**Supplementary information for**

**Estimates of caribou herd size using post-calving surveys in the Northwest Territories and Nunavut, Canada: A meta-analysis**

**Appendix 1-Details on analyses of individual data sets**

This section provides listings of field data and summaries of each of the post-calving survey data sets used in the paper. Lower confidence limits were constrained to be equal to the total count of caribou during the survey.

**Bluenose-East (BE) herd**

**2000**

The BE herd was surveyed in 2000 (Patterson et al. 2004) from July 2 to July 6. Of 33 collars that were available, 23 were detected, with 1 to 3 collars per group of caribou observed.

**Table 1: Field data for the Bluenose-East 2000 post calving survey**

| Date | Group | No. of collars | Caribou counted |  | Date | Group | No. of collars | Caribou counted |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 02-Jul | 8 | 3 | 4,975 |  | 02-Jul | 15 | 1 | 2,844 |
| 02-Jul | 9 | 3 | 7,109 |  | 06-Jul | 19 | 1 | 2,493 |
| 02-Jul | 5 | 2 | 16,727 |  | 06-Jul | 20 | 1 | 1,953 |
| 02-Jul | 10 | 2 | 5,468 |  | 06-Jul | 21 | 1 | 11,334 |
| 04-Jul | 17 | 2 | 3,424 |  | 06-Jul | 22 | 1 | 5,461 |
| 30-Jun | 1 | 1 | 2,023 |  | 01-Jul | 2 | 0 | 1,386 |
| 02-Jul | 3 | 1 | 1,787 |  | 02-Jul | 4 | 0 | 452 |
| 02-Jul | 6 | 1 | 11,389 |  | 02-Jul | 7 | 0 | 682 |
| 02-Jul | 11 | 1 | 1,745 |  | 02-Jul | 12 | 0 | 3,249 |
| 02-Jul | 13 | 1 | 3,558 |  | 04-Jul | 16 | 0 | 2,904 |
| 02-Jul | 14 | 1 | 3,148 |  | 06-Jul | 18 | 0 | 1,925 |
|  |  |  |  |  | Total |  | 23 | 96,036 |

A – Patterson et al. (2004) in their Table 1 derived a total count of 84,412 adult caribou for the BE herd in 2012; the reduction from 96,036 was based on estimated overlap with BW collared caribou. The adjusted 84,412 total was used in Fig. 15. The Rivest estimate in Fig. 15 was adjusted downward by the same factor to 245,545; however, all Rivest estimates for this survey had low precision.

A threshold Rivest model with groups of 2 or more collars having detection probabilities of 1 had the highest likelihood. Groups with less than 2 collars had detection probabilities of 0.5. All Rivest herd estimates were imprecise (CV>31%) and ranged between 204,944 and 279,358. Lincoln-Petersen estimates were substantially lower. Patterson et al (2004) used only groups with collars for Lincoln-Petersen estimates so this estimate is included in addition to an estimate using counts from all groups.

**Table 2: Rivest model estimates and LP estimate for Bluenose-East herd 2000 survey**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Detection Model | Log-likelihood | Detection probabilities | | Estimate of herd size | | | |
|  |  | Estimate | SE |  | SE ( | CI(±) | CV |
|
| Threshold (B=2) | -6.48 | 0.52 | 0.11 | 279,358 | 96597.3 | 189,331 | 34.6% |
| Homogeneity | -6.47 | 0.70 | 0.11 | 204,944 | 62474.5 | 122,450 | 30.5% |
| Independence | -6.37 | 0.43 | 0.10 | 250,961 | 83547.8 | 163,754 | 33.3% |
| Threshold (B=3) | -6.28 | 0.63 | 0.11 | 239,048 | 74442.9 | 145,908 | 31.1% |
| Lincoln-Petersen (all groups) |  |  |  | 121,038 | 13126.6 | 25,728 | 10.8% |
| Lincoln-Peterson (collared groups only) |  |  |  | 104,570 | 11340.5 | 22,227 | 10.8% |

Tests for random distribution of collars suggest this assumption was not violated in the BE 2000 survey.

**Table 3: Tests for randomness of collar distribution for the Bluenose-East 2000 survey**

|  |  |  |
| --- | --- | --- |
| Model | Z | p-value |
| Threshold (B=3) | -0.124 | 0.550 |
| Independence | -0.056 | 0.523 |
| Homogeneity | -0.119 | 0.547 |
| Threshold (B=2) | 0.056 | 0.478 |

**2010**

The Bluenose-East herd was primarily surveyed from July 6-12, 2010, at which time caribou groups congregated into 3 geographic areas. During this time 47 collared caribou were monitored of which 44 were located within photographed groups. Thirty nine groups were counted on photos which amounted to a total count of 92,481 caribou (Adamczewski et al. 2017).

**Table 4: Field data for the Bluenose East 2010 post-calving survey**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Date | Group | No. of collars | Caribou counted |  | Date | Group | No. of collars | Caribou counted |
| Groups with collars | | |  |  | Groups without collars | | | |
| 06-Jul | Southern | 1 | 11,461 |  | 12-Jul | Northern | 0 | 3,870 |
| 06-Jul | Southern | 1 | 4,080 |  | 12-Jul | Northern | 0 | 914 |
| 06-Jul | Southern | 1 | 804 |  | 12-Jul | Northern | 0 | 268 |
| 06-Jul | Southern | 1 | 385 |  | 12-Jul | Northern | 0 | 226 |
| 06-Jul | Southern | 1 | 5 |  | 12-Jul | Northern | 0 | 175 |
| 06-Jul | Southern | 1 | 3 |  | 12-Jul | Northern | 0 | 6 |
| 09-Jul | Main | 8 | 11,652 |  | 12-Jul | Northern | 0 | 2 |
| 09-Jul | Main | 3 | 8,327 |  | 06-Jul | Southern | 0 | 175 |
| 09-Jul | Main | 2 | 7,585 |  | 06-Jul | Southern | 0 | 2 |
| 09-Jul | Main | 5 | 7,528 |  | 06-Jul | Southern | 0 | 2 |
| 09-Jul | Main | 1 | 7,365 |  | 09-Jul | Main | 0 | 2,263 |
| 09-Jul | Main | 4 | 4,989 |  | 09-Jul | Main | 0 | 1,980 |
| 09-Jul | Main | 2 | 4,942 |  | 09-Jul | Main | 0 | 1,523 |
| 09-Jul | Main | 2 | 1,943 |  | 09-Jul | Main | 0 | 670 |
| 09-Jul | Main | 1 | 1,014 |  | 09-Jul | Main | 0 | 242 |
| 12-Jul | Northern | 3 | 5,999 |  | 09-Jul | Main | 0 | 79 |
| 12-Jul | Northern | 2 | 1,106 |  | 09-Jul | Main | 0 | 2 |
| 12-Jul | Northern | 1 | 760 |  | 09-Jul | Main | 0 | 1 |
| 12-Jul | Northern | 1 | 115 |  |  |  |  |  |
| 12-Jul | Northern | 1 | 14 |  |  |  |  |  |
| 12-Jul | Northern | 1 | 3 |  |  |  |  |  |
| 12-Jul | Northern | 1 | 1 |  |  |  |  |  |

A threshold model with group sizes of 8 or more caribou having a probability of detection of 1 had the highest log-likelihood score. Estimates were precise and relatively similar between the Rivest models.

