Montana Fish, Wildlife & Parks' 2019 Chronic Wasting Disease Surveillance and Monitoring Report

Federal Aid in Wildlife Restoration Grant W-171-M

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STATE:	***Montana***
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Executive Summary

Montana Fish, Wildlife, and Parks (FWP) has been conducting surveillance for chronic wasting disease (CWD) since 1998, and first detected CWD in wild deer in 2017. In 2019, FWP prioritized sampling in southeastern Montana (the southern halves of hunting districts (HDs) 702, 704, and 705), the Philipsburg area (HDs 210, 212, 217), the Hi-Line (HDs 400, 401, 600, 611, 620, 630, 640, 641, and 670), and the Libby CWD Management Zone (portions of HDs 100, 103, and 104). In addition, FWP organized two special CWD hunts with mandatory CWD sampling known as the Libby and Moffat Bridge Special CWD Hunts. FWP offered free state-wide testing available via mail-in, CWD-check stations, and all regional FWP headquarter offices for the first time in 2019.

During the 2019 season, FWP collected and tested 7025 samples from mule deer (n=3837), white-tailed deer (n=2828), elk (n=332), and moose (n=28). Of these, 144 animals tested positive for CWD, including 53 mule deer, 88 white-tailed deer, 1 elk, and 2 moose. These were Montana's first detections in elk and moose. In 2019, we detected new CWD-positive areas in northwestern Montana (Libby), southwestern Montana (near Sheridan), and in eastern and southeastern Montana. In addition, we expanded the boundaries of known CWD-positive areas with new detections south of Highway 2 along the Hi-Line and north of the Yellowstone River in southcentral Montana. In total, we had CWD detections in 12 new hunting districts around the state: 100, 103, 104, 322, 590, 630, 650, 690, 701, 702, 704, 705. Detections of 8 positive animals in 5 new hunting districts were the result of expanded, free testing. No positive animals were found in the Philipsburg area, and with our sample sizes to date, we likely would have detected a positive if prevalence there were ≥ 5% in mule deer and ≥ 1% in white-tailed deer.

Among CWD-positive hunt districts across the state, prevalence estimated from hunter-harvested animals sampled from 2017-2019 ranged from <1% -7% in mule deer and <1% - 18% in white-tailed deer. In the town of Libby, 13% (95%CI: 9-19%) of hunter-harvested or trapped white-tailed deer were positive for CWD, whereas only 4% (95%CI: 2-5%) were positive outside the town within the Libby CWD Management Zone. Within the Moffat Bridge Special Hunt area, prevalence was estimated to be 1% (95%CI: 0-3%) in mule deer and 5% (95%CI: 1-22%) in white-tailed deer. Preliminary information from the Sheridan-Twin Bridges area suggests prevalence may be quite high among white-tailed deer there (hunter-harvest prevalence in HD 322 = 18%, 95%CI: 5-48%), although more intensive sampling is needed to improve the precision of our estimate.

An analysis of all data collected from 2017-2020 from hunter-harvested deer in CWD-positive hunting districts suggests several state-wide patterns of infection across species, sex, and age class. Alone, species was not a significant predictor of infection risk, suggesting prevalences are similar among deer species, or patterns are variable enough across hunting districts to preclude a general pattern. Among mule deer, adult males had 3.7 times the risk of infection as adult females across Montana's hunting districts, whereas among white-tailed deer, sex was not significantly associated with infection status. The risk of infection was greatest in adults, followed by yearlings and young of the year.

FWP continues to plan for long-term CWD management in positive areas. In 2020, FWP may move toward a carcass disposal requirement in lieu of carcass transport restrictions associated with CWD Management Zones. Sampling in 2020 will focus on eastern, southeastern, northwestern, and southwestern Montana.

Background

Chronic Wasting Disease (CWD) is a fatal neurologic disease of cervids (deer, elk, moose and caribou) for which there is no known cure. CWD is caused by an infectious, mis-folded prion protein which is shed by infected individuals for much of their approximately 2-year infection. The CWD associated prion is transmitted via direct animal-to-animal contact and through the ingestion of prion-contaminated materials in the environment. Since CWD was discovered in Colorado in 1967, it has been documented in captive or free-ranging cervid populations in 26 US states, three Canadian Provinces, Norway, Sweden, Finland, and South Korea. CWD is a relatively slow-moving disease, and if left unmanaged, may take decades to reach prevalences of 20-30%. Significant herd-level declines are predicted at such high prevalences (Gross and Miller 2001, Wasserberg et al. 2009, Almberg et al. 2011), and have been documented among mule deer and white-tailed deer in Wyoming (DeVivo 2015, Edmunds et al. 2016) and Colorado (Miller et al. 2008). Surveillance programs aimed at detecting CWD early are essential to providing the best options for managing the spread and prevalence of the disease. While CWD is not known to infect humans, public health authorities advise against consuming meat from a CWD-positive animal and recommend hunters have their deer, elk, or moose tested if it was harvested within a CWD-endemic area.

Introduction

Surveillance programs for CWD are essential to the early detection of the disease in wild cervid populations. Detection of CWD while prevalence is still low is thought to be critical to the success of managing the disease. Nationally, surveillance efforts for CWD have varied over time and have fluctuated in response to funding and public interest. This has been true for Montana as well. More recently, renewed concerns over the potential risk to human health (Czub et al. 2017), the discovery of CWD in wild cervids in several new states, and renewed national legislative discussion on CWD have fueled interests to increase surveillance once again. With additional surveillance and concerted efforts at managing the disease, such as those outlined in the Western Association of Fish and Wildlife Agencies' 2017 recommendations for adaptive management of CWD in the West, our goal is to effectively manage the disease in wild populations and stave off the worst of the predicted population declines.

