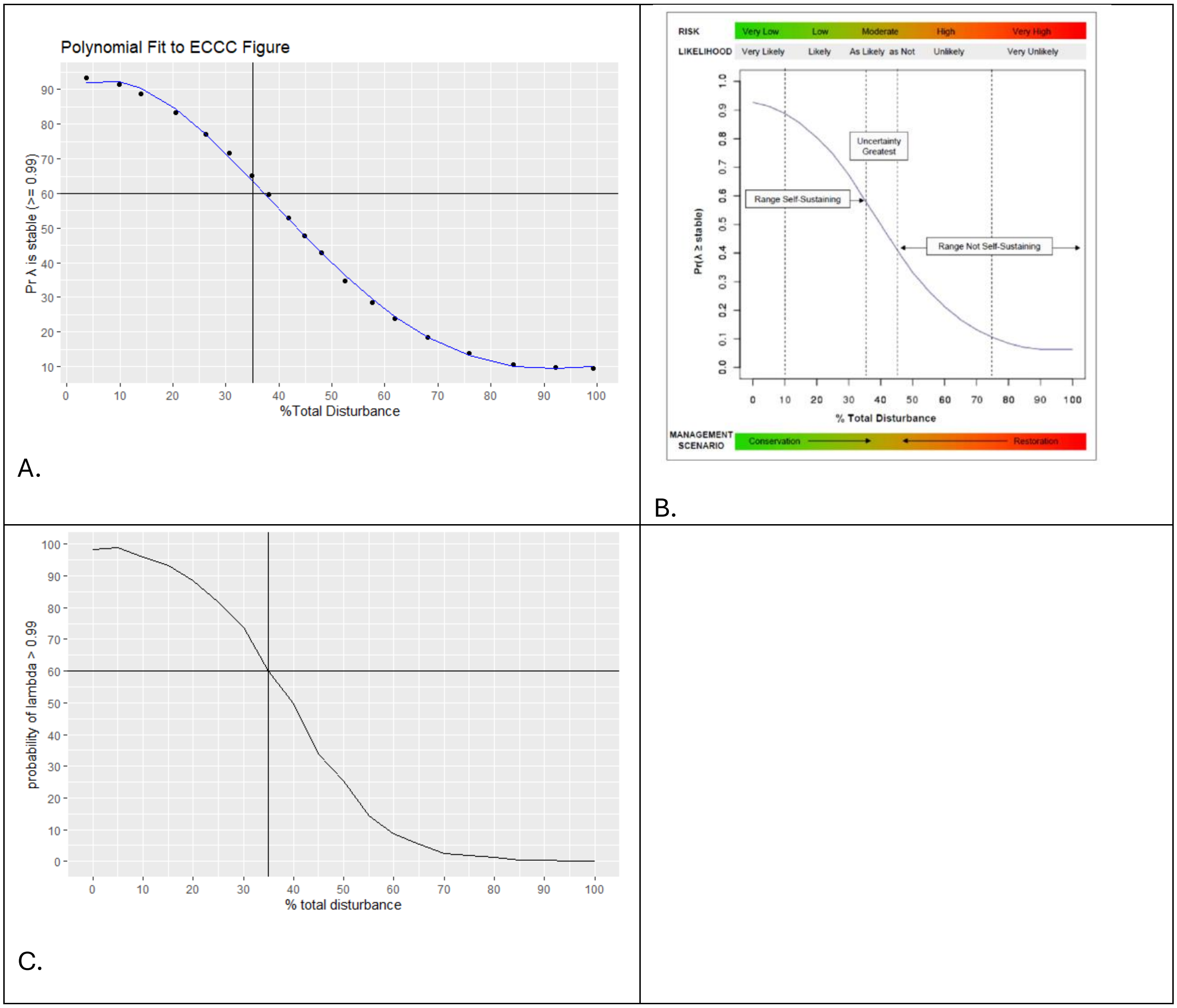

Figure 7. ECCC ensemble model relating probability of a self-sustaining population to total disturbance. A. Digital version of original ECCC 2011 relationship; B. Original ECCC 2011 figure, C. carbiouMetrics package emulating original ECCC relationship.