**Table 5: Rivest model estimates and LP estimate for the Bluenose-East 2010 survey[[1]](#footnote-1).**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Detection Model | Log-likelihood | Detection probabilities | | Estimate of herd size | |  |  |  |
|  |  | Estimate | SE |  | SE ( | Confidence limit | | CV |
| Threshold (B=8) | 2.474 | 0.92 | 0.067 | 121,702 | 15,934.3 | 92,481 | 152,933 | 13.1% |
| Threshold (B=5) | 2.415 | 0.91 | 0.069 | 122,697 | 16,202.2 | 92,481 | 154,453 | 13.2% |
| Homogeneity | 2.412 | 0.94 | 0.066 | 120,495 | 15,673.3 | 92,481 | 151,215 | 13.0% |
| Threshold (B=2) | 2.364 | 0.81 | 0.098 | 127,841 | 18,361.2 | 92,481 | 152,933 | 13.1% |
| Independence | 2.363 | 0.83A | 0.087 | 127,101 | 18,055.5 | 92,481 | 163,829 | 14.4% |
| Threshold (B=4) | 2.361 | 0.90 | 0.072 | 123,872 | 16,349.6 | 92,481 | 162,490 | 14.2% |
| Threshold (B=3) | 2.313 | 0.88 | 0.079 | 124,934 | 17,060.2 | 92,481 | 155,917 | 13.2% |
| Lincoln-Petersen |  |  |  | 98,646 | 3635.3 | 92,481 | 105,772 | 3.7% |

Tests for randomness of collar distribution suggested that this assumption was met in the BE 2010 survey.

**Table 6: Tests for randomness of collared caribou across groups for the Bluenose-East 2010 survey**

|  |  |  |
| --- | --- | --- |
| Model | Z | p-value |
| Independence | 1.11 | 0.133 |
| Homogeneity | 0.97 | 0.165 |
| Threshold B=2 | 1.13 | 0.128 |
| Threshold B=3 | 1.07 | 0.142 |

**Bluenose-West (BW) herd**

**2005**

The Bluenose-West 2005 survey was conducted on July 6 (Nagy and Johnson 2013). Sixty three caribou with collars were available during the survey, of which 54 were detected in photographed groups. Overall, 17,875 caribou were counted of which 16,824 were in groups that contained one or more collared caribou.

**Table 7: Field data for the Bluenose-West 2005 post calving survey**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Group | No. of collars | Caribou counted |  | Group | No. of collars | Caribou counted |
| 8 | 6 | 1,750 |  | 28 | 0 | 1 |
| 19 | 2 | 1,678 |  | 39 | 1 | 2 |
| 9 | 7 | 1,321 |  | 29 | 0 | 44 |
| 10 | 3 | 1,256 |  | 30 | 0 | 3 |
| 6 | 1 | 619 |  | 26 | 0 | 1 |
| 13 | 3 | 591 |  | 33 | 0 | 116 |
| 11 | 2 | 571 |  | 31 | 0 | 1 |
| 18 | 1 | 556 |  | 38 | 0 | 135 |
| 17 | 4 | 470 |  | 37 | 0 | 71 |
| 2 | 1 | 360 |  | 22 | 2 | 857 |
| 4 | 1 | 338 |  | 24 | 0 | 1 |
| 3 | 0 | 282 |  | 23 | 1 | 826 |
| 1 | 1 | 203 |  | 21 | 10 | 4,913 |
| 5 | 0 | 185 |  | 25 | 1 | 91 |
| 7 | 0 | 33 |  | 27 | 0 | 3 |
| 12 | 1 | 12 |  | 32 | 1 | 83 |
| 14 | 1 | 7 |  | 34 | 2 | 308 |
| 15 | 0 | 1 |  | 35 | 1 | 11 |
| 16 | 0 | 1 |  | 36 | 0 | 170 |
| 20 | 1 | 1 |  | 40 | 0 | 3 |

A Rivest threshold model with group sizes of 6 or greater having a detection probability of 1 and groups of less than 6 having a detection rate of 0.78 had the highest likelihood. The resulting herd estimate was reasonably precise with a CV of 11.4%. The model estimates ranged between 25,370 and 27,863.

**Table 8: Rivest estimator results and LP estimate for the Bluenose-West 2005 survey**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Detection Model | Log-likelihood | Detection probabilities | | Estimate of herd size | | | |
|  |  | Estimate | SE |  | SE ( | CI(±) | CV |
| Threshold(B=6) | 15.60 | 0.78 | 0.09 | 26,228 | 2999.02 | 5,878 | 11.4% |
| Threshold(B=10) | 15.33 | 0.83 | 0.09 | 25,370 | 2813.98 | 5,515 | 11.1% |
| Threshold(B=4) | 15.31 | 0.75 | 0.10 | 26,826 | 2967.00 | 5,815 | 11.1% |
| Homogeneity | 15.30 | 0.86 | 0.09 | 25,632 | 2783.88 | 5,456 | 10.9% |
| Threshold(B=3) | 15.18 | 0.70 | 0.10 | 27,464 | 3104.98 | 6,086 | 11.3% |
| Independence | 15.12 | 0.36 | 0.09 | 27,542 | 3166.07 | 6,206 | 11.5% |
| Threshold(B=2) | 14.86 | 0.59 | 0.10 | 27,863 | 3252.04 | 6,374 | 11.7% |
| Lincoln-Petersen |  |  |  | 20,800 | 1040.8 | 2,040 | 5.0% |

Tests for randomness of collared caribou across groups suggested that this assumption was met for all the models that were considered in the BW 2005 survey.

**Table 9: Tests for randomness of collared caribou across groups for the Bluenose-West 2005 survey**

|  |  |  |
| --- | --- | --- |
| Model | Z | p-value |
| Homogeneity | -0.007 | 0.503 |
| Threshold(B=3) | -0.055 | 0.522 |
| Independence | -0.014 | 0.505 |
| Threshold(B=2) | 0.039 | 0.485 |

**2006**

The 2006 BW survey was conducted on two sampling occasions; a smaller number of groups were counted on July 4, and then sampling was repeated on July 7 and 8, with a larger number of groups being counted (Nagy and Johnson 2006).

**Table 10: Field data for the Bluenose-West 2006 post calving survey**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Group | No. of Collars | Caribou counted |  | Group | No. of  Collars | Caribou counted |  | Group | No. of  Collars | Caribou counted |
| July 4, 2006 | | |  | 18 | 1 | 229 |  | 49 | 0 | 111 |
| 1 | 12 | 5,388 |  | 19 | 1 | 2 |  | 50 | 0 | 81 |
| 2 | 9 | 3,358 |  | 20 | 1 | 511 |  | 51 | 0 | 32 |
| 3 | 4 | 644 |  | 21 | 1 | 3 |  | 52 | 0 | 4 |
| 4 | 2 | 1,196 |  | 22 | 1 | 310 |  | 53 | 0 | 1 |
| 5 | 1 | 135 |  | 23 | 1 | 418 |  | 54 | 0 | 153 |
| 6 | 1 | 74 |  | 24 | 1 | 284 |  | 55 | 0 | 2 |
| 7 | 1 | 7 |  | 25 | 1 | 75 |  | 56 | 0 | 9 |
| 8 | 1 | 7 |  | 26 | 1 | 105 |  | 57 | 0 | 23 |
| 9 | 0 | 80 |  | 27 | 1 | 1365 |  | 58 | 0 | 23 |
| 10 | 0 | 13 |  | 28 | 1 | 616 |  | 59 | 0 | 8 |
| Total | 31 | 10,902 |  | 29 | 1 | 114 |  | 60 | 0 | 9 |
|  |  |  |  | 30 | 1 | 6 |  | 61 | 0 | 1 |
| July 7 and 8, 2006 | | |  | 31 | 1 | 35 |  | 62 | 0 | 2 |
| 1 | 10 | 3,028 |  | 32 | 1 | 2 |  | 63 | 0 | 3 |
| 2 | 7 | 1,511 |  | 33 | 1 | 22 |  | 64 | 0 | 5 |
| 3 | 6 | 1,271 |  | 34 | 1 | 337 |  | 65 | 0 | 154 |
| 4 | 3 | 486 |  | 35 | 1 | 7 |  | Total | 65 | 17,781 |
| 5 | 2 | 173 |  | 36 | 1 | 24 |  |  |  |  |
| 6 | 2 | 384 |  | 37 | 1 | 354 |  |  |  |  |
| 7 | 2 | 283 |  | 38 | 1 | 127 |  |  |  |  |
| 8 | 2 | 757 |  | 39 | 1 | 76 |  |  |  |  |
| 9 | 1 | 844 |  | 40 | 0 | 3 |  |  |  |  |
| 10 | 1 | 86 |  | 41 | 0 | 199 |  |  |  |  |
| 11 | 1 | 8 |  | 42 | 0 | 12 |  |  |  |  |
| 12 | 1 | 689 |  | 43 | 0 | 189 |  |  |  |  |
| 13 | 1 | 1,223 |  | 44 | 0 | 4 |  |  |  |  |
| 14 | 1 | 136 |  | 45 | 0 | 3 |  |  |  |  |
| 15 | 1 | 97 |  | 46 | 0 | 27 |  |  |  |  |
| 16 | 1 | 3 |  | 47 | 0 | 137 |  |  |  |  |
| 17 | 1 | 377 |  | 48 | 0 | 208 |  |  |  |  |

For the July 4 data set, a Rivest model with detection rates of groups with greater or equal to 9 collared caribou showing detection probabilities of 1 displayed the highest likelihood score. Detection rates were relatively low (.22) for groups with less than 9 collared caribou. Rivest model estimates for the July 4 sampling session varied between 25,000 and 30,000 caribou with good to marginal precision. In comparison, the Lincoln Petersen estimate was 22,827.

