Provincial Moose Winter Tick Surveillance Program

January 1st – April 30th, 2021

Photo Credit Linda Thompson

Kevin Watt
BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development
Suite 400, 10003 - 110th Ave.
Fort St. John, BC V1J 6M7

BRITISH COLUMBIA
Ministry of Forests, Lands, Natural Resource Operations and Rural Development

Executive Summary

Concern regarding the effects of winter tick on the health of moose populations in western Canada has increased in recent years. There has been little research in British Columbia (BC) on the distribution, severity, and population impacts of winter ticks on moose. The geographical range of winter tick has been reported to be expanding northward, although most available historic information is anecdotal. Each year, the prevalence and severity of winter tick infestations are dependent on early spring snow levels and autumn snowfall events, air temperatures, and moose densities. Initiated in 2015, the Provincial Moose Winter Tick Surveillance Program uses citizen-science to document the distribution and infestation severity of winter ticks in BC, and to gather those observations to a central reporting body. Surveys were made available in January 2021 in multiple formats including electronic PDF, online, and via a smart-phone application. Participants documented observations of moose both with and without hair loss, recording sex, age class, general body condition, and hair loss severity. A total of 323 moose observations were submitted during the survey period of January 1st to April 30th, 2021. Most submissions were from the Omineca, and Peace regions, combining for 81% of all observations. Peak infestation period occurred from March–April, during which 43% in the Omineca, and 19% in the Peace regions of moose exhibited some degree of hair loss. Province-wide trends indicated that 19% of moose observed exhibited some degree of hair loss due to tick infestations, a decrease from the 31% infestation rate reported by the program in 2020. Utilizing cost-effective, public engagement methods, the Provincial Moose Winter Tick Surveillance Program documents the prevalence, trends, and severity of winter ticks in BC. Results from this program provide a better understanding of winter tick impacts on moose populations and help to inform future management action.

Table of Contents

List of Tables

List of Figures

Introduction

Moose (*Alces alces*) are widely distributed across Canada, and within British Columbia (BC) are most plentiful in the central interior, northeast, and northwest areas of the province. Concern over recent population declines in BC (and broadly across North America) has spurred investigation into possible causes and contributing factors. Natural fluctuations in moose populations do occur; within the last two decades numbers have reached a high of 190,000 (2011) and a low of 148,000 in BC (2017) (Kuzyk 2016, Kuzyk pers. comm; Figure 1). A variety of factors can influence population change including nutrition, predators, landscape change, climate, diseases, and parasites (Kuzyk et al. 2019). The ectoparasite, winter tick (*Dermacentor albipictus*), has been an increasing concern for moose populations in BC. In years of high infestation, winter ticks have caused mortality and have been associated with die-off events (Samuel 2007, Severud and DelGiudice 2016; Smedley and Wickman 2017). Winter tick occurs naturally in most moose populations; however, their severity and distribution are reported to be increasing and expanding northward (Leo et al. 2014).

Winter tick is primarily associated with ungulates, their common name, "moose tick" is credited to their overwhelming abundance and effects on moose specifically (Samuel 2004, Franzmann and Schwartz 2007). Elk (*Cervus canadensis*), white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), caribou (*Rangifer tarandus*), and bison (*Bison bison*) are less affected by winter ticks due to different grooming habits, immunological resistance and hair coat characteristics (Welch et al. 1990, Zarnke et al. 1990, Franzmann and Schwartz 2007, Schwantje et al. 2014).

Winter tick require only a single host to complete their lifecycle, compared to that of the other 32 species of tick in Canada that require multiple hosts (Pybus 1999, Samuel 2004, Severud and DelGiudice 2016). Tick larvae attach to a host during peak moose breeding season (mid-September - mid-October), taking a blood meal in October and then remaining dormant until January when they take a second blood meal (Addison and McLaughlin 1988). Female ticks require high energy demands for producing eggs and engorge from March into April, after which they will take a final blood meal and drop to the ground to lay thousands of eggs (Addison and McLaughlin 1988, Pybus 1999, Samuel 2004, Franzmann and Schwartz 2007).

Increased signs of excessive grooming and irritation in moose coincide with the late phase of infestation (i.e., late winter or early spring), when ticks have their greatest growth, development, and feeding (Addison et al. 1994). Peak engorging occurs in March and April when moose are often in poor condition following winter; a difficult period of scarcity, and physical and environmental extremes (Smedley and Wickman 2017). Moose have been documented with tick numbers ranging from tens to 10,000s, with extreme cases of over 100,000 ticks counted on individual moose (Samuel and Barker 1979, Drew and Samuel 1986, Mooring and Samuel 1999).

The summation of both winter hardships and high numbers of winter ticks can be a fatal combination for moose.