Assessing Change in Breeding Habitat

Methods exist to predict change in GHD categories 2 and 3 (range level habitat) resulting from changes in landscape condition, and these were applied in a separate report to assess change in general habitat (FERIT Environmental Consulting 2024c,b) . In contrast, GHD Category 1 habitat includes only calving and nursing habitat as a component, but has been traditionally mapped manually using aerial surveys and a mapping protocol. No predictive models currently exist to assess changes in future condition. To address this, I developed a predictive model presented in a separate report (FERIT Environmental Consulting 2024a) to predict and map Category 1 habitat as a function of disturbance and other landscape variables using some of the same variables and similar methods as used in the Category 2 predictive models. The Cat 1 model demonstrated good performance relative to MECP mapped polygons of breeding and nursery habitat, and was used here to estimate percent change in calving and nursery habitat as a consequence of adding disturbance from the Springpole Project. This % change was then used as a direct estimate to reduce recruitment rate in the Leslie Matrix model as an additional metric to assess change in sustainability resulting from the Springpole Project.

This same Cat 1 model was also used to assess change in calving and nursery habitat between the reference current condition and future condition with the Springpole Project present, over 80 years as landscape condition (disturbance) aged.

Results - Change in vital rates.

The % change in buffered disturbance between current condition and future condition with the Springpole Project was very small at the RSA-Population and RSA-Habitat analysis scales, at less than a 1% increase, with 0.33 % and 0.58% for RSA-Population and RSA-Habitat scales, respectively (Table 6; Table 7). As expected, the % change at the LSA scale was much larger at an almost 14 % increase.

As a result of this increase in disturbance, the predicted change in recruitment (R_f) was -0.26%, -0.17%, and -8.26% for the RSA-Population, RSA-Habitat, and LSA analysis scales, respectively (Table 8). Likewise, the predicted change in survival was less than 1%, with a change of -0.005%, -0.042%, and -0.413% for the RSA-Population, RSA-Habitat, and LSA analysis scales, respectively (Table 8**Error! Reference source not found.**).

The % change in recruitment is also estimated by determining the % change in calving and nursing habitat resulting from addition of the Springpole Project footprint. This resulted in a decrease of habitat of 0.040%, 0.174%, and 1.155%, for the RSA-population, RSA-Habitat, and LSA analysis scales, respectively (Table 9). Note that in a related study by Row (2024) on calving areas where a calving RSF was developed using GPS collar data, they found similar results where the Springpole Project footprint would reduce suitable calving habitat (binary classification) by 0.035%, 0.12%, and 0.88% for the RSA – Population , RSA-Habitat , and LSA scales, respectively (Table 5 in Row (2024)).

Table 6. Area of fire and anthropogenic disturbance calculated using Provincial methods for current conditions (CC) and future conditions (FC).

Study Area	Study Area (km2)	Fire	Anthro	Both	%Fire	%Anthro	%Total disturbance	Overlap[1]
RSA-Hab (CC)	21264.8	1480.565	7369.491	8850.057	7.0%	34.7%	41.6%	6.8%
RSA-Hab (FC)	21264.8	1480.565	7420.625	8901.19	7.0%	34.9%	41.9%	6.8%

1. Percentage of anthropogenic disturbance that overlaps with natural disturbance (fire).

Table 7. Percent change in buffered disturbance at 3 scales of analysis.

Study Area	Study Area (km^2)	Disturbance CC (km^2)	Disturbance FC (km^2)	% Disturbance CC	% Disturbance FC	% Change
RSA-Pop	75919.7	22416.6	22495.6	31.7%	31.8%	0.33%
RSA-Hab	21264.8	8850.1	8901.2	41.6%	41.9%	0.58%
LSA	992.1	365.4	416.5	36.8%	42.0%	13.99%

Table 8. Predicted change in survivorship and recruitment from Johnson et al. (2020) model M4 relationship with % disturbance.

SA	Condition	% Anthro	% Fire	F Surv	Calves: 100 Cows	R_f	% Change Surv	% Change R_f
RSA-Pop	CC	7.07	24.61	0.870	26.22	0.132		
RSA-Hab	CC	34.66	6.96	0.848	18.87	0.095		
LSA	CC	7.29	29.54	0.871	25.09	0.127		
RSA-Pop	FC	7.18	24.61	0.870	26.15	0.132	-0.005%	-0.26%
RSA-Hab	FC	34.90	6.96	0.847	18.84	0.095	-0.042%	-0.17%
LSA	FC	12.45	29.54	0.867	23.02	0.116	-0.413%	-8.26%

Table 9. Percent change between current and future condition for Category 1 (calving and nursery area) habitat based on predictive habitat modelling.