Montana Fish, Wildlife, and Parks (FWP) has been conducting surveillance for CWD since 1998, with varying levels of intensity. In 2017, FWP renewed its CWD surveillance and management plans with the help of an internal CWD Action Team and a CWD Citizen's Advisory Panel. FWP's plan outlines a strategy to maximize our ability to detect CWD in high-priority areas where it is not known to exist. This entails (1) continuing to test any symptomatic deer, elk, or moose statewide, (2) focusing surveillance on mule deer, which in other states and provinces tend to exhibit higher prevalences than white-tailed deer, elk and moose, and (3) employing a weighted surveillance strategy aimed at detecting 1% CWD prevalence with 95% confidence (Walsh 2012) that rotates among high-priority CWD surveillance areas. High priority surveillance areas (Figure 1) were defined as those areas within Montana that had both high mule deer densities and that were closest to the nearest known cases of CWD (Russell et al. 2015). In addition, once an area is determined to be positive for CWD, FWP may set up special CWD hunts, or use hunter-harvest samples from the general season to monitor the distribution and prevalence of the disease.

In the fall of 2019, FWP conducted CWD surveillance in southeastern Montana (the southern portions of hunting districts 702, 704, and 705), around Philipsburg (hunting districts 210, 212, and 217), and continued monitoring CWD prevalence in the districts along the Hi-Line (northern border), which were identified as positive in 2017-2018 (Figure 1). FWP held two special CWD hunts in 2019: the Moffat Bridge Special CWD Hunt, in response to a detection on the Marias River in 2018; and the Libby Special CWD Hunt, in response to a detection in Libby in April, 2019. Lastly, FWP provided free, state-wide CWD testing of hunter-harvested animals for the first time in 2019. Below, we report on the results and lessons learned from the 2019 CWD surveillance and monitoring efforts.

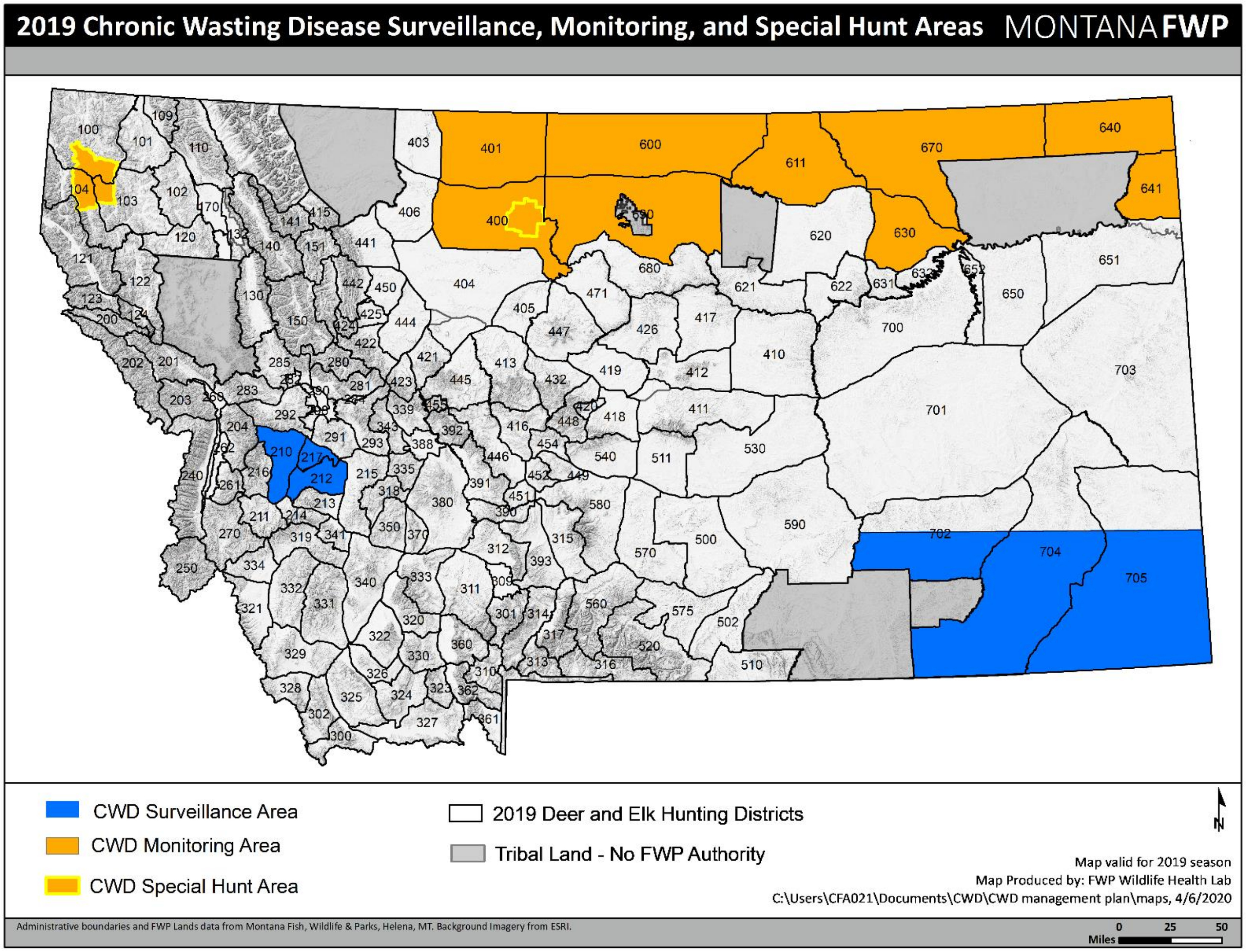


Figure 1. CWD priority sampling areas in Montana, 2019. CWD surveillance areas included southeastern Montana and around Philipsburg. CWD monitoring to measure prevalence and distribution occurred along the Hi-Line and in the Libby area. Special CWD hunts occurred at Moffat Bridge and within the Libby CWD Management Zone.