For the July 7 and 8th data set, a threshold model with groups with 6 or more collared caribou showing detection probabilities of 1 and groups with less than 6 collars still showing high detection rates (0.97) was most supported. All models estimated high detection probabilities and in general estimates were very close and in the range of 28,000 caribou.

The two estimates basically suggest that the majority of groups were counted on July 7 and 8 compared to July 4th. Reassuringly, the estimates from the 2 sessions are relatively close despite the differences in the number of groups counted. This result suggests that the Rivest estimator was effectively estimating the fact that groups were missed on July 4th, but bias cannot be inferred from these results given that the true number was not known. The July 7-8 estimate is preferred due to higher precision and a higher proportion of collars found.

**Table 11: Rivest Estimator results for the Bluenose-West July 4 and July 7-8, 2006 data sets (Nagy and Johnson 2006). The Lincoln-Petersen estimate is based on (Nagy and Johnson 2006).**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Detection Model | Log-likelihood | Detection probabilities | | Estimate of herd size | |  |  |
|  |  | Estimate | SE |  | SE ( | CI(±) | CV |
| July 4, 2006 |  |  |  |  |  |  |  |
| Threshold(B=9) | 28.45 | 0.22 | 0.10 | 25,331 | 5837.25 | 11,441 | 23.04% |
| Threshold(B=4) | 28.28 | 0.15 | 0.06 | 33,067 | 4964.98 | 9,731 | 15.01% |
| Independence | 28.17 | 0.84 | 0.05 | 28,291 | 4671.63 | 9,156 | 16.51% |
| Homogeneity | 27.98 | 0.47 | 0.17 | 26,700 | 2567.38 | 5,032 | 9.62% |
| Threshold(B=12) | 27.86 | 0.35 | 0.15 | 25,429 | 3084.58 | 6,046 | 12.13% |
| Threshold(B=2) | 27.09 | 0.10 | 0.05 | 29,273 | 5394.27 | 10,573 | 18.43% |
| Lincoln-Petersen |  |  |  | 22,827 | 2868.0 | 5,621 | 13% |
|  |  |  |  |  |  |  |  |
| July 7-8, 2006 |  |  |  |  |  |  |  |
| Threshold (B=6) | 6.97 | 0.977 | 0.027 | 28,461 | 3791.2 | 7,431 | 13.32% |
| Threshold (B=7) | 6.96 | 0.980 | 0.028 | 28,381 | 3791.7 | 7,432 | 13.36% |
| Threshold (B=10) | 6.94 | 0.982 | 0.028 | 28,310 | 3783.4 | 7,415 | 13.36% |
| Homogeneity | 6.93 | 0.985 | 0.029 | 28,262 | 3758.9 | 7,367 | 13.30% |
| Threshold (B=4) | 6.93 | 0.977 | 0.027 | 28,461 | 3791.2 | 7,431 | 13.32% |
| Threshold (B=3) | 6.88 | 0.975 | 0.027 | 28,508 | 3796.1 | 7,440 | 13.32% |
| Independence | 6.80 | 0.031 | 0.030 | 28,621 | 3818.1 | 7,483 | 13.34% |
| Threshold (B=2) | 6.80 | 0.969 | 0.031 | 28,626 | 3819.0 | 7,485 | 13.34% |
| Lincoln-Petersen |  |  |  | 17,781 |  |  |  |

Tests for randomness of collared caribou distribution suggested that collared caribou were randomly distributed within groups for both the July 4 and July 7-8 data sets in the BW 2006 survey.

**Table 12: Tests for randomness of collared caribou for the Bluenose-West July 4 and July 7-8, 2006 data sets**

|  |  |  |
| --- | --- | --- |
| Model | Z | p-value |
| July 4, 2006 |  |  |
| Independence | -0.861 | 0.805 |
| Homogeneity | -0.808 | 0.790 |
| Threshold (B=2) | -0.817 | 0.793 |
| July 7-8, 2006 |  |  |
| Homogeneity | 1.180 | 0.119 |
| Threshold (B=3) | 1.211 | 0.113 |
| Independence | 1.238 | 0.108 |
| Threshold (B=2) | 1.239 | 0.108 |

**2009**

For the BW 2009 survey, larger groups had more collared caribou with one notable exception where group 42 of 2,515 had only one collared caribou (Davison et al. 2014). There were 54 collared caribou during the survey. Of these, 50 collars were found during the survey in 21 groups with 15,108 caribou counted in all groups that had collars. If groups without collars are considered then 16,595 caribou were counted.

**Table 13: Bluenose-West 2009 post calving field data**

| Date | Group | No. of Collars | Caribou counted |  | Date | Group | No. of Collars | Caribou counted |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 12-Jul-09 | 1 | 2 | 950 |  | 12-Jul-09 | 35 | 1 | 254 |
| 12-Jul-09 | 3 | 1 | 25 |  | 12-Jul-09 | 36 | 1 | 62 |
| 12-Jul-09 | 6 | 0 | 3 |  | 12-Jul-09 | 37 | 1 | 166 |
| 12-Jul-09 | 9 | 0 | 25 |  | 12-Jul-09 | 38 | 0 | 1 |
| 12-Jul-09 | 12 | 0 | 13 |  | 12-Jul-09 | 40 | 1 | 363 |
| 12-Jul-09 | 13 | 0 | 4 |  | 12-Jul-09 | 41 | 0 | 599 |
| 12-Jul-09 | 14 | 0 | 84 |  | 12-Jul-09 | 42 | 1 | 2,515 |
| 12-Jul-09 | 15 | 0 | 5 |  | 12-Jul-09 | 43 | 0 | 19 |
| 12-Jul-09 | 16 | 1 | 486 |  | 12-Jul-09 | 44 | 1 | 190 |
| 12-Jul-09 | 17 | 1 | 258 |  | 12-Jul-09 | 52 | 0 | 6 |
| 12-Jul-09 | 18 | 1 | 51 |  | 12-Jul-09 | 53 | 0 | 1 |
| 12-Jul-09 | 19 | 1 | 24 |  | 12-Jul-09 | 54 | 0 | 3 |
| 12-Jul-09 | 20 | 0 | 6 |  | 12-Jul-09 | 55 | 0 | 1 |
| 12-Jul-09 | 21 | 0 | 1 |  | 12-Jul-09 | 56 | 0 | 1 |
| 12-Jul-09 | 22 | 0 | 3 |  | 12-Jul-09 | 57 | 0 | 3 |
| 12-Jul-09 | 23 | 0 | 1 |  | 13-Jul-09 | 58 | 0 | 1 |
| 12-Jul-09 | 24 | 0 | 5 |  | 13-Jul-09 | 59 | 0 | 1 |
| 12-Jul-09 | 25 | 10 | 3,210 |  | 13-Jul-09 | 60 | 0 | 7 |
| 12-Jul-09 | 26 | 3 | 1,162 |  | 13-Jul-09 | 61 | 0 | 1 |
| 12-Jul-09 | 27 | 3 | 195 |  | 13-Jul-09 | 63 | 0 | 14 |
| 12-Jul-09 | 28 | 4 | 1,446 |  | 13-Jul-09 | 64 | 1 | 1 |
| 12-Jul-09 | 29 | 2 | 287 |  | 13-Jul-09 | 65 | 0 | 6 |
| 12-Jul-09 | 30 | 0 | 70 |  | 13-Jul-09 | 66 | 0 | 20 |
| 12-Jul-09 | 31 | 1 | 741 |  | 13-Jul-09 | 67 | 0 | 1 |
| 12-Jul-09 | 32 | 12 | 2,539 |  | 13-Jul-09 | 68 | 0 | 3 |
| 12-Jul-09 | 33 | 0 | 163 |  | 13-Jul-09 | 69 | 1 | 183 |
| 12-Jul-09 | 34 | 0 | 1 |  | 13-Jul-09 | 70 | 0 | 415 |
|  |  |  |  |  |  | Total | 50 | 16,595 |