Study Area	% area in Category 1 (Current Condition)	% area in Category 1 (Future Condition)	% Change in Cat1 Habitat
RSA-Pop	0.4045	0.4043	-0.040%
RSA-Hab	0.3267	0.3262	-0.174%
LSA	0.6229	0.6157	-1.155%

Results - Change in Sustainability (λ) Estimates

The estimated effect of disturbance on vital rates from the Johnson et al. (2020) resulted in a decrease in the sustainability metric λ of less than 2%, with estimates of -0.034%, -0.050%, and -1.341% for the RSA-Population, RSA-Habitat, and LSA analysis scales, respectively (Table 10**Error! Reference source not found.**).

The same rate of decrease as estimated from the Johnson et al. (2020) relationships was applied to the Leslie Matrix model to reduce fecundity and survival rates, which provides a longer term, more integrated analysis of λ. From this model, λ decreased by -0.044%, -0.061%, and -0.442% for the RSA, RSA-Habitat, and LSA analysis scales, respectively (Table 11).

The % change in category 1 (nursery and calving habitat) was applied directly to reduce fecundity in the Leslie model. The effect of disturbance on survival was based on the Johnson et al. (2020) report. This resulted in a decrease in λ of less than 1%, with a decrease of -0.011%, -0.042%, and -0.444% for the RSA-Population, RSA-Habitat, and LSA analysis scales, respectively (Table 12Table 11).

An analysis was conducted of long-term change in Category 1 habitat as a result of forest aging, with a comparison of reference condition versus future condition (with Springpole Project footprint added). This analysis reveals a significant increase in Category 1 habitat over 40 years (

Table 13). The increase is a result of aging forest resulting in better Category 1 habitat conditions, as estimated by the predictive model (FERIT Environmental Consulting 2024a). The analysis revealed the largest change in Category 1 habitat occurred at the RSA- habitat scale.

Finally, an analysis of the percent probability of maintaining a self-sustaining population (% Pr λ >= 0.99) was assessed in the RSA-Population, RSA-Habitat, and LSA, respectively (Figure 7). This resulted in a % change in the estimate of -0.39%, -0.73%, and -15.91% in the RSA-Population, RSA-Habitat, and LSA, respectively, using the original ECCC table (

Table 14). The caribouMetrics package provides a slightly revised method of deriving these values, and this resulted in a higher rate of change in lambda of -3.74%, -6.53%, -25.64% in the RSA-Population, RSA-Habitat, and LSA, respectively (Table 13).

Table 10. Effect of disturbance on λ based on ECCC model M4 relationships with recruitment and survival.

SA	**Condition**	**Anthro**	**Fire**	λ	% Change λ
RSA-Pop	CC	7.07	24.61	0.983523	
RSA-Hab	CC	34.66	6.96	0.926927	
LSA	CC	7.29	29.54	0.979586	
RSA-Pop	FC	7.18	24.61	0.983185	-0.034%
RSA-Hab	FC	34.90	6.96	0.926461	-0.050%
LSA	FC	12.45	29.54	0.966449	-1.341%

Table 11. Change in λ (Leslie matrix eigen value) between current and future condition for 3 scales of analysis using ECCC model M4 to estimate the decrease in vital rates resulting from additional disturbance.

SA	Prop Change Surv	Prop Change R_f	λ	% Change λ
CC			0.9365033	
RSA-Pop	-0.000045	-0.002629	0.9360888	-0.044%
RSA-Hab	-0.000417	-0.001663	0.9359336	-0.061%
LSA	-0.004129	-0.082601	0.9323641	-0.442%

Table 12. Change in λ (Leslie matrix eigen value) between current and future condition for 3 scales of analysis, using change in cat1 habitat to estimate drop in fecundity from additional disturbance.

Breeding Habitat Disturbance (Cat 1)	% change in survival	% change in fecundity	λ	% change in λ
Current Condition			0.93650	
RSA-Pop (FC)	-0.006%	-0.040%	0.93640	-0.011%
RSA-Hab (FC)	-0.018%	-0.174%	0.93611	-0.042%
LSA (FC)	-0.312%	-1.155%	0.93236	-0.444%

Table 13. Long-term change in Category 1 breeding and nursery habitat for the 3 study areas.