Methods

Surveillance

In 2017, FWP identified priority surveillance areas around the state that had both high mule deer densities (within the upper quartile, based on resource selection functions integrated with count data) and were within the lowest 25% of distances to the nearest known cases of CWD (Russell et al. 2015). In 2019, FWP focused its surveillance efforts on two of these priority areas: southeastern Montana and around Philipsburg (for the second year). The priority surveillance area in southeastern Montana was divided into three minimum surveillance units (the southern halves of hunting districts 702, 704, and 705), and the area around Philipsburg (hunting districts 210, 212, and 217) constituted a single minimum surveillance unit (Figure 1). Each minimum surveillance unit was defined as a portion of, or an aggregation of hunting districts meant to capture discrete and well-mixed population units of deer with ≤15,000 mule deer (Table 1). Within each minimum surveillance unit, we employed a weighted surveillance strategy aimed at detecting 1% CWD prevalence with 95% confidence (Walsh 2012). Under the weighted surveillance framework, different demographic groups (age, sex, or cause of death categories) of a species are assigned different point-values based on their relative risk of being infected (Table 2). A total of 300 points were necessary to establish our detection goals within each minimum surveillance unit. Sample size goals were specific to a single species within a minimum surveillance unit, and our efforts prioritized the sampling of mule deer since they appear to have the highest prevalences among the different cervid species where they overlap (Miller et al. 2000). Elk, white-tailed deer, and moose were sampled opportunistically.

Table 1. Minimum CWD surveillance units within the 2019 priority surveillance areas and estimated mule deer population sizes (2015 estimates). In addition, CWD monitoring was conducted along the Hi-Line and in the Libby CWD Management Area.

Minimum CWD surveillance units for mule deer populations (Aggregations or portions of hunting districts)	Estimated mule deer population size
Philipsburg: HDs 210, 212, 217	2,000
SE MT: Southern half of 702	5,000
SE MT: Southern half of 704	12,000
SE MT: Southern half of 705	15,000

Table 2. Relative weights or "points" associated with each demographic group of deer and elk that count towards meeting a sample size goal using a weighted surveillance strategy based on data from mule deer and elk in CWD-positive areas in Colorado (Walsh and Otis 2012) and white- tailed deer in Wisconsin's CWD management zone (Jennelle et al. 2018).

	Weight/Points		
Demographic Group	**Mule Deer**	**White-tailed Deer**	**Elk**
Symptomatic female	13.6	9.09	18.75
Symptomatic male	11.5	9.09	8.57
Road-killed males/females	1.9	0.22	0.41
Other mortalities (predation, other unexplained in adults and yearlings)	1.9	7.32	0.41
Harvest-adult males	1	3.23	1.16
Harvest-adult females	0.56	1.30	1.00
Harvest-yearling females	0.33	0.85	0.23
Harvest-yearling males	0.19	1	NA
Harvest-fawns/calves	0.001	0.04	NA

FWP staff collected samples between April 1, 2019 – March 15, 2020 from mule deer, white-tailed deer, elk, and moose that were either hunter-harvested, road-killed, symptomatic and euthanized, or found dead. An animal was considered symptomatic if it appeared extremely sick and/or displayed symptoms consistent with CWD (emaciation, lack of coordination, drooping head/ears, excessive salivation, etc.). FWP used a variety of tools to obtain samples, including working with hunters at check stations, processors and taxidermists, outfitters, landowners, Montana Department of Transportation, Highway Patrol, and by sending letters to license holders notifying them of the surveillance effort. Field and laboratory staff collected retropharyngeal lymph nodes (Hibler et al. 2003) or an obex sample if lymph nodes were not available (both lymph nodes and obex were collected from moose), an incisor tooth for aging, and a small genetic sample (muscle tissue) for each cervid sampled as part of the CWD surveillance program. Field staff worked with hunters or others to gather precise location information on where the animal was harvested/found, as well as species, age, and sex information for each sampled animal. Lymph nodes and obex from deer and elk were frozen for subsequent enzyme-linked immunosorbent assay (ELISA) testing, whereas lymph nodes and obex from moose were fixed in 10% buffered formalin for immunohistochemistry (IHC) testing. Samples were submitted to Colorado State Veterinary Diagnostic Laboratory on a weekly basis. Testing costs were $17/sample for the ELISA, and $35/sample for IHC (used to confirm positive test results). Results from hunter-harvested animals were posted on FWP's website as soon as results were received from the lab. When a harvested animal tested positive for CWD, FWP directly contacted the associated hunter to inform them of the test results, to let them know the meat could be legally disposed of, and to discuss proper disposition of the carcass parts.

In addition to the focused sampling efforts in the 2019 priority surveillance areas, FWP collected or received samples from symptomatic or hunter-harvested animals state-wide. Hunters that harvested an animal outside of the priority surveillance areas that wanted to have their animal tested either brought their animal to a CWD check station or a regional headquarters office or were instructed on how to collect and mail in their samples for testing that was paid for by FWP. The video instructing hunters how to collect their own CWD sample can be found at fwp.mt.gov/CWD under "Submitting Samples."