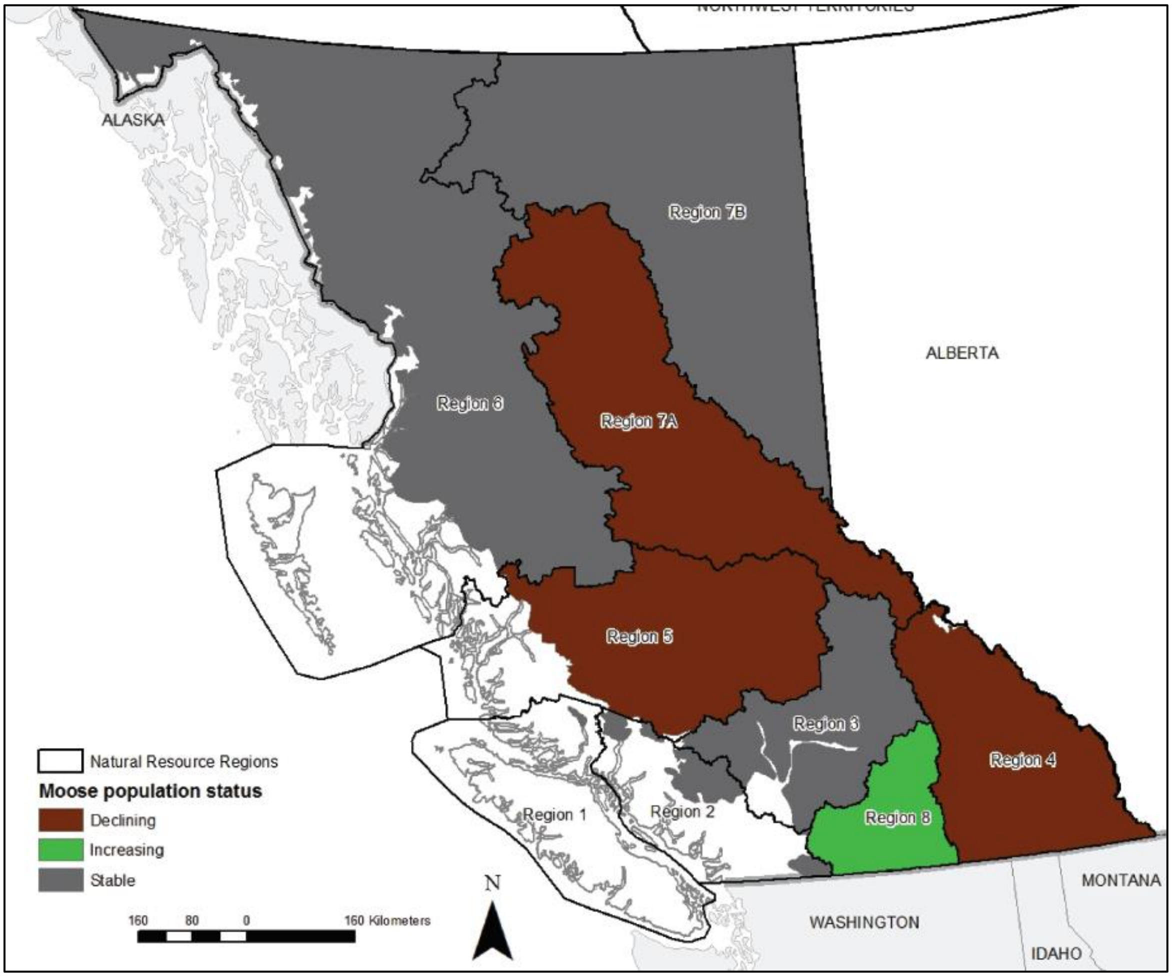


Figure 1. Distribution and population status (i.e., stable, increasing, decreasing) of moose in 7 regions in British Columbia, Canada, 2014. Adapted from "Provincial population and harvest estimates of moose in British Columbia," by Gerald Kuzyk.

Moose with moderate to severe tick infestations can have physiological and behavioural implications. Winter ticks in high abundance can remove significant amounts of blood, resulting in anemia, reduced growth in young individuals, and reduced mass and visceral fat stores in moose of all ages (Samuel 1991, Addison et al. 1994, Samuel 2004, Franzmann and Schwartz 2007, Musante et al. 2007). Excessive grooming by biting, licking, scratching, and rubbing causes damage to the winter coat which can lead to increased heat loss and reduced time spent foraging to rebuild energy reserves (Samuel 1991, Samuel 2004, Franzmann and Schwartz 2007, Samuel 2007). During the critical months of winter, these factors cause nutritional and energetic stress on moose resulting in lethargy, emaciation, predisposition to predation, and can ultimately be fatal (Samuel 2004, Franzmann and Schwartz 2007, Samuel 2007).

Damage or breakage of guard hairs and hair loss are the most visible effects of grooming in response to tick infestations. Hair loss from excessive grooming is most common on the neck, shoulders, upper mane, withers, and hind quarters. The extent of hair loss and damage is used as an indicator of tick infestation severity in individual moose, where greater amounts of hair loss suggest a higher tick burden (Samuel 1989, Pybus 1999, Samuel 2004, Franzmann and Schwartz 2007, Bergeron and Pekins 2014).

Tick prevalence is believed to be influenced by moose densities, weather conditions, and tick reproductive success (Pybus 1999, Samuel 2004, Franzmann and Schwartz 2007). Spring snow levels are the primary factor affecting tick survival according to Bergeron and Pekins (2014). If air temperatures are low (-5 °C to -20 °C) when females drop from the host onto snow in the spring, they may not survive long enough to deposit eggs (Drew and Samuel 1986). Tick loads can also be reduced by drought, cold temperatures, and early snow events in the fall. New research suggests that winter tick larvae can tolerate short-term cold shock down to -25ºC, which could enable range expansion to more northerly locations (Holmes et al. 2018). The effects of annual climatic conditions suggest that such factors may be used as an index for predicting the severity of tick infestations in the following year (Jex *pers. comm*., Bridger 2015).

The objectives of the 2021 Provincial Winter Tick Surveillance Program were to:

1) Continue to develop a systematic and repeatable method for establishing a province-wide, citizen science-based program, documenting observations of winter tick distribution and severity in moose.

2) Collect climate data to develop an index for predicting the severity of winter tick infestations.

3) Document and map the distribution of winter ticks in moose and estimate the severity of infestations within moose populations across the province during the winter of 2021.