Model selection results from the Rivest estimator suggested that a threshold model with groups with 12 or more collars displaying detection rates of 1 with groups that had less than 12 collars displaying detection probability of 0.90. The homogeneity model assumes that collar mixing in groups is random and that all groups will have the same detection probability (of 0.93). The estimate of herd size from the best threshold model was 21,773 (± 4,884) caribou with a CV of 11.4% for the estimate, and similar to the other estimates.

**Table 14: Rivest estimator results and LP estimate for the Bluenose-West 2009 data set**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Detection Model | Log-likelihood | Detection probabilities | | Estimate of herd size | |  |  |
|  |  | Estimate | SE |  | SE ( | CI(±) | CV |
| Threshold(B=12) | 19.42 | 0.90 | 0.09 | 21,773 | 2491.6 | 4,884 | 11.4% |
| Homogeneity | 19.34 | 0.93 | 0.09 | 21,425 | 2459.7 | 4,821 | 11.5% |
| Threshold(B=10) | 19.19 | 0.88 | 0.08 | 22,068 | 2621.7 | 5,139 | 11.9% |
| Threshold(B=3) | 19.17 | 0.82 | 0.09 | 22,716 | 2871.4 | 5,628 | 12.6% |
| Threshold(B=4) | 19.16 | 0.86 | 0.09 | 22,210 | 2733.4 | 5,357 | 12.3% |
| Independence | 18.87 | 0.21 | 0.09 | 22,981 | 3002.5 | 5,885 | 13.1% |
| Threshold(B=2) | 18.75 | 0.78 | 0.10 | 23,104 | 3047.3 | 5,973 | 13.2% |
| Lincoln-Petersen |  |  |  | 17,897 | 1306.5 | 1,310 | 7.3% |

Tests for randomness of collar distribution across groups suggested this assumption may have been violated. Therefore, estimates of herd size for the Rivest estimator may be negatively biased for this survey. Regardless, they are higher than the Lincoln-Petersen estimates for the BW 2009 data set.

**Table 15: Tests for randomness of collared caribou for the Bluenose-West 2009 data set**

|  |  |  |
| --- | --- | --- |
| Model | Z | p-value |
| Homogeneity | 1.979 | 0.024 |
| Threshold (B=2) | 2.207 | 0.014 |
| Independence | 2.192 | 0.014 |
| Threshold (B=6) | 2.160 | 0.015 |

**2012**

Fifty five collared caribou were available during the 2012 post calving survey (Davison et al. 2016). Of these 38 were detected in photographed groups. Field observations suggested that the herd did not aggregate as well as in other years, which was the main reason that 17 collared caribou were not in photographed groups.

**Table 16: Caribou groups counted for the 2012 Bluenose-West survey**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Group | No. of collars | Caribou counted |  | Group | No. of collars | Caribou counted |
| 1 | 9 | 1,949 |  | 17 | 0 | 1 |
| 2 | 0 | 2 |  | 18 | 1 | 1,423 |
| 3 | 0 | 24 |  | 19 | 3 | 822 |
| 4 | 1 | 183 |  | 20 | 1 | 408 |
| 5 | 3 | 596 |  | 21 | 1 | 316 |
| 6 | 1 | 117 |  | 22 | 1 | 785 |
| 7 | 0 | 101 |  | 23 | 1 | 211 |
| 8 | 1 | 174 |  | 24 | 0 | 1 |
| 9 | 1 | 1 |  | 25 | 3 | 547 |
| 10 | 1 | 129 |  | 26 | 2 | 350 |
| 11 | 0 | 1 |  | 27 | 2 | 3,652 |
| 12 | 1 | 448 |  | 28 | 0 | 696 |
| 13 | 0 | 559 |  | 29 | 2 | 747 |
| 14 | 1 | 1 |  | 30 | 1 | 3 |
| 15 | 0 | 1 |  | 31 | 1 | 1 |
| 16 | 0 | 3 |  | 17 | 0 | 1 |
|  |  |  |  | 18 | 1 | 1423 |
|  |  |  |  | Total | 39 | 15,676 |

A threshold model with groups of 9 or more collars having detection probabilities of 1 and other groups with lower detection rates was most supported. Estimates were generally imprecise with coefficients of variation > 20%.

**Table 17: Rivest Model estimates and LP estimate for Bluenose-West 2012 survey**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Detection Model | Log-likelihood | Detection probabilities | | Estimate of herd size | |  |  |
|  |  | Estimate | SE |  | SE ( | CI(±) | CV |
| Threshold (B=9) | -1.21 | 0.63 | 0.10 | 32,326 | 7899.1 | 15,482 | 24.4% |
| Homogeneity | -1.47 | 0.69 | 0.12 | 28,969 | 7354.7 | 14,415 | 25.4% |
| Threshold (B=3) | -1.63 | 0.54 | 0.09 | 38,370 | 9440.6 | 18,504 | 24.6% |
| Independence | -1.82 | 0.50 | 0.08 | 36,144 | 8168.2 | 16,010 | 22.6% |
| Threshold (B=2) | -2.36 | 0.45 | 0.09 | 37,307 | 8018.3 | 15,716 | 21.5% |
| Lincoln-Petersen |  |  |  | 20,465 | 1780.5 | 3,490 | 8.7% |

Tests for randomness of collar distribution across groups suggested this assumption was violated and as a result, herd estimates may be negatively biased.

**Table 18: Tests for randomness of collared caribou for the Bluenose-West 2012 data set**

|  |  |  |
| --- | --- | --- |
| Model | Z | p-value |
| Homogeneity | 3.552 | <0.001 |
| Threshold (B=3) | 3.711 | <0.001 |
| Independence | 3.854 | <0.001 |
| Threshold (B=2 | 4.136 | <0.001 |

**2015**

In 2015, 25 groups of caribou were counted of which 22 contained collared caribou (Davison et al. 2017). Forty nine of 55 available collars were located within photographed groups.

**Table 19: Summary of collar and group data for the 2015 Bluenose-West post calving survey**

| Group | Number of collared caribou | Number of Caribou |  | Group | Number of collared caribou | Number of Caribou |
| --- | --- | --- | --- | --- | --- | --- |
| 19 | 11 | 3,524 |  | 11 | 1 | 60 |
| 2 | 6 | 987 |  | 12 | 1 | 505 |
| 6 | 4 | 1,010 |  | 15 | 1 | 448 |
| 1 | 3 | 1,045 |  | 16 | 1 | 554 |
| 5 | 3 | 831 |  | 17 | 1 | 471 |
| 18 | 3 | 613 |  | 22 | 1 | 1 |
| 21 | 3 | 2300 |  | 23 | 1 | 1 |
| 8 | 2 | 157 |  | 24 | 1 | 1 |
| 3 | 1 | 472 |  | 25 | 1 | 1 |
| 4 | 1 | 1 |  | 13 | 0 | 1 |
| 7 | 1 | 371 |  | 14 | 0 | 2 |
| 9 | 1 | 146 |  | 20 | 0 | 4 |
| 10 | 1 | 131 |  |  |  |  |
|  |  |  |  | Totals | 49 | 13,637 |

Model selection results indicated that a threshold model with groups of 3 or more having a sighting probability of 1 had the highest likelihood. The estimate from this model (21,535) was reasonably precise with a CV of 12.2%. Other Rivest model estimates were similar.