Monitoring of prevalence and distribution within CWD Positive Areas

In 2019, FWP initiated special hunts around Moffat Bridge and Libby to measure CWD prevalence and distribution in these areas (Figure 1). In addition, FWP prioritized sampling in the districts along the Hi-Line to better estimate prevalence there. Estimates of prevalence were calculated using only data from hunter-harvested, or agency trapped and euthanized animals (in Libby), from 2017-2020.

Data summaries and analyses

Weighted surveillance points were calculated separately for mule deer, white-tailed deer and elk (relative risk of infection data currently does not exist for moose). For each species, we tallied the number of samples collected within each of the age/sex/cause of death categories outlined in Table 2, multiplied this by their assigned point value, and summed all points within a minimum surveillance unit. We then modified the equation for the sample size (n) needed to establish freedom from disease at a specified prevalence level (P; proportion of the population that is positive), with a desired level of statistical confidence (α),

$$n = \frac{-\ln(1-a)}{P}$$

to calculate the threshold prevalence above which we would expect to detect at least one positive given our weighted surveillance points (n) and assuming 95% statistical confidence:

$$P = \frac{-\ln(1-a)}{n}$$

Following detection, we explored patterns of infection among hunter-harvested deer in CWD-positive hunting districts using logistic, generalized linear mixed models. We evaluated the odds of infection as a function of species, sex, age class, and relative timing of harvest within the general season (early-rut: Oct 15-Nov 14; late-rut: Nov 15-Dec 5), while using hunting district as a random effect. Models with various permutations of these covariates were evaluated using Akaike's Information Criterion (AIC; Burnham and Anderson 2002), and unless otherwise noted, we report the estimated covariate effects from the best supported models (< 2 AIC units from the top model). Odds ratios (exponentiated logistic coefficients) were converted to estimates of relative risk to facilitate interpretation (relative risk = odds ratio/(1-p_0 + (p_0*odds ratio)), where p_0 is the prevalence within the baseline group; Grant 2014). All analyses were carried out in Program R (R Core Team 2017).

We reported prevalence at several different scales, including at the scale of hunting districts, Special CWD Hunt areas, and by using a standardized 50 x 50 mile^2 grid across the state. We calculated 95% binomial confidence intervals using the Wilson method.

Results

During April 1, 2019 – March 15, 2020, FWP submitted 7025 samples to Colorado State University's Veterinary Diagnostic Lab for testing, which was a 3.5-fold increase over the number of samples collected in 2018 (n=2016). Of these samples, 3837 were collected from mule deer, 2828 from white-tailed deer, 332 from elk, and 28 from moose. Thirty eight percent (n=2678) of samples were collected from outside our priority sampling areas. Hunters collected and submitted 1150 of their own samples in 2019, of which 1112 (97%) were suitable for testing. The majority of these hunter-submitted samples were collected in known CWD-positive areas (Appendix I, Figure 1A). Since FWP's renewed surveillance efforts in 2017, we have tested 11159 samples statewide (Figure 2).