Methods

The 2021 Provincial Moose Winter Tick Surveillance Program methods followed that of the previous six years of this program (Bridger 2015, Walsh and Bridger 2016, Walsh and Bridger 2017, Jones 2018, Jones 2019, Watt 2020). A standardized form (Appendix A) was used to document observations of moose and the extent of hair loss across BC during the winter of 2021. Bill Jex, Dr. Helen Schwantje, and Cait Nelson of the BC Wildlife Branch developed the first template of the form which was adapted from Dr. William Samuel (Samuel 1989, Samuel 2004), and then further adapted to suit the purpose of this program. Hair loss severity is classified according to five descriptive categories (Samuel 1989, Samuel 2004, Bergeron and Pekins 2014): no loss, slight loss (5–25% of winter hair lost or broken at or near skin level), moderate loss (25–40% of hair lost), severe loss (40–80% of hair lost), and "ghost" moose (>80% of hair lost). Additional information requested on the survey form included: observation location, nearest city or landmark, date and time of sighting, as well as sex, age class, and overall body condition of the observed moose. Surveys were made available as an electronic portable document format (PDF), through the online website, or by downloading an application for smart-phones and tablets to access an interactive version of the survey.

Surveys were distributed to all regions across the province where moose populations were present (Figure 1). Program information was distributed via email in January 2021, prior to when the period of expected hair loss occurs. Survey information was distributed to conservation officers, regional wildlife biologists, Indigenous communities, environmental consulting companies, conservation organizations, hunters, trappers, outdoor recreationists, the general public, and to a list of previous survey users. Program reminders, and updates were sent out via monthly e-mails.

Completed surveys were received from January 1st to April 30th, 2021. Moose observations received after the monitoring period or from out-of-province were not included in the analysis. Data from the survey forms were recorded in a Microsoft Excel spreadsheet and were later imported into ArcGIS for spatial analysis of observations. All surveys were screened by program staff for duplicates, errors (i.e., missing information) and erroneous submissions. No observations reported in 2021 were determined to be double-counts.

A Hair Loss Index (HLI; Wilton and Garner 1993, Mooring and Samuel 1999, Steinberg 2008, Bergeron and Pekins 2014) was used to estimate the infestation severity in regions where sample sizes were >50 (Bergeron and Pekins 2014). Severity of hair loss typically increases and becomes more visible in moose throughout the winter, peaking in early spring (Samuel 2004, Franzmann and Schwartz 2007). Based on this trend, survey data were grouped into two separate time periods (i.e., January–February and March–April). The HLI was calculated by multiplying the number of moose observed (M) by their respective hair loss category (1– representing no loss, through 5– representing "ghost" moose). A high HLI score indicates a more severe infestation of winter ticks, while a score close to zero indicates low tick severity. In previous studies, an HLI greater than 2.5 has been associated with mortality events (Steinberg 2008, Bergeron and Pekins 2014).

$$\text{Hair Loss Index (HLI)} = \frac{(\mathrm{M}_1 * 1) + (M_2 * 2) + (\mathrm{M}_3 * 3) + (\mathrm{M}_4 * 4) + (M_5 * 5)}{\mathrm{n} = \text{ Total \# of Moose Observed}}$$

Data were collected from the local weather stations to develop an index for predicting severity of tick infestations from year to year (Environment Canada; accessed May 2021). The Tick Severity Prediction index (TSP) was adapted from Bill Jex (BC Wildlife Branch), where the prediction for a given year was calculated as the sum of the mean daily snow-on-ground (SOG [cm]) from March to April multiplied by 0.01 in order to scale the scores (*pers. comm.,* Bill Jex,). Higher scores predict less severe infestations, while lower scores predict more severe infestations.

Results

The program began January 1st, 2021 and observations were accepted until it concluded on April 30th, 2021. A total of 323 usable surveys of moose observations were received over this period. Participants primarily used the mobile phone application (127; 39.3% of submissions); followed by online surveys (111; 34.4%) and the electronic PDF survey (85 surveys; 26.3%).

Moose observations were heavily concentrated in the Omineca and Peace regions (Figure 2 and 3; Table 1). This year had a record amount of submissions from the Peace region but a large decline in submissions from the Omineca, Skeena, and Cariboo regions, which led to a decline in overall submissions. The decline in submissions is possibly due to no public bulletin being posted, which had occurred in previous years. For all regions, 70% of observations were classified as adults and 30% were classified as calves. Province-wide trends indicated 19% of all observations showed signs of hair loss, with 18% of adults and 21% of calves showing some degree of hair loss.

Table 1. Number of moose observations (reports) collected during two time periods (January–February and March–April, 2021) in British Columbia, Canada.

Region	January – February	March – April	Total for 2021
Cariboo	5	4	9
Kootenay	2	2	4
Lower Mainland	0	0	0
Thompson	7	2	9
Okanagan	3	6	9
Omineca	39	30	69
Peace	122	71	193
Skeena	13	17	30

The Omineca, and Peace accounted for 262 of the moose observations submitted, of which 17% indicated signs of tick infestation. Of these observations, 13% reported slight hair loss, 4% moderate hair loss, 1% severe hair loss, and none were classified as “ghost” moose, while 82% reported no hair loss (Table 2). In all cases, the number of moose exhibiting hair loss was greater in March–April for the Omineca (43%) and the Peace (19%) regions than in January–February (5%, and 13% respectively). Only the Omineca and Peace regions had the required sample size to calculate the HLI.

Table 2. Classifications of moose hair loss severity observed in 2021 for the Omineca and Peace regions of British Columbia, Canada.