**Table 20: Model selection and herd size estimates for the Bluenose-West 2015 post-calving survey**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Detection Model | Log-likelihood | Detection probabilities | | Estimate of herd size | | CI (±) | CV |
|  |  | Estimate | SE |  | SE ( |  |  |
| Threshold (B=3) | 14.54 | 0.73 | 0.10 | 21,535 | 2620.4 | 5,136 | 12.2% |
| Threshold (B=17) | 14.22 | 0.86 | 0.09 | 20,676 | 2508.8 | 4,917 | 12.1% |
| Threshold ( B=4) | 14.17 | 0.84 | 0.09 | 21,059 | 2495.9 | 4,892 | 11.9% |
| Homogeneity | 14.13 | 0.89 | 0.09 | 20,531 | 2356.3 | 4,618 | 11.5% |
| Independence | 13.80 | 0.28 | 0.09 | 21,760 | 2622.2 | 5,140 | 12.1% |
| Threshold (B=2) | 13.51 | 0.70 | 0.10 | 21,907 | 2638.3 | 5,171 | 12.0% |
| Lincoln-Petersen |  |  |  | 15,274 | 698.8 | 1,369 | 4.5% |

Tests for randomness of collar distribution across groups suggested that this assumption was not violated during the 2015 survey with non-significant tests for all models.

**Table 21: Tests for randomness of collars across group sizes for the 2015 Bluenose-West survey.**

|  |  |  |
| --- | --- | --- |
| Model | Z | p-value |
| Threshold (B=3) | -0.091 | 0.536 |
| Homogeneity | -0.139 | 0.556 |
| Independence | -0.031 | 0.512 |
| Threshold (B=2) | 0.0051 | 0.498 |

**Cape Bathurst (CB) herd**

**2005**

Thirty two collared caribou were monitored during sampling that occurred on June 9, 2005. Of these, 29 were located within photographed groups (Nagy and Johnson 2013).

**Table 22: Field data for the 2005 Cape Bathurst post calving survey**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Group | No. of Collars | Caribou counted |  | Group | No. of Collars | Caribou counted |
| 6 | 10 | 492 |  | 5 | 1 | 1 |
| 15 | 3 | 174 |  | 7 | 1 | 173 |
| 1 | 2 | 7 |  | 10 | 1 | 6 |
| 8 | 2 | 228 |  | 11 | 1 | 421 |
| 9 | 2 | 138 |  | 12 | 1 | 453 |
| 2 | 1 | 22 |  | 13 | 1 | 15 |
| 3 | 1 | 9 |  | 14 | 1 | 1 |
| 4 | 1 | 73 |  |  |  |  |
|  |  |  |  | Total | 29 | 2,213 |

The most supported Rivest model was the homogeneity model, however, other model estimates were relatively similar. Tests for randomness of collared caribou distribution across groups suggested a non-random distribution, and therefore it is likely that these estimates are negatively biased.

**Table 23: Rivest estimator results and LP estimate for Cape Bathurst 2005 survey**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Detection Model | Log-likelihood | Detection probabilities | | Estimate of herd size | | |  |
|  |  | Estimate | SE |  | SE ( | CI(±) | CV |
| Homogeneity | 0.18 | 0.91 | 0.11 | 3,566 | 700.4 | 1373 | 19.6% |
| Independence | -0.06 | 0.21 | 0.10 | 3,967 | 793.7 | 1556 | 20.0% |
| Threshold ( B=2) | -0.08 | 0.77 | 0.12 | 4,029 | 811.9 | 1591 | 20.1% |
| Threshold (B=3) | -0.09 | 0.84 | 0.10 | 3,812 | 732.3 | 1435 | 19.2% |
| Threshold (B=10) | 0.31 | 0.86 | 0.09 | 3,739 | 706.8 | 1385 | 18.9% |
| Lincoln-Petersen |  |  |  | 2,434 | 131.0 | 257 | 5.4% |

**Table 24: Tests for randomness of collar distribution for the Cape Bathurst 2005 survey**

|  |  |  |
| --- | --- | --- |
| Model | Z | p-value |
| Homogeneity | 3.547 | 0.000195 |
| Independence | 3.892 | 0.000050 |
| Threshold ( B=2) | 3.939 | 0.000041 |
| Threshold (B=3) | 3.793 | 0.000074 |

**2006**

Three sampling sessions for the CB Bathurst herd were conducted in July 2006 (July 6, 9 and 13) and 33 collared caribou were monitored (Nagy and Johnson 2006). The largest number of groups detected was on July 9.

**Table 25: Summary of field data on three dates for the Cape Bathurst herd in 2006**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Group No. | No of collars | Caribou counted |  | Group No. | No of collars | Caribou counted |
| July 6, 2006 | |  |  | July 9, 2006 | | |
| 1 | 1 | 6 |  | 1 | 6 | 166 |
| 2 | 9 | 364 |  | 2 | 3 | 58 |
| 3 | 1 | 1 |  | 3 | 1 | 192 |
| 4 | 1 | 7 |  | 4 | 2 | 106 |
| 5 | 1 | 161 |  | 5 | 0 | 14 |
| 6 | 4 | 197 |  | 6 | 4 | 70 |
| 7 | 0 | 2 |  | 7 | 3 | 128 |
| 8 | 7 | 350 |  | 8 | 3 | 224 |
| 9 | 1 | 2 |  | 9 | 1 | 6 |
| 10 | 0 | 16 |  | 10 | 1 | 34 |
| 11 | 1 | 146 |  | 11 | 0 | 1 |
| 12 | 1 | 256 |  | 12 | 0 | 15 |
| Total | 27 | 1,508 |  | 13 | 0 | 48 |
|  |  |  |  | 14 | 1 | 1 |
| July 13, 2006 | |  |  | 15 | 1 | 67 |
| 1 | 1 | 1 |  | 16 | 1 | 264 |
| 2 | 2 | 106 |  | 17 | 0 | 2 |
| 3 | 7 | 225 |  | 18 | 1 | 53 |
| 4 | 19 | 1367 |  | 19 | 0 | 35 |
| 5 | 1 | 1 |  | 20 | 0 | 9 |
| 6 | 0 | 1 |  | 21 | 1 | 18 |
| 7 | 1 | 3 |  | 22 | 1 | 2 |
| 8 | 0 | 5 |  | 23 | 0 | 1 |
| 9 | 0 | 2 |  | Total | 30 | 1,514 |
| 10 | 0 | 2 |  |  |  |  |
| 11 | 0 | 1 |  |  |  |  |
| Total | 31 | 1,714 |  |  |  |  |

Estimates were run for each survey date. In general, estimates were reasonably similar for each sampling session with the highest level of precision obtained on July 13, which was presumably due to the higher level of aggregation at this time (19 collared caribou in one group of 1367 caribou). This estimate is the preferred one for the herd in 2006.