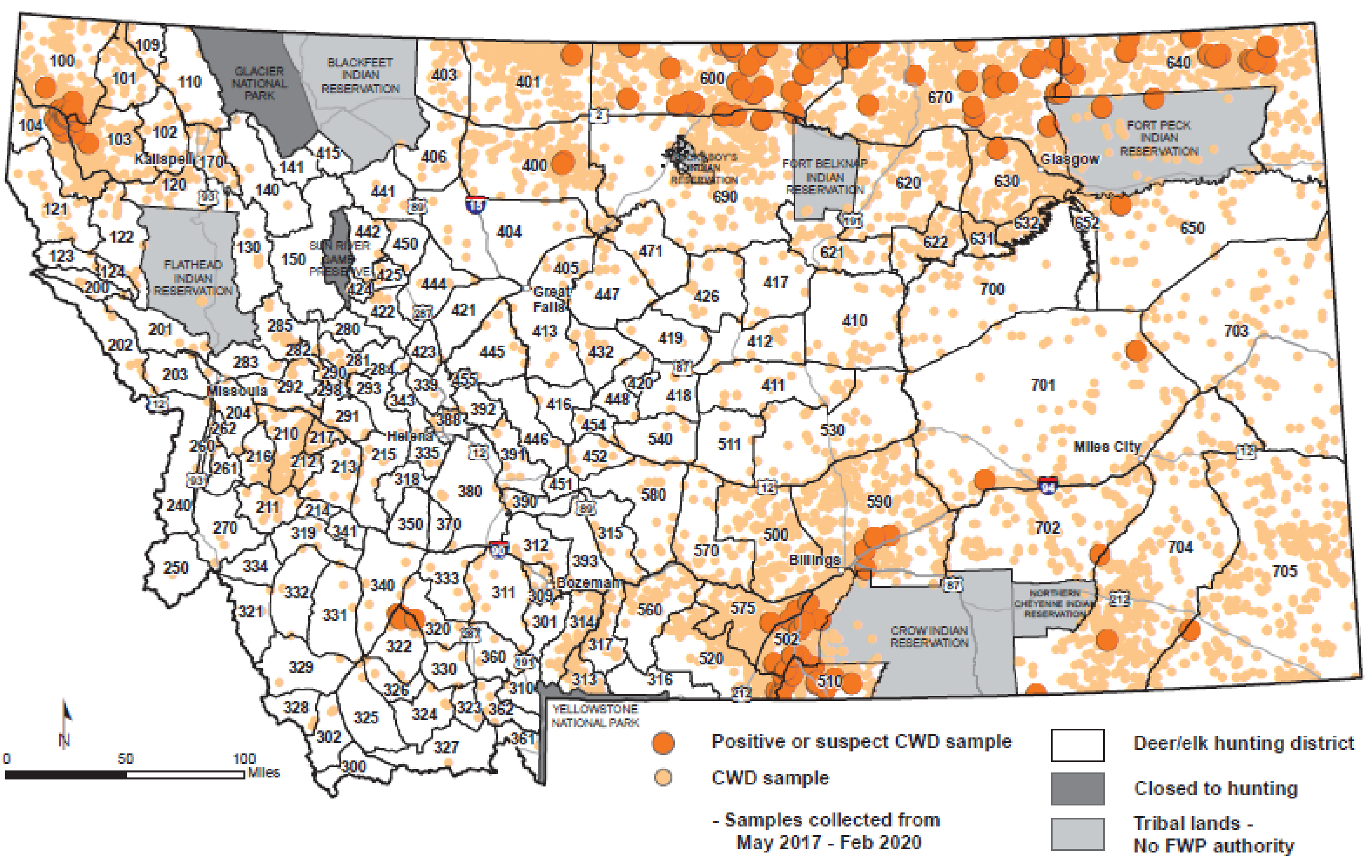


Figure 2. Map of sampling locations and CWD positives among deer, elk, and moose from 2017-2020.

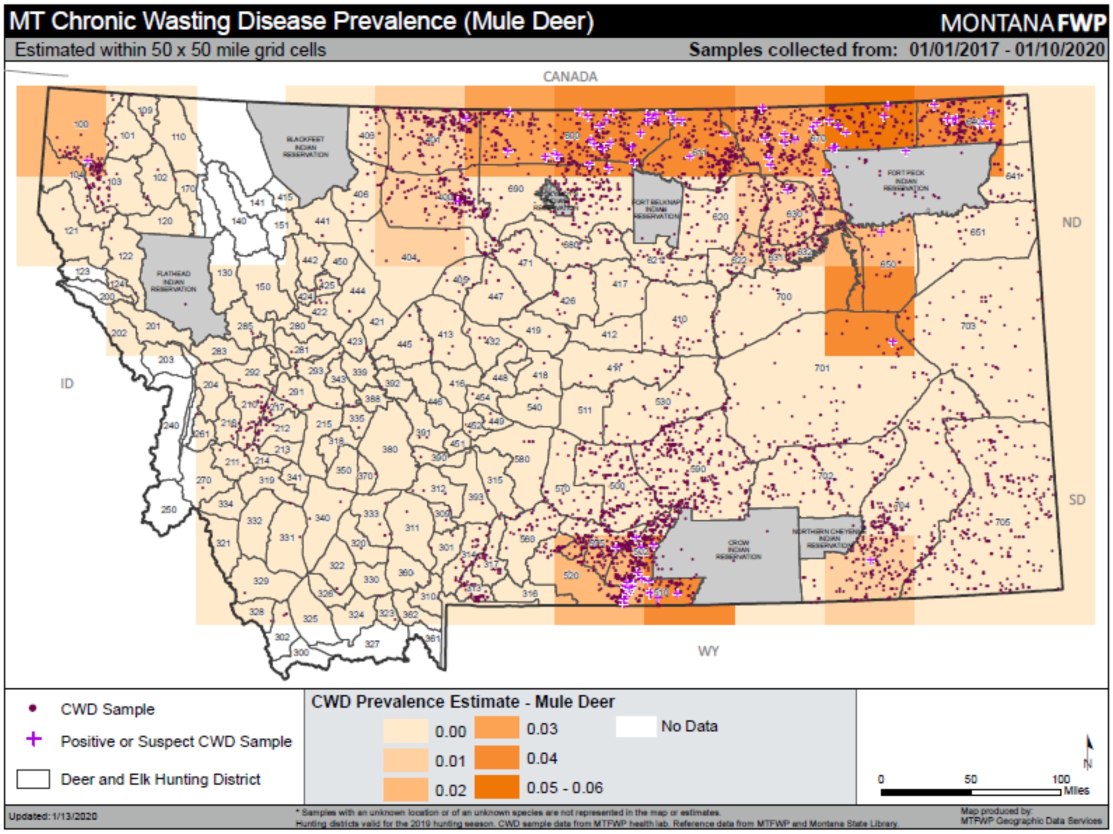
FWP detected 144 CWD positive cervids during the 2019 season, including 53 mule deer, 88 white-tailed deer, 1 elk, and 2 moose. These were Montana's first detections in elk and moose. In 2019, we detected new CWD-positive areas in northwestern Montana (Libby), southwestern Montana (near Sheridan), and in eastern and southeastern Montana (Figure 2). In addition, we expanded the boundaries of known CWD-positive areas with new detections south of Highway 2 along the Hi-Line and north of the Yellowstone River in southcentral Montana. In total, we had CWD detections in 12 new hunting districts around the state: 100, 103, 104, 322, 590, 630, 650, 690, 701, 702, 704, 705. Detections of 8 positives in 5 new hunting districts were the result of expanded, statewide testing offered free of charge to hunters.

Priority surveillance hunting districts 702, 704, and 705 were all found to have CWD present (Figure 2). After a second year of testing (2018-2019), we did not detect CWD within the Philipsburg surveillance unit (Appendix I, Figure 2A). In the Philipsburg area, with our sampling effort to date we would have detected at least 1 positive with 95% confidence if prevalence were ≥5% in mule deer, ≥1% in white-tailed deer, and ≥6% in elk.