Region	No Loss	Slight Loss	Moderate Loss	Severe Loss	Ghost
Omineca	54	11	3	1	0
Peace	163	22	7	1	0

Total	240	38	12	2	0

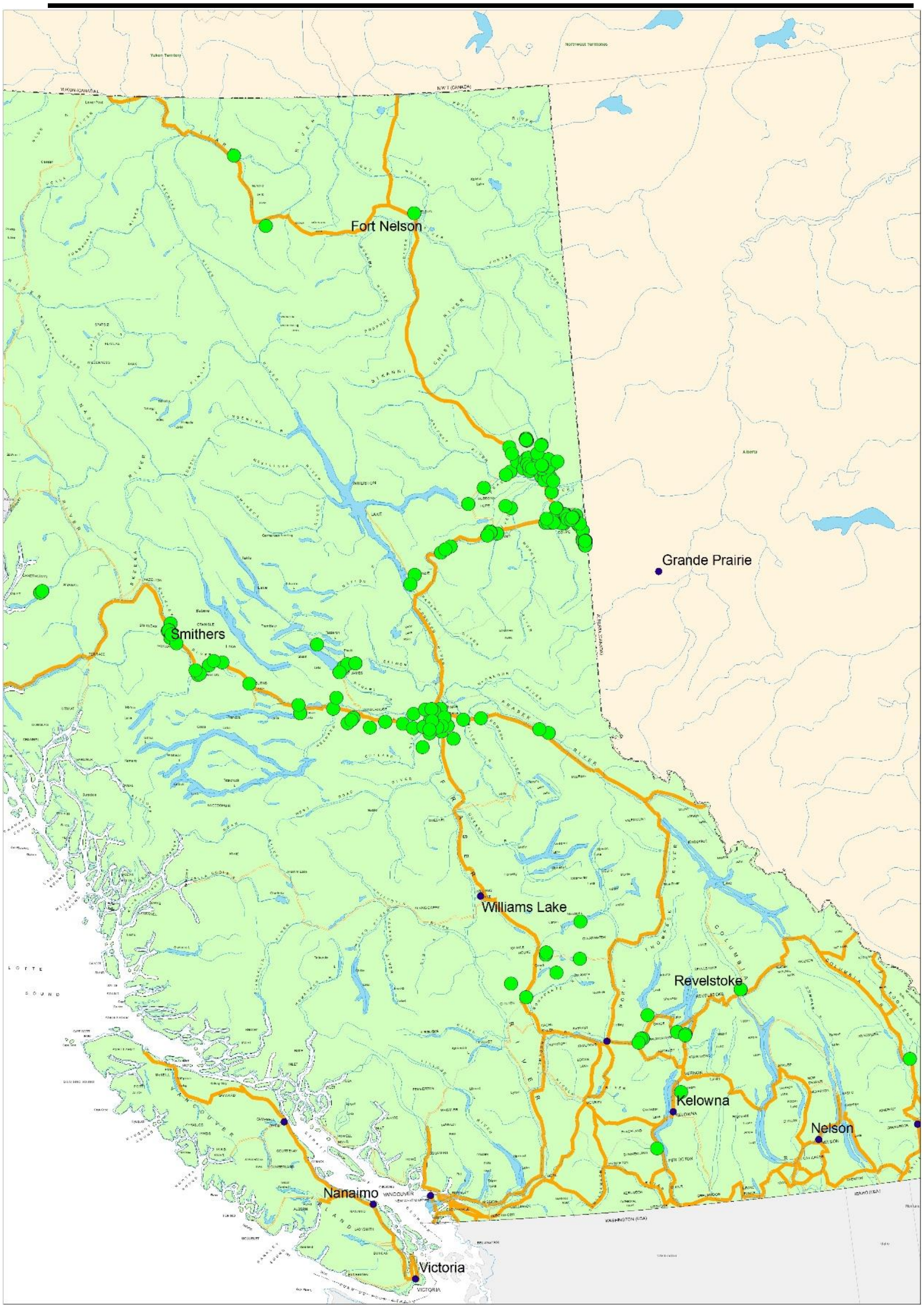


Figure 2. Locations of all moose observations (N=323) collected during winter of 2021 (January 1st - April 30th) in British Columbia, Canada.

Hair Loss Index (HLI)

Overall Hair Loss Index (HLI) for adult and calf moose was 1.26 and 1.27 (Table 3), respectively. A sample size of >50 observations is required to calculate HLI, therefore HLI was determined for only for the Omineca (HLI = 1.29) and Peace (HLI = 1.20; Figure 3 and Table 4) regions. The Omineca, and Peace regions all had lower HLI scores compared to the previous year (Table 5; Watt, 2020). The Skeena and Cariboo regions in previous years had the required sample size to calculate HLI but this year there were not enough submission to calculate HLI for those regions.

For the January–February period, adults had a slightly lower HLI value than calves (HLI = 1.13 and 1.19; Table 3). The March–April period had a slightly higher HLI score for the adult age class than the calf age class (HLI = 1.45 and 1.39) while overall age classes were very similar for adults and calves (HLI = 1.27 and 1.26; Table 3). Overall, results indicated that 34% of calves (n=131) and 29% of adults (n=294) exhibited signs of hair loss.

Table 3. Hair Loss Index (HLI) for moose observed during two time periods in 2021 by age class in British Columbia, Canada.

Age Class	January – February	March – April	Overall
Adult	1.13 (n=131)	1.45 (n=94)	1.26 (n=225)
Calf	1.19 (n=59)	1.38 (n=39)	1.27 (n=98)

Table 4. Hair Loss Index (HLI) for moose observed during two time periods in 2021 in the Omineca and Peace regions of British Columbia, Canada.

Region	January – February	March – April	Overall
Omineca	1.05 (n=39)*	1.60 (n=30)*	1.29 (n=70)
Peace	1.16 (n=121)	1.28 (n=72)	1.20 (n=193)

*Bergeron and Pekins (2014) suggest a sample size > 50 when calculating HLI

Table 5. Hair Loss Index (HLI) overall scores for moose observed in the Skeena, Omineca, Peace and Cariboo regions of British Columbia, Canada, for each year of the program.