**Table 26: Rivest Estimator results and LP estimates for the Cape Bathurst July 6, 9, and 13, 2006 data sets. The Lincoln-Petersen estimate is based on Nagy and Johnson (2006).**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Detection Model | Log-likelihood | Detection probabilities | | Estimate of herd size | |  |  |
|  |  | Estimate | SE |  | SE ( | CI(±) | CV |
| July 6, 2016 |  |  |  |  |  |  |  |
| Threshold (B=7) | 12.78 | 0.65 | 0.168 | 2462 | 468.1 | 917 | 19.0% |
| Threshold (B=9) | 12.51 | 0.75 | 0.177 | 2297 | 376.6 | 738 | 16.4% |
| Homogeneity | 12.30 | 0.82 | 0.160 | 2193 | 321.0 | 629 | 14.6% |
| Threshold (B=10) | 12.27 | 0.82 | 0.160 | 2193 | 321.0 | 629 | 14.6% |
| Threshold (B=4) | 12.15 | 0.54 | 0.138 | 2729 | 508.1 | 996 | 18.6% |
| Independence | 11.10 | 0.45 | 0.133 | 2701 | 509.8 | 999 | 18.9% |
| Lincoln-Petersen |  |  |  | 1831 |  | 278 | 8.0% |
| July 9, 2016 |  |  |  |  |  |  |  |
| Threshold (B=3) | -3.53 | 0.79 | 0.119 | 2288 | 419.3 | 822 | 18.3% |
| Threshold (B=6) | -3.73 | 0.89 | 0.092 | 2117 | 364.9 | 715 | 17.2% |
| Homogeneity | -3.78 | 0.91 | 0.088 | 2076 | 352.4 | 691 | 17.0% |
| Threshold (B=4) | -3.80 | 0.87 | 0.099 | 2163 | 371.8 | 729 | 17.2% |
| Independence | -3.95 | 0.23 | 0.114 | 2311 | 432.6 | 848 | 18.7% |
| Threshold (B=2) | -4.10 | 0.75 | 0.125 | 2338 | 438.8 | 860 | 18.8% |
| Lincoln-Petersen |  |  |  | 1661 | 149.0 | 292 | 5.0% |
| July 13, 2016 |  |  |  |  |  |  |  |
| Threshold (B=7) | 41.97 | 0.71 | 0.202 | 2039 | 162.6 | 319 | 8.0% |
| Threshold (B=2) | 41.84 | 0.60 | 0.219 | 2038 | 172.0 | 337 | 8.4% |
| Independence | 41.80 | 0.36 | 0.196 | 2038 | 168.5 | 330 | 8.3% |
| Threshold (B=19) | 41.69 | 0.86 | 0.202 | 1998 | 152.3 | 298 | 7.6% |
| Homogeneity | 41.67 | 0.94 | 0.152 | 2036 | 162.9 | 319 | 8.0% |
| Lincoln-Petersen |  |  |  | 1821 |  | 149 | 4.0% |

Tests for randomness of collar distribution across groups suggested this assumption was only violated on July 9. Inspection of the data suggested irregular groupings of caribou with one group of 6 collared caribou in a group of only 166 caribou suggesting aggregation of collared caribou that was different than the levels of aggregation of other caribou groups.

**Table 27: Tests for randomness of collared caribou for the Cape Bathurst 2006 data sets.**

|  |  |  |
| --- | --- | --- |
| Model | Z | p-value |
| July 6, 2013 |  |  |
| Homogeneity | 0.716 | 0.237 |
| Independence | 1.194 | 0.116 |
| July 9, 2013 |  |  |
| Threshold (B=3) | 1.865 | 0.031 |
| Independence | 1.884 | 0.030 |
| Threshold (B=2) | 1.900 | 0.029 |
| July 13, 2013 |  |  |
| Threshold (B=2) | -0.254 | 0.600 |
| Independence | -0.268 | 0.606 |
| Homogeneity | -0.203 | 0.580 |

**2009**

Twenty eight collared caribou were available during the Cape Bathurst 2009 survey of which 22 were observed in photographed groups (Davison et al. 2014). Overall, 1,534 caribou were counted. Only 111 caribou in 3 groups were seen without collared caribou within the groups.

**Table 28: Post calving field data for Cape Bathurst 2009 survey**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Date | Group | No. of Collars | Caribou counted |  | Date | Group | No. of Collars | Caribou counted |
| 18-Jul-09 | 8 | 5 | 511 |  | 18-Jul-09 | 6 | 1 | 59 |
| 18-Jul-09 | 9 | 5 | 282 |  | 18-Jul-09 | 11 | 1 | 15 |
| 18-Jul-09 | 10 | 4 | 267 |  | 18-Jul-09 | 12 | 1 | 127 |
| 13-Jul-09 | 1 | 1 | 1 |  | 18-Jul-09 | 13 | 1 | 144 |
| 13-Jul-09 | 2 | 1 | 14 |  | 18-Jul-09 | 5 | 0 | 4 |
| 13-Jul-09 | 3 | 1 | 2 |  | 18-Jul-09 | 7 | 0 | 66 |
| 13-Jul-09 | 4 | 1 | 1 |  | 18-Jul-09 | 14 | 0 | 41 |
|  |  |  |  |  | Total |  | 22 | 1,534 |

Rivest model analysis suggested that a threshold model with detection probabilities of 1 for groups with 5 or more collars was most supported. Groups with less than 4 collars had a detection probability of 0.57. This model produced an estimate of 2,925 caribou compared to an estimate of 1,934 caribou from the Lincoln-Petersen estimator. Estimates had marginal precision (CV>20%).

**Table 29: Rivest estimator results for the Cape Bathurst 2009 data set. The Lincoln-Petersen estimate is based on Davison et al. (2014).**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Detection Model | Log-likelihood | Detection probabilities | | Estimate of herd size | |  |  |
|  |  | Estimate | SE |  | SE ( | CI(±) | CV |
| Threshold (B=4) | 5.53 | 0.57 | 0.13 | 2,925 | 638.7 | 1252 | 21.8% |
| Threshold (B=5) | 5.21 | 0.67 | 0.16 | 2,706 | 554.4 | 1087 | 20.5% |
| Threshold (B=3) | 4.97 | 0.57 | 0.13 | 2,925 | 638.7 | 1252 | 21.8% |
| Homogeneity | 4.85 | 0.79 | 0.14 | 2,595 | 457.2 | 896 | 17.6% |
| Independence | 4.49 | 0.42 | 0.13 | 2,897 | 630.1 | 1235 | 21.8% |
| Threshold (B=2) | 4.04 | 0.57 | 0.13 | 2,925 | 638.7 | 1252 | 21.8% |
| Lincoln-Petersen |  |  |  | 1934 | 350.1 | 350 | 18.1% |

Tests for randomness of collared caribou across groups suggested that this assumption was met with the CB 2009 data set.

**Table 30: Tests for randomness of collared caribou for the Cape Bathurst 2009 data set.**

|  |  |  |
| --- | --- | --- |
| Model | Z | p-value |
| Threshold (B=3) | -0.705 | 0.759 |
| Homogeneity | -0.743 | 0.771 |
| Independence | -0.658 | 0.745 |
| Threshold (B=2) | -0.592 | 0.723 |

**2012**

For the 2012 Cape Bathurst post calving survey, 24 collared caribou were available during the survey and all 24 were found in photographed groups, with 2,427 caribou counted in collared and non-collared groups (Davison et al. 2016).

**Table 31: Field data collected for Cape Bathurst 2012 post calving survey**

|  |  |  |
| --- | --- | --- |
| Group | collars | Caribou counted |
| 23 | 11 | 1410 |
| 10 | 6 | 523 |
| 12 | 5 | 265 |
| 1 | 1 | 2 |
| 22 | 1 | 47 |
| 3 | 0 | 3 |
| 4 | 0 | 140 |
|  | 0 | 19X1A |
| 11 | 0 | 15 |
| 17 | 0 | 2 |
| Total | 24 | 2,427 |

A19 observations of single caribou

The Rivest model estimates were similar for the homogeneity and threshold models with detection probabilities of groups equal to 1 in all cases. In this case, the Rivest models basically estimated that a high proportion of the herd had been found and therefore all models converged on the same estimate of caribou. The Lincoln-Petersen equaled the number of caribou counted with no estimate of standard error.

**Table 32: Rivest model estimates and LP estimate for Cape Bathurst 2012 post calving survey**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Detection Model | Log-likelihood | Detection probabilities | | Estimate of herd size | | |  |
|  |  | Estimate | SE |  | SE ( | CI(±) | CV |
| Homogeneity | 21.76 | 1.00 | 0.00 | 2,447 | 175.3 | 344 | 7.2% |
| Independence | 21.76 | 0.00 | 0.00 | 2,447 | 175.3 | 344 | 7.2% |
| Lincoln Petersen |  |  |  | 2,427 | 0.0 |  |  |

Tests for randomness of collared caribou were similar (Z=-0.375, p=0.646) for all models which suggested the assumption of randomness was not violated.