Among CWD-positive hunt districts, prevalence estimated from hunter-harvested animals sampled from 2017-2019 ranged from <1% -7% in mule deer and <1% - 18% in white-tailed deer (see Appendix II for prevalence estimates by hunting district), with varying levels of precision. Estimates of prevalence along the Hi-Line were greatly improved by another year of sampling and in many cases allowed us to reach our targeted range of precision of ± 3% margin of error (Figures 3 and 4). In the town of Libby, 13% (95%CI: 9-19%) of hunter-harvested or trapped white-tailed deer were positive for CWD, whereas only 4% (95%CI: 2-5%) were positive outside the town within the Libby CWD Management Zone (additional details below). Within the Moffat Bridge Special Hunt area, prevalence was estimated to be 1% (95%CI: 0-3%, n=162) in mule deer and 5% (95%CI: 1-22%, n=22) in white-tailed deer (additional details below). Preliminary information from the Sheridan-Twin Bridges area suggests prevalence among hunter-harvested white-tailed deer in HD 322 is 18% (95%CI: 5-48%, n=11) and 4 of 6 sick, symptomatic, or unexplained deaths among white-tailed deer were positive in HD 322 as well. More intensive sampling is needed to improve the precision of our estimate in the Sheridan-Twin Bridges area.

An analysis of all data collected from 2017-2020 from hunter-harvested deer in CWD-positive hunting districts suggested several state-wide patterns of infection across species, sex, and age class. Our best supported model included deer species, sex, a species by sex interaction, and age class (see Appendix III for the list of evaluated models). Alone, deer species was not a significant predictor of infection risk (Relative risk of white-tailed deer: mule deer = 1.2 (95%CI: 0.8 – 1.7); white-tailed deer prevalence = 2%, mule deer prevalence = 2%), suggesting prevalences are similar among deer species, or patterns are variable enough across hunting districts to preclude a general pattern. Among mule deer, adult males had 3.7 times the risk of infection as adult females (adult male mule deer prevalence = 2%, adult female prevalence = 0.6%; Relative risk of males:females = 3.7, 95%CI: 1.8 – 7.4). By contrast, among white-tailed deer, females had 1.5 the risk of infection as males, although this pattern was not statistically significant (adult white-tailed deer female prevalence = 3%, adult white-tailed deer male prevalence = 2%; Relative risk of females:males = 1.5, 95%CI: 0.9 – 2.4). Across deer species in CWD-positive hunting districts, young of the year and yearlings had 0.3 times (95%CI: 0.1 – 1.1) and 0.4 times (95%CI: 0.2 – 0.9), respectively, the risk of infection as adults (young of the year prevalence = 0.6%, yearling prevalence = 0.8%, and adult prevalence = 2%).

During the general rifle season (October 15 – December 5), deer harvested during the late rut (after November 15th) were 1.5 times more likely to be infected than those deer harvested during the early rut (prevalence during early rut: 1%, prevalence during late rut: 2%; Relative risk late:early = 1.5, 95%CI: 1.1 – 2.3; Appendix III, Table A2). When we repeated the analysis within each species' datasets and looked for an interaction with sex, we found mule deer harvested during the late rut had twice the risk of being infected versus those harvested earlier in the general season (prevalence in early rut: 1%, prevalence during late rut: 2%, relative risk of late:early = 1.9, 95%CI: 1.2 – 3.1), but we found no evidence that this effect varied by sex. Among white-tailed deer, timing of harvest was not associated with infection probability (Relative risk of late:early = 0.8, 95%CI: 0.4 – 1.3), nor did the effect vary significantly among the sexes.