Region	**2021**	**2020**	**2019**	**2018**	**2017**	**2016**	**2015**
Skeena	NA*	1.60 (n=94)	1.71 (n=108)	1.33 (n=91)	1.84 (n=80)	2.21 (n=135)	1.79 (n=81)
Omineca	1.29 (n=69)	1.70 (n=140)	2.17 (n=232)	1.69 (n=89)	1.87 (n=117)	2.03 (n=120)	2.17 (n=160)
Peace	1.20 (n=183)	1.31 (n=105)	1.46 (n=102)	1.62 (n=265)	1.84 (n=75)	2.57 (n=182)	1.66 (n=87)
Cariboo	NA*	1.29 (n=58)	1.43 (n=58)	NA*	NA*	NA*	NA*

*Bergeron and Pekins (2014) suggest a sample size > 50 when calculating HLI

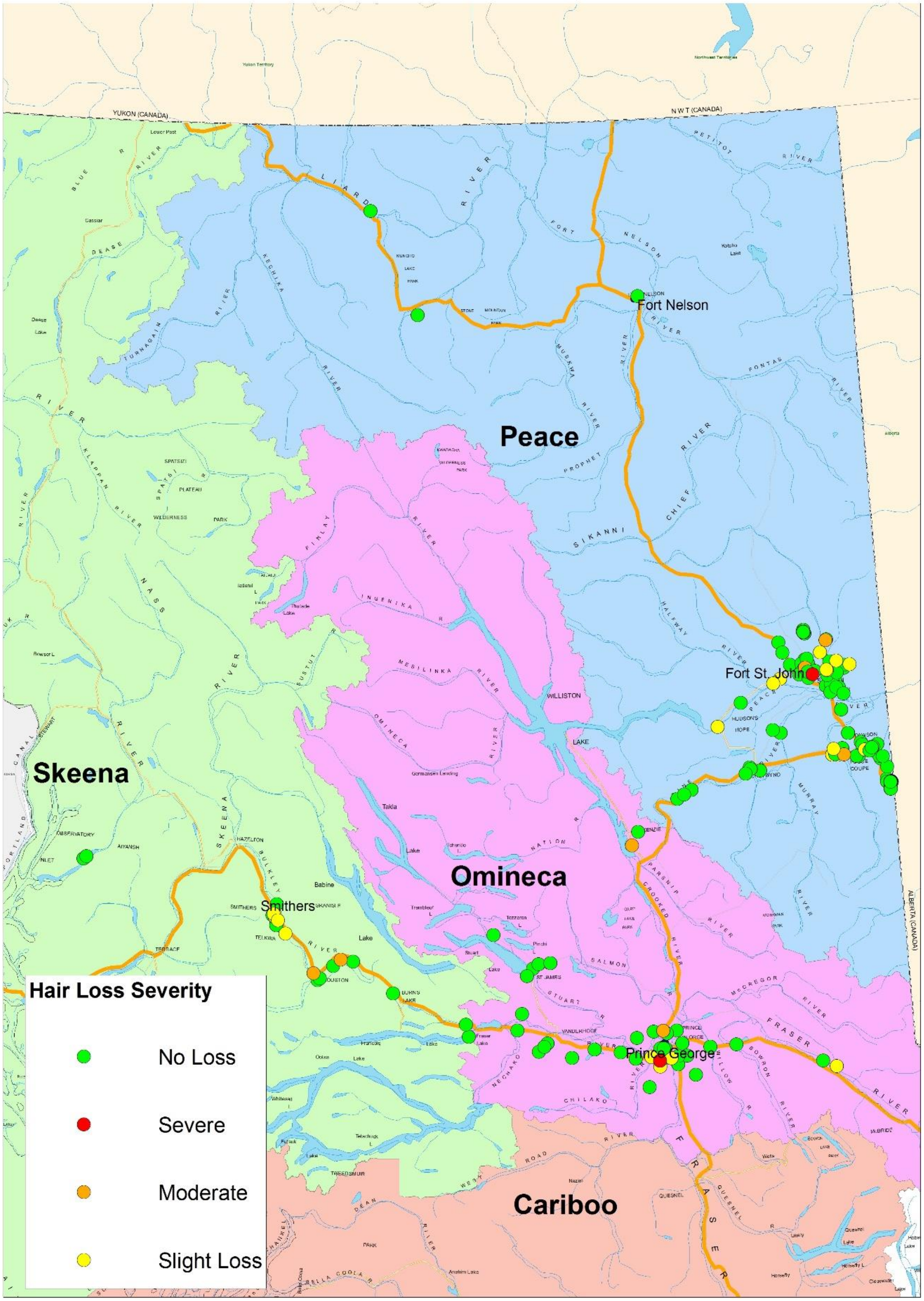


Figure 3. Locations and associated hair loss severity of moose observed in the Skeena, Omineca, and Peace regions of British Columbia, Canada.

Tick Severity Predictions (TSP)

Tick Severity Predictions (TSP) were only calculated for the Skeena, Omineca, Peace, and Cariboo regions, as they are the regions in which >50 observations are usually received. However, since only the Omineca and Peace regions had the necessary sample size to calculate HLI, these were the only regions for which TSP could be correlated with the 2021 HLI. The 2021 TSP scores were based on snow accumulation data from March and April of 2020. Lower TSP scores predict a higher severity of tick infestations. The Omineca regions had high TSP scores for the winter of 2020, which predicted a low severity tick infestation. The Peace region had a moderate TSP score, which predicted a moderate tick infestation (Table 6). In actuality, the 2021 data indicates that tick severity decreased in the Omineca and Peace. For 2022, climatic data predicts more severe infestations than the 2021 predictions in the Omineca and Peace (Table 6). These scores are based on snow accumulation data collected from March and April, 2021.

Table 6. Tick Severity Prediction (TSP) for the Skeena, Omineca, Peace and Cariboo regions of British Columbia, Canada, based on snow accumulation data collected from March – April of each year at the Smithers, Prince George, Fort St. John and Williams Lake weather stations. Higher scores predict lower severity of winter tick infestations.