Study Area	CC (T1)	FD (T1)	CC (T2)	FD (T2)	% Change 1	% Change 2
RSA-Pop	0.4045	0.4043	0.4410	0.4291	9.03	6.13
RSA-Hab	0.3267	0.3262	0.7794	0.7794	25.12	26.59
LSA	0.6229	0.6157	0.3599	0.3599	10.15	10.33

1. CC is current (reference) condition and FD is future disturbance with Springpole Project footprint added.
2. T1 is time period 1, Project start, (0-20 years), with no aging of forest disturbance, and T2 is time period 2, with aging of forest disturbance to > 40 years of age (40-80 years).
3. % change 1 is change in reference condition at time periods T1 and T2, and % change 2 is comparison of future disturbance at time periods T2 versus reference condition at Project start (T1).

Table 14. Probability of maintaining a self-sustaining population (PMSSP) where $\lambda >= 0.99$.

SA	**Condition**	**% Fire**	**% Anthro**	**% Total disturbance**	**PMSSP[4]**	**PMSSP[5]**	**% change[4]**	**% change[5]**
RSA-Pop[1]	CC			31.75	0.687	0.703		
RSA-Hab[2]	CC	6.96	34.66	41.62	0.529	0.427		
LSA[3]	CC	29.54	7.29	36.83	0.606	0.549		
RSA-Pop	FC			31.92	0.685	0.674	-0.39%	-3.74%
RSA-Hab	FC	6.96	34.90	41.86	0.525	0.399	-0.73%	-6.53%
LSA	FC	29.54	12.45	41.99	0.523	0.450	-15.91%	-25.64%

1. Disturbance % calculated from ECCC 2020 data source (Environment and Climate Change Canada 2024), using ECCC method
2, 3. Disturbance % calculated from Provincial (PIAMM) data source, using Provincial methods
4. PMSSP based on digital version of original ECCC figure
5. PMSSP based on caribouMetrics package emulation of ECCC figure

Summary

The analysis of caribou sustainability metrics for current condition in Section1 reveals remarkable consistency in the estimates of long-term sustainability (λ), regardless of method used. Empirical methods based on survey data regression, analytical methods and Leslie matrix methods all produced estimates of λ ranging from about 0.937 to 0.9490, regardless of analysis scale. All these estimates suggest caribou are in a state of long-term decline regardless of whether habitat is assessed across the entire Churchill range (RSA-Habitat level) or combination of regional ranges (RSA-Population level). The highest estimate resulted from analysis of new recruitment data from aerial surveys, with λ increasing to 0.977. Most of these estimates were within the range of λ given in Integrated Range Assessment (IRA) reports (Ontario Ministry of Natural Resources and Forestry [MNRF] 2014) The Leslie Matrix eigen value estimate of λ is particularly useful as it integrates long-term trends and age-specific survivorship and provides a more robust perspective on λ for assessing effects of disturbance.

The scenario analysis of the Springpole Project footprint on λ also revealed consistencies among methods, especially for the RSA-Population and RSA-Habitat scales. These are the scales most ecologically meaningful to caribou given their home range size. The LSA scale was included mainly for completion but does not estimate the effect of disturbance at the level of the caribou herd as a whole. At the RSA-Population and RSA-Habitat scales, the % change in λ decreased by less than 1%, with decreases ranging from a low of 0.011% to a high of 0.061%. Change was generally lower when assessed at the RSA-Population scale versus the RSA-Habitat scale. Of course, change was much higher when assessed at the local LSA scale of a 10 km buffer around the Project footprint, with a % decrease in λ of between 0.44% to 1.34%, but even for the LSA level the % change in λ was small.

The assessed impacts to sustainability varied depending on the scale of analysis. At RSA-Population level with 31.92 % total disturbance, under future condition the probability of maintaining a self-sustaining population was 68.85%, resulting in a moderate-low risk to sustainability (Figure 7,

Table 14). For the RSA-Habitat and LSA scales with 42% total disturbance, probabilities of maintaining a self-sustaining population of 52.5% and 52.3% translate to moderate risk to sustainability. Springpole Project adds marginally to the impact, with a decrease in λ of less than 1% caused by disturbance resulting from the overall Project footprint, and a decrease in probability of maintaining a self-sustaining population of -0.39% at the RSA-POP level. Note, however, that when using the new caribouMetrics package for estimates, this estimate decreases the sustainability estimate by -3.74% at the RSA-POP level.

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