**2015**

In 2015, 50 of 51 collared caribou were observed in 9 groups totaling 2203 caribou in the CB herd. In addition 3 groups composed of 13 caribou were observed without collared caribou (Davison et al. 2017).

**Table 33: Summary of field data for the 2015 Cape Bathurst survey**

|  |  |  |
| --- | --- | --- |
| Group | Number of collars | Number of caribou |
| 4 | 32 | 1200 |
| 3 | 8 | 759 |
| 2 | 3 | 168 |
| 11 | 2 | 69 |
| 1 | 1 | 1 |
| 5 | 1 | 2 |
| 8 | 1 | 1 |
| 10 | 1 | 1 |
| 12 | 1 | 2 |
| 6 | 0 | 8 |
| 7 | 0 | 4 |
| 9 | 0 | 1 |
|  | 50 | 2216 |

A threshold model with all groups of 2 or more collars having sighting probabilities of 1 had the highest log-likelihood score. Groups of less than 2 caribou had a sighting probability of 0.83. Estimates from this model were precise and relatively similar to estimates from the other Rivest models.

**Table 34: Rivest model estimates and LP estimate for the Cape Bathurst 2015 post calving survey**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Detection Model | Log-likelihood | Detection probabilities | | Estimate of herd size | |  |  |
|  |  | Estimate | SE |  | SE ( | CI(±) | CV |
| Threshold (B=2) | 84.16 | 0.83 | 0.15 | 2,524 | 144.86 | 283.9 | 5.7% |
| Independence | 84.14 | 0.16 | 0.14 | 2,524 | 144.38 | 283.0 | 5.7% |
| Threshold( B=32) | 84.12 | 0.95 | 0.11 | 2,548 | 149.77 | 293.6 | 5.9% |
| Threshold (B=3) | 84.08 | 0.88 | 0.13 | 2,523 | 142.78 | 279.8 | 5.7% |
| Homogeneity | 84.07 | 0.98 | 0.09 | 2,524 | 159.49 | 312.6 | 6.3% |
| Threshold (B=8) | 84.07 | 0.91 | 0.12 | 2,526 | 140.59 | 275.6 | 5.6% |
| Lincoln Petersen |  |  |  | 2,259 | 43.0 | 84.3 | 3.7% |

Tests for randomness of collars across groups indicated that this assumption was potentially violated as indicated by p-values of less than 0.05. In that case the Rivest estimates may be slightly negatively biased.

**Table 35: Tests for randomness of collar distribution for the Cape Bathurst 2015 post calving survey**

|  |  |  |
| --- | --- | --- |
| Model | Z | p-value |
| Homogeneity | 1.73 | 0.042 |
| Independence | 1.75 | 0.040 |
| Threshold (B=2) | 1.75 | 0.040 |
| Threshold (B=3) | 1.75 | 0.040 |

**Tuktoyaktuk Peninsula (TP) Herd**

**2006**

On July 9 and 13, 2006, the Tuktoyaktuk Peninsula Herd was sampled with all 27 collared caribou detected in photographed groups (Nagy and Johnson 2006). On both dates, collared caribou were detected as single individuals so that the collar size equaled the group size.

**Table 36: Summary of sampling for the Tuktoyaktuk Peninsula Herd on two dates in July 2006**

| Sessions | | |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Group | No. of collars | Caribou counted |  | Group | No. of collars | Caribou counted |
| July 9, 2006 | | |  | July 13, 2006 | |  |
| 1 | 5 | 951 |  | 1 | 10 | 1627 |
| 2 | 3 | 112 |  | 2 | 7 | 335 |
| 3 | 3 | 167 |  | 3 | 4 | 317 |
| 4 | 3 | 230 |  | 4 | 2 | 135 |
| 5 | 2 | 293 |  | 5 | 1 | 1 |
| 6 | 2 | 364 |  | 6 | 1 | 228 |
| 7 | 1 | 8 |  | 7 | 1 | 250 |
| 8 | 1 | 18 |  | 8 | 1 | 1 |
| 9 | 1 | 8 |  | 9 | 0 | 147 |
| 10 | 1 | 16 |  | 10 | 0 | 9 |
| 11 | 1 | 352 |  | 11 | 0 | 13 |
| 12 | 1 | 82 |  | 12 | 0 | 1 |
| 13 | 1 | 1 |  | 13 | 0 | 13 |
| 14 | 1 | 1 |  | 14 | 0 | 1 |
| 15 | 1 | 74 |  | Total | 27 | 3078 |
| 16 | 0 | 7 |  |  |  |  |
| 17 | 0 | 16 |  |  |  |  |
| 18 | 0 | 38 |  |  |  |  |
| 19 | 0 | 5 |  |  |  |  |
| 20 | 0 | 35 |  |  |  |  |
| 21 | 0 | 84 |  |  |  |  |
| 22 | 0 | 4 |  |  |  |  |
| Total | 27 | 2866 |  |  |  |  |

Identical log-likelihood scores and estimates were returned for all models for both survey dates suggesting the herd had been effectively censused during the survey. The estimate for July 13 is preferred as it had higher precision.

**Table 37: Rivest Estimator results and LP estimate for the Tuktoyaktuk Peninsula herd on July 9, 2006**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Detection Model | Log-likelihood | Detection probabilities | | Estimate of herd size | |  |  |
|  |  | Estimate | SE |  | SE ( | CI(±) | CV |
| Independence | -1.6045 | 0.00 | 0.00 | 4188 | 760.96 | 1491 | 18.2% |
| Homogeneity | -1.6046 | 1.00 | 0.00 | 4188 | 760.86 | 1491 | 18.2% |
| Threshold (B=2) | -1.6046 | 1.00 | 0.00 | 4188 | 760.86 | 1491 | 18.2% |
| Threshold (B=3) | -1.6046 | 1.00 | 0.00 | 4188 | 760.86 | 1491 | 18.2% |
| Threshold (B=4) | -1.6046 | 1.00 | 0.00 | 4188 | 760.86 | 1491 | 18.2% |
| Threshold (B=5) | -1.6046 | 1.00 | 0.00 | 4188 | 760.86 | 1491 | 18.2% |
| Threshold (B=6) | -1.6046 | 1.00 | 0.00 | 4188 | 760.86 | 1491 | 18.2% |
| Lincoln Petersen |  |  |  | 2677 | 0.0 |  |  |

**Table 38: Rivest Estimator results and LP estimate for the Tuktoyaktuk Peninsula Herd on July 13, 2006**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Detection Model | Log-likelihood | Detection probabilities | | Estimate of herd size | |  |  |
|  |  | Estimate | SE |  | SE ( | CI(±) | CV |
| Homogeneity | 15.4796 | 1.00 | 0.00 | 3320 | 318.09 | 623 | 9.6% |
| Independence | 15.4795 | 0.00 | 0.00 | 3321 | 318.11 | 623 | 9.6% |
| Threshold (B=2) | 15.4796 | 1.00 | 0.00 | 3320 | 318.09 | 623 | 9.6% |
| Threshold (B=3) | 15.4796 | 1.00 | 0.00 | 3320 | 318.09 | 623 | 9.6% |
| Threshold (B=4) | 15.4796 | 1.00 | 0.00 | 3320 | 318.09 | 623 | 9.6% |
| Threshold (B=6) | 15.4796 | 1.00 | 0.00 | 3320 | 318.09 | 623 | 9.6% |
| Threshold (B=7) | 15.4796 | 1.00 | 0.00 | 3320 | 318.09 | 623 | 9.6% |
| Threshold (B=10) | 15.4796 | 1.00 | 0.00 | 3320 | 318.09 | 623 | 9.6% |
| Threshold (B=9) | 15.4796 | 1.00 | 0.00 | 3320 | 318.09 | 623 | 9.6% |
| Lincoln Petersen |  |  |  | 2894 | 0.00 | 0 | 0.0% |

Tests for randomness returned similar scores for all models for both July 9 (Z=-0.47, p=0.68) and July 13 (Z=0.52, p=0.3) suggesting that the assumption of randomness was not violated for surveys on either date.