Region	*2022*	2021	2020	2019	2018	2017	2016	2015
Skeena	*6.4*	11.2	9.2	20.4	<0.1	0.6	2.3	6.1
Omineca	*3.3*	13.2	12.6	17.4	1.0	0.3	1.9	9.2
Peace	*1.5*	7.1	4.7	19.7	6.7	3.5	2.1	6.3
Cariboo	*13.1*	3.6	7.2	13.7	3.4	0.38	0.51	11.7

Discussion

Northward range expansion of the winter tick is a serious concern for moose populations and other host species. Studies have shown that winter tick can survive in regions of the Yukon and Alaska where originally, they were thought to be unable to survive due to long winters and very low temperatures (Zarnke et al. 1990, Leo et al. 2014). Warming climatic conditions are potentially creating opportunities for tick survival in previously unsuitable habitat and establishment of winter tick populations in the more northern latitudes. The data and initial results from this program do not necessarily show a distribution change or range expansion of winter tick; however, the citizen-science-based methodology may not be best suited for documenting expansion of winter ticks in remote, uninhabited areas of the province.

Hair Loss Index estimates in this study were based on methods developed in Alberta, Ontario, and New Hampshire (Samuel 2004, Steinberg 2008, Bergeron and Pekins 2014), and caution should be applied when comparing these predictions across regions of BC. This program has collected six consecutive years of HLI data for the province, but normal levels of hair loss severity are still relatively unknown for each region and may differ amongst regions. Over the course of the program, regional averages of HLIs varied from 1.36 to 1.85 (Table 7).

Table 7. Average HLI for the Skeena, Omineca, Peace, and Cariboo regions over the course of the Moose Winter Tick Surveillance Program (2015–2021).

	Skeena	Omineca	Peace	Cariboo
Average	1.75	1.85	1.68	1.36

In the two regions where there were >50 observations, overall HLI scores decreased from 2021 (suggesting a decrease in infestation severity). The Peace region scores have shown a reduction in tick severity since 2016. The HLI for the Omineca and Peace regions were the lowest since the program was started, indicating a low tick infestation for this year. The Skeena and the Cariboo did not meet the required sample size to calculate the HLI, so this year's data were not included in the averages for those regions. Literature indicates that young-of-the-year moose tend to exhibit greater effects of tick infestations (Addison et al. 1994, Samuel 2004, Franzmann and Schwartz 2007). The low tick severity recorded this year decreases the likelihood of mortality events, which would indicate a higher survival rate for both adult and moose calves over the winter.

The correlation between HLI and TSP is still relatively unknown. In 2017 the Updated Tick Severity Predictor (UTSP) was created, which attempted to include autumn climatic conditions as indicators of infestation severity. In 2021, UTSP and TSP scores were very similar (within 1 point of each other) and therefore only the TSP index was used. It is hypothesized that TSP and HLI are negatively correlated, as TSP decreases, HLI would increase and vice-versa. Only the Peace region from 2016 to 2019 showed a trend to support this hypothesis where TSP has correctly predicted HLI. For the Peace region the TSP scores predicted less severe tick infestations from 2020, and the data 2021 data supported that prediction. For the Omineca, the TSP predicted a similar HLI as in 2020, however, the data suggested that tick severity was lower than expected. It remains unclear from the short-term data if these predictors are useful for understanding tick infestations, as there are other factors contributing to winter tick prevalence. For all cases, the HLI did increase from January–February to March–April time periods as the severity of infestation and visibility of hair loss increases, as expected. Tick Severity Predictor scores based on snow accumulation data from spring 2021 suggest that tick severity will increase for the Peace and Omineca regions in 2022 (Table 6). Comparisons between 2021 and 2022 cannot be made for the Skeena and Cariboo due to the low sample size in 2021. Continuing this program may provide long-term data to better support the relationship between tick infestation severity and annual climatic conditions.

Research on prescribed burning suggests that fire is effective in reducing numbers of winter tick available for transmission in the autumn (Drew and Samuel 1985, Gleim et al. 2014). In BC, wildfires have been increasing in number and severity over the past decade, but the effects on winter tick severity and distribution are largely unknown. Failure to account for stochastic events, such as fire, may explain some of the conflicting results between HLI and TSP scores. The spatial scale at which such events occur, however, may not result in an effect that is detectable in a large-scale study, such as this. Regardless, the use of prescribed fire should be considered as a management option in areas where high tick loads are a limiting factor for moose populations.

A recent study in Maine and New Hampshire has identified soil fungi species in wallow sites that are pathogenic to winter tick larvae (Yoder et al. 2018). Moose using such wallow sites were exposed to these fungi species which may act as an on-host mechanism of tick control (Yoder et al. 2018). The relationship between wallowing behaviour of moose, winter tick abundance, and fungi pathogenic to winter tick should be further investigated, and hints that there may be other behavioural tendencies affecting winter tick abundance that may not yet be known. While this particular citizen-science program is not designed to address these behavioural issues, it does present valuable information that can be used to inform further research.

Conclusions

The 2021 Provincial Moose Winter Tick Surveillance Program received 323 submissions, down from 425 submissions in 2020, and the lowest number of submissions received since implementation of the program. In 2021, the Peace region had the most submissions since the start of the program but there was a large decline in submissions from the Omineca, Skeena, and Cariboo regions. It is possible that the continued effects of COVID-19 virus along with no media release from the Government Communications & Public Engagement (GCPE) led to lower engagement from the public. In the future more outreach should be done with local groups (e.g., rod and gun clubs) in hopes of getting more submissions. Hair Loss Index data for 2021 indicate winter tick infestations were less severe than 2020 in the Omineca and Peace regions, while other regions did not meet the required sample size to provide reliable inferences. For 2021, the TSP scores for the Peace region predicted the HLI relatively well but poorly predicted the HLI for the Omineca region. This suggests the methods used to predict yearly tick infestation severity require further refinement. This cost-effective program continues to provide valuable information on tick abundance, severity, and distribution across the province. Intensive, hands-on research of tick severity and abundance can be costly and time-intensive to complete on a large geographic expanse, such as BC. Citizen-science programs engage a wide variety of participants and can be a successful, inexpensive alternative to other research methods. Although the program has inherent challenges and biases, its ability to document moose tick infestation and distribution over a large geographic area and short time span, while engaging members of the public and increasing awareness of significant wildlife health issues, reaffirms the importance of continuing this research for years to come.