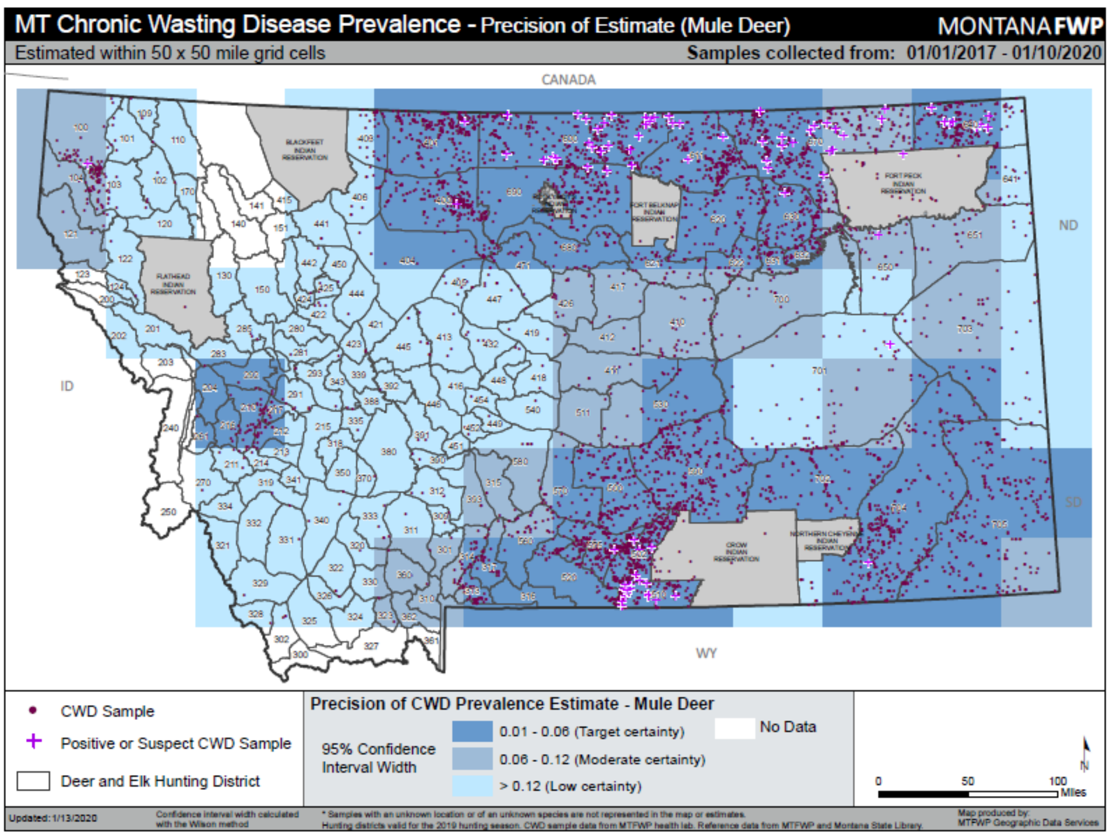
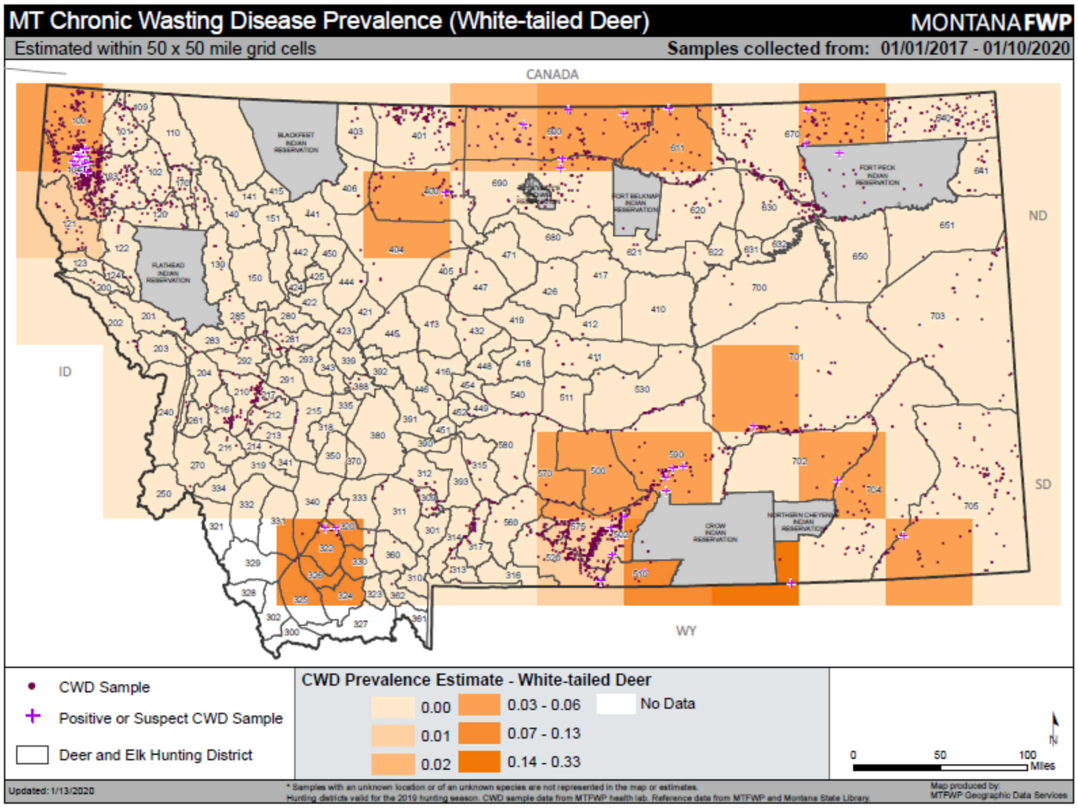


Figure 3. CWD prevalence in mule deer (top figure), estimated within 50 x 50 mile grid cells across Montana, 2017-2020. Prevalence is calculated by dividing the number of test-positives by the total number of animals sampled. Only data from hunter-harvested or agency removal/trapping were used to calculate prevalence. The corresponding precision of these estimates is displayed in the bottom figure. Small 95% confidence interval widths (dark blue) indicate higher certainty in prevalence estimates; large 95% confidence interval widths (light blue) indicate low certainty in the estimates. Where CWD has not been detected (i.e. prevalence = 0 in top figure), additional sampling may still be necessary to declare the area free from disease, or below 0.01 prevalence, with 95% confidence.