**2009**

The Tuktoyaktuk Peninsula Herd was surveyed in 2009 with 27 collared caribou available during the survey. Of these 25 were detected with 2,556 caribou being counted during the survey (Davison et al. 2014). Of these, 2,138 were in groups that contained at least one collared caribou.

**Table 39: Post calving field data from Tuktoyaktuk Peninsula herd on July 13, 2009.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Group | No of Collars | Caribou counted |  | Group | No of Collars | Caribou counted |
| 12 | 8 | 372 |  | 3 | 0 | 2 |
| 17 | 4 | 357 |  | 4 | 0 | 2 |
| 18 | 3 | 633 |  | 6 | 0 | 42 |
| 13 | 2 | 169 |  | 8 | 0 | 6 |
| 14 | 2 | 85 |  | 9 | 0 | 7 |
| 19 | 2 | 397 |  | 10 | 0 | 109 |
| 5 | 1 | 4 |  | 15 | 0 | 12 |
| 7 | 1 | 44 |  | 16 | 0 | 8 |
| 11 | 1 | 35 |  | 20 | 0 | 150 |
| 23 | 1 | 42 |  | 21 | 0 | 47 |
| 1 | 0 | 1 |  | 22 | 0 | 30 |
| 2 | 0 | 2 |  |  |  |  |
|  |  |  |  |  | 25 | 2,556 |

A model that assumed detection probabilities were one for groups that had 2 or more collars was most supported with detection probabilities of 0.67 for groups that had less than 2 collars. The estimate of herd size from this model was 2,889 (±765) caribou with a CV of the estimate of 13.5%. Interestingly, this estimate was reasonably close to the Lincoln-Petersen estimate.

**Table 40: Rivest Estimator results for the Tuktoyaktuk Peninsula Herd in 2009. The Lincoln-Petersen estimate is based on (Davison et al. 2014).**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Detection Model | Log-likelihood | Detection probabilities | | Estimate of herd size | |  |  |
|  |  | Estimate | SE |  | SE ( | CI(±) | CV |
| Threshold (B=2) | 4.96 | 0.67 | 0.19 | 2,889 | 390.5 | 765 | 13.5% |
| Independence | 4.84 | 0.27 | 0.15 | 2,899 | 390.1 | 765 | 13.5% |
| Threshold (B=8) | 4.78 | 0.89 | 0.11 | 2,917 | 391.5 | 767 | 13.4% |
| Homogeneity | 4.71 | 0.93 | 0.10 | 2,841 | 410.8 | 805 | 14.5% |
| Threshold (B=4) | 4.64 | 0.87 | 0.12 | 2,953 | 398.8 | 782 | 13.5% |
| Lincoln-Petersen |  |  |  | 2,752 | 275.2 | 539 | 10.0% |

Tests for randomness of collared caribou across groups suggested that this assumption may have been weakly violated which could cause a negative bias in estimates and associated variances.

**Table 41:. Tests for randomness of collared caribou for the Tuktoyaktuk Peninsula herd 2009 data set**

|  |  |  |
| --- | --- | --- |
| Model | Z | p-value |
| Threshold (B=2) | 1.33 | 0.092 |
| Independence | 1.30 | 0.097 |
| Homogeneity | 1.23 | 0.110 |
| Threshold (B=3) | 1.26 | 0.104 |

**2012**

Twenty three collars were available during the 2012 Tuktoyaktuk Peninsula herd post calving survey. Of these, 22 were observed with the majority in a single group of caribou (Davison et al. 2016).

**Table 42: Field data for the 2012 Tuktoyaktuk Peninsula Herd post calving survey**

|  |  |  |
| --- | --- | --- |
| Group | No. of collars | Caribou counted |
| 4 | 19 | 1,871 |
| 2 | 2 | 95 |
| 7 | 1 | 21 |
| 1 | 0 | 3 |
| 3 | 0 | 1 |
| 5 | 0 | 72 |
| 6 | 0 | 38 |
| Total | 22 | 2,101 |

A threshold Rivest model with groups sizes of 2 or more having detection rates of 1 and group sizes below having detection rates of 0.5 had the highest log-likelihood, but all model estimates were very similar and had high precision.

**Table 43: Rivest model estimates and LP estimate for the 2012 Tuktoyaktuk Peninsula Herd post calving survey**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Detection Model | Log-likelihood | Detection probabilities | | Estimate of herd size | |  |  |
|  |  | Estimate | SE |  | SE ( | CI(±) | CV |
| Threshold (B=2) | 36.53 | 0.50 | 0.35 | 2,237 | 182.7 | 358.2 | 8.2% |
| Independence | 36.40 | 0.39 | 0.28 | 2,224 | 175.2 | 343.3 | 7.9% |
| Homogeneity | 36.28 | 0.96 | 0.17 | 2,225 | 145.3 | 284.7 | 6.5% |
| Threshold (B=3) | 36.24 | 0.75 | 0.28 | 2,212 | 167.2 | 327.7 | 7.6% |
| Lincoln-Peterson |  |  |  | 2,192 | 90.9 | 178.2 | 4.1% |

**Table 44: Tests for randomness of collars for the 2012 Tuktoyaktuk Peninsula herd survey**

|  |  |  |
| --- | --- | --- |
| Model | Z | p-value |
| Threshold (B=2) | -0.736 | 0.769 |
| Independence | -0.734 | 0.768 |
| Homogeneity | -0.723 | 0.765 |
| Threshold (B=3) | -0.730 | 0.767 |

**2015**

In 2015, all 26 collared caribou were counted in photographed groups in the TP post calving survey. Of the groups detected, 3 did not have collared caribou with 15 caribou total in the non-collar groups (Davison et al. 2017). Overall, 1701 caribou were counted in the survey.

**Table 45: Field data for the 2015 Tuktoyaktuk Peninsula Herd post calving survey**

|  |  |  |
| --- | --- | --- |
| Group | No of collars | Caribou counted |
| 1 | 14 | 1,011 |
| 2 | 1 | 354 |
| 3 | 4 | 57 |
| 4 | 1 | 15 |
| 5 | 2 | 131 |
| 6 | 3 | 116 |
| 7 | 0 | 12 |
| 8 | 1 | 2 |
| 9 | 0 | 2 |
| 10 | 0 | 1 |
|  |  | 1701 |

Log-likelihood scores and Rivest estimates were identical for all models which indicates that all the groups were very detectable (sighting probability=1). The Lincoln-Petersen estimator equaled the count of caribou observed given that all the collars were accounted for in observed groups.

**Table 46: Rivest model estimates and LP estimate for the 2015 Tuktoyaktuk Peninsula herd post calving survey**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Detection Model | Log-likelihood | Detection probabilities | | Estimate of herd size | |  |  |
|  |  | Estimate | SE |  | SE ( | CI(±) | CV |
| Independence | 18.00 | 1.00 | 0.01 | 1,930 | 176.9 | 346.8 | 9.2% |
| Homogeneity | 18.00 | 1.00 | 0.00 | 1,930 | 176.9 | 346.7 | 9.2% |
| Threshold (B=2) | 18.00 | 1.00 | 0.00 | 1,930 | 176.9 | 346.7 | 9.2% |
| Threshold (B=3) | 18.00 | 1.00 | 0.00 | 1,930 | 176.9 | 346.7 | 9.2% |
| Threshold (B=4) | 18.00 | 1.00 | 0.00 | 1,930 | 176.9 | 346.7 | 9.2% |
| Threshold (B=17) | 18.00 | 1.00 | 0.00 | 1,930 | 176.9 | 346.7 | 9.2% |
| Lincoln-Petersen |  |  |  | 1,701 | 0.0 |  |  |

Tests for randomness of collars indicated that this assumption was not violated during the TP 2015 survey. All models returned similar test scores (Z=0.049, p=0.481) suggesting the assumption of randomness was not violated.

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1. In earlier analyses of this data set, a threshold model with B=5 was found to have the best log-likelihood. Those results were used by Adamczewski et al. (2017). The difference is 1005 caribou for the herd estimate. [↑](#footnote-ref-1)