Acknowledgements

This project was funded by the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development – North Area. Thank-you to Michael Bridger of the BC Wildlife Branch who initiated this program in 2015 and since has provided guidance through each year of the program. Dr. Helen Schwantje and Cait Nelson of the BC Wildlife Branch and Wildlife Health Program were instrumental in establishing the program in 2015, thank-you. Courtney Jones and Dustin Walsh deserves thanks for developing this program over the years, their work is greatly appreciated. We would also like to thank Andy Muma and Dave Amirault for developing the interactive survey and managing the online database, Helen Davies and Elizabeth Enloe for establishing the online survey and winter tick website, and Lisa Roscoe for distributing the program information online. Most of all, we would like to thank all the survey users who took time to report moose observations through the winter/spring, and to the media outlets who advertised the program.

References

Addison, E.M., and R.F. McLaughlin. 1988. Growth and development of winter tick, *Dermacentor albipictus*, on moose, Alces alces. Journal of Parasitology 74:670–678.

Addison, E.M., R.F. McLaughlin, and J.D. Broadfoot. 1994. Growth of moose calves (Alces alces americana) infested and uninfested with winter ticks (*Dermacentor albipictus*). Canadian Journal of Zoology 72:1469–1476.

Bergeron, D.H., and P.J. Pekins. 2014. Evaluating the usefulness of three indices for assessing winter tick abundance in northern New Hampshire. Alces 50:1–15.

Bridger, M.C. 2015. Provincial moose winter tick surveillance program. Retrieved from the Government of British Columbia website: http://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-health/wildlife-health-matters/moose-health

Drew, M.L., and W.M. Samuel. 1985. Factors affecting transmission of larval winter ticks, Dermacentor albipictus (Packard), to moose, Alces alces L., in Alberta, Canada. Journal of Wildlife Diseases 21:274–282.

Drew, M.L., and W.M. Samuel. 1986. Reproduction of the winter tick, Dermacentor albipictus, under field conditions in Alberta, Canada. Canadian Journal of Zoology 64:714–721.

Franzmann, A.W., and C.C. Schwartz. 2007. Ecology and management of the North American moose. Wildlife Management Institute. University press of Colorado.

Gleim, E. R., L.M. Conner, R.D. Berghaus, M.L. Levin, G.E. Zemtsova, and M.J. Yabsley. 2014. The phenology of ticks and the effects of long-term prescribed burning on tick population dynamics in southwestern Georgia and northwestern Florida. Plos One 9(11)

Holmes, C. J., C.J. Dobrotka, D.W. Farrow, A.J. Rosendale, J.B. Benoit, P.J Pekins, and J.A. Yoder. 2018. Low and high thermal tolerance characteristics for unfed larvae of the winter tick *Dermacentor albipictus* (Acari: Ixodidae) with special reference to moose. Ticks and Tick-borne Diseases 9: 25-30.

Jones, C.N. 2018. 2018 provincial moose winter tick surveillance program. Retrieved from the Government of British Columbia website: http://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-health/wildlife-health-matters/moose-health/moose-winter-tick-survey

Jones, C.N. 2019. 2019 provincial moose winter tick surveillance program. Retrieved from the Government of British Columbia website:

http://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-health/wildlife-health-matters/moose-health/moose-winter-tick-survey

Kuzyk, G.M. 2016. Provincial population and harvest estimates of moose in British Columbia. Alces 52:1-11.

Kuzyk, G., C. Procter, S. Marshall, H. Schindler, H. Schwantje, M. Scheideman, D. Hodder. 2019. Factors affecting Moose population declines in British Columbia. 2019Progress Report: February 2012–May2019. B.C. Minist. For., Lands and Nat. Resour. Operations and Rural Dev. Victoria, BC. Wildl. Working Rep. No. WR-127. 73 pp.

Leo, S.S.T., W.M. Samuel, M.J. Pybus, and F.A.H. Sperling. 2014. Origin of Dermacentor albipictus (Acari; Ixodidae) on elk in the Yukon, Canada. Journal of Wildlife Diseases

Mooring, M.S., and W.M. Samuel. 1999. Premature loss of winter hair in free-ranging moose (Alces alces) infested with winter ticks (Dermacentor albipictus) is correlated with grooming rate. Canadian Journal of Zoology 77:148-156.

Pybus, M.J. 1999. Moose and ticks in Alberta: a die-off in 1998/99. Alberta Environment - Fisheries and Wildlife Management Division. Pub. No.1/788.

Samuel, W.M. 1989. Locations of moose in northwestern Canada with hair loss probably caused by the winter tick, Dermacentor albipictus (Acari: Ixodidae). Journal of Wildlife Diseases 25:436–439.

Samuel, W.M. 1991. Grooming by moose (Alces alces) infested with the winter tick, Dermacentor albipictus (Acari): a mechanism for premature loss of winter hair. Canadian Journal of Zoology 69:1255–1260.

Samuel, W.M. 2004. White as a Ghost: Winter Ticks and Moose. Natural History Series, Volume 1. Federation of Alberta Naturalists, Edmonton, Alberta.

Samuel, W.M. 2007. Factors affecting epizootics of winter ticks and mortality of moose. Alces 43:39-48.