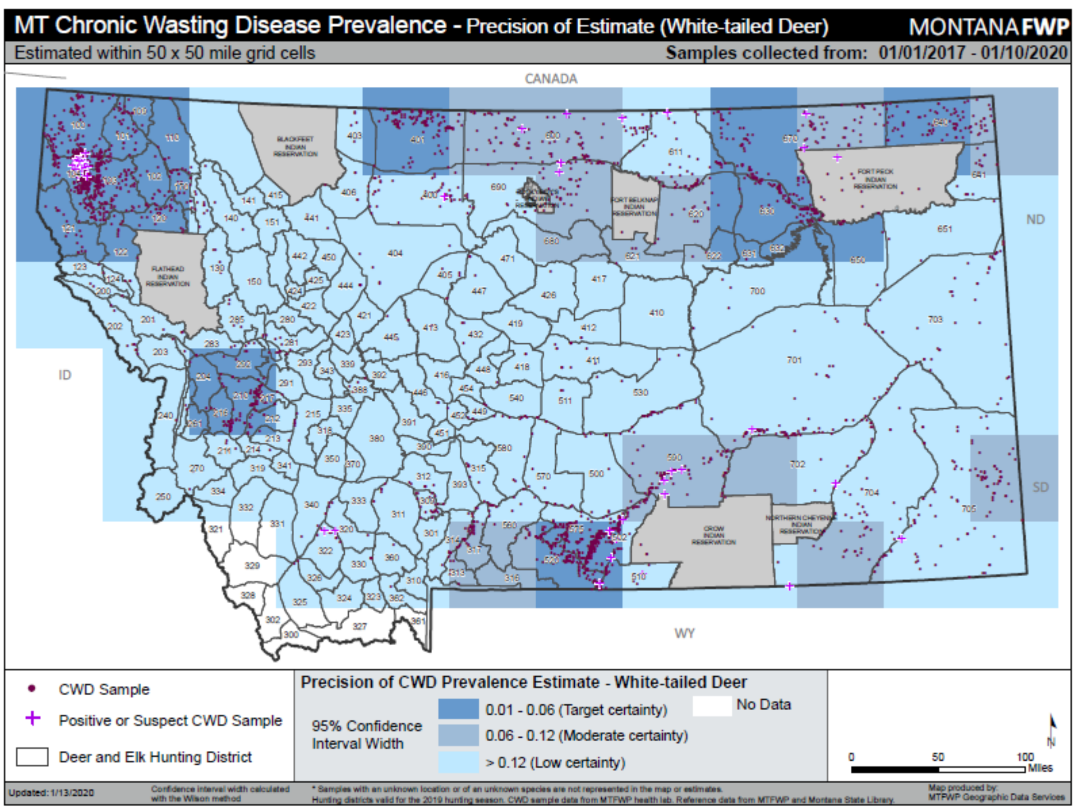


Figure 4. CWD prevalence in white-tailed deer (top figure), estimated within 50 x 50 mile grid cells across Montana, from hunter-harvested or agency removed/trapped deer from 2017-2020. Prevalence is calculated by dividing the number of test-positives by the total number of animals sampled. The corresponding precision of these estimates is displayed in the figure below. Small 95% confidence interval widths (dark blue) indicate higher certainty in prevalence estimates; large 95% confidence interval widths (light blue) indicate low certainty in the estimates. Where CWD has not been detected (i.e. prevalence = 0 in top figure), additional sampling may still be necessary to declare the area free from disease, or below 0.01 prevalence, with 95% confidence.

Special CWD Hunts:

Moffat Bridge

FWP sold 50 either-sex mule deer B-licenses and 155 of 300 antlerless mule deer licenses for the 2019 Moffat Bridge Special CWD Hunt. These special hunt licenses were in addition to the general deer license, over-the-counter white-tailed deer B-license and antlerless mule deer B-license that were also valid within the Special Hunt area. Together, these licenses resulted in a harvest of 143 mule deer (76 does, 67 bucks) between October 26-December 1, 2019. From 2017-2019, FWP detected only 2 CWD positive deer within the Moffat Bridge Special CWD Hunt area, including one mule deer buck and one white-tailed buck. Prevalence was estimated to be 1% in mule deer (95%CI: 0-3%, n=162) and 5% in white-tailed deer (95%CI: 1-22%, n=22).

Libby

FWP sold 600 antlerless white-tailed deer licenses for the 2019 Libby Special CWD Hunt. Between September 9-December 1, 2019, hunters harvested 699 white-tailed deer, of which 25 were positive for CWD. From August 15, 2019 through January 5, 2020, FWP trapped, euthanized, and tested an additional 106 white-tailed deer of which 20 were positive. Of 16 symptomatic white-tailed deer sampled in the Libby Management Zone, 9 were positive (prevalence = 56%, 95%CI: 33-77%); of 72 road-killed white-tailed deer, 5 were positive (prevalence = 7%, 95%CI: 3-15%). Using only data from hunter-harvested or trapped and euthanized deer, the estimated prevalence was 6% (95%CI: 4-7%) in the entire Libby CWD Management Zone. Within this zone, the core "Libby Surveillance Area" (the town of Libby) had a prevalence of 13% (95%CI: 9-19%), whereas the remaining outer ring of the Management Zone had a prevalence of 4% (95%CI: 2-5%). Only 73 mule deer were harvested, of which 1 was positive (prevalence = 1%, 95%CI: 0-7%). Of 4 moose harvested, 2 were found positive. None of the 21 elk tested were positive.

Testing and reporting turn-around time

On average, it took 19 calendar days (sd = 6 days) from the day a sample was collected to the day the test results were posted online. Of this time, it took on average 4 days (sd = 3 days) from the time the sample was collected until shipment to the Colorado State University lab, and an average of 14 days (sd = 4 days) from the day of shipment until results were received, which includes 1-2 days of transit time and 2-4 weekend days.

When a suspect CWD test result was received, FWP staff called hunters to notify them and to inquire about the disposal of the meat/carcass. If meat had gone to a processor, the Department of Public Health and Human Services contacted the processor and followed up with any hunters who may have received meat that was batch-processed with the positive animal. FWP knows of 5 positive animals that went to processors this season. The vast majority of hunters with positive animals either waited for their test result prior to processing or processed their animal at home.

Discussion

To date, targeted CWD surveillance has confirmed our predictions of CWD presence within the north-central, north-eastern, south-central, and south-eastern borders of our state. However, we have also detected CWD in places where we did not expect to find it, including Libby, Sheridan, and southeast of Fort Peck Reservoir. These detections indicate the disease is more widely distributed than we initially expected, consistent with