Samuel, W.M., and M.J. Barker. 1979. The winter tick, Dermacentor albipictus (Packard, 1869), on moose, Alces alces (L.), of central Alberta. In Proceedings of 15th North American Moose Conference and Workshop, Soldotna-Kenai, Alaska, March 1979. Lakehead University, Thunder Bay, Ont. p. 303–348.

Schwantje, H., Macbeth, B.J., Kutz, S., and B. Elkin. 2014. British Columbia Boreal Caribou Health Program Progress Report: Year 1 (November 1, 2013 – December 31, 2014). Retrieved from the BC Oil and Gas Research and Innovation Society website:

http://www.bcogris.ca/sites/default/files/bcip-2014-05-bc-boreal-caribou-health-program-year-end-report-28201429-ver-1c.pdf.

Severud, W.J., and G.D. DelGiudice. 2016. Potential vertical transmission of winter ticks (Dermacentor albipictus) from moose (Alces americanus) dams to neonates. Journal of Wildlife Diseases 52(1): 186-188.

Smedley, S.R., and T. Wickman. 2017. Winter ecology: Insights from biology and history. Northeastern Naturalist. 24 (Special Issue 7):ii-viii.

Steinberg, B. 2008. Algonquin Park Moose Hair-loss Survey Report. Ontario Parks, Ontario, Canada.

Walsh, D.A., and M.C. Bridger. 2016. 2016 provincial moose winter tick surveillance program. Retrieved from the Government of British Columbia website: http://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-health/wildlife-health-matters/moose-health

Walsh, D.A., and M.C. Bridger. 2017. 2017 provincial moose winter tick surveillance program. Retrieved from the Government of British Columbia website: http://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-health/wildlife-health-matters/moose-health/moose-winter-tick-survey

Watt, K.W. 2020. 2020 provincial moose winter tick surveillance program. Retrieved from the Government of British Columbia website: http://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-health/wildlife-health-matters/moose-health/moose-winter-tick-survey

Welch, D. A., W.M. Samuel, and C.J. Wilke. 1991. Suitability of moose, elk, mule deer, and white-tailed deer as hosts for winter ticks (*Dermacentor albipictus*). Canadian Journal of Zoology 69: 2300-2305.

Wilton, M.L., and D.L. Garner. 1993. Preliminary observations regarding mean April temperature as a possible predictor of tick-induced hair-loss on moose in south central Ontario, Canada. Alces 29:197–200.

Zarnke, R.L., W.M. Samuel, A.W. Franzmann, and R. Barrett. 1990. Factors influencing the potential establishment of the winter tick (Dermacentor albipictus) in Alaska. Journal of Wildlife Diseases 26:412–415.

Appendix A.

BRITISH COLUMBIA | Ministry of Forests, Lands, Natural Resource Operations and Rural Development

BC WILDLIFE HEALTH PROGRAM

MOOSE WINTER TICK SURVEY (FS1436)

Please return this form via email to **FLNRMooseTickSurvey@gov.bc.ca**

The BC Wildlife Health Program is asking for observations of moose winter tick. All observations of moose should be recorded using this form for consistent data collection. This observation record is important to Ministry Wildlife staff as it will allow us to develop an index of moose tick infestations over time. Your assistance is greatly appreciated.

SECTION 1: PLEASE FILL IN ALL INFORMATION ON MOOSE OBSERVATION

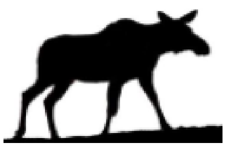
DATE: YYYY/MM/DD	TIME	NEAREST CITY OR LANDMARK

LOCATION OF OBSERVATION: (PLEASE BE AS SPECIFIC AS POSSIBLE; I.E COORDINATES, FOREST SERVICE ROAD KM MARKERS, INTERSECTIONS OF ROADS, ETC.)

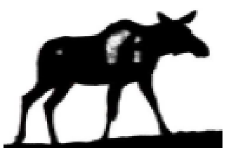
SEX	AGE CLASS	BODY CONDITION
◯ MALE ◯ FEMALE ◯ UNKNOWN	◯ CALF ◯ ADULT	◯ POOR ◯ MODERATE ◯ GOOD ◯ EXCELLENT

SECTION 2: CHECK THE BOX BELOW TO DESCRIBE THE AMOUNT OF HAIR LOSS (FOR CARCASSES - SEE SECTION 3)

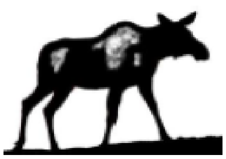
IF BOTH SIDES ARE VIEWED, THE MORE SEVERELY INFESTED SIDE SHOULD BE RECORDED



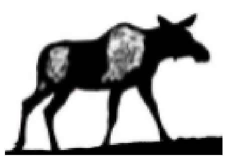
◯ **NO LOSS**: *Normal haircoat. No obvious indications of tick infestation.*



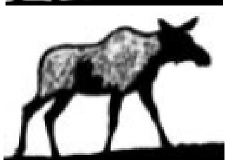
◯ **SLIGHT LOSS**: *Few small patches of hair loss. Tick infestation affecting 5–25% of winter hair (lost or broken at or near skin level).*



◯ **MODERATE**: *Large patches of hair loss. Tick infestation affecting 25–40% of winter hair.*



◯ **SEVERE**: *Significant hair loss on shoulders and hind quarters. Tick infestation affecting 40–80% of winter hair.*



◯ **GHOST**: *Hair loss over most of body (except head). Tick infestation affecting over 80% of winter hair.*

SECTION 3: FOR CARCASSES ONLY: CHECK APPROPRIATE BOX TO DESCRIBE TICK ABUNDANCE

◯ Light tick abundance (<100 swollen ticks on head and neck)
◯ Moderate tick abundance (100–1000 swollen ticks on head, neck, shoulders)
◯ Heavy tick abundance (1000+ swollen ticks everywhere)

FS1436 01/16 V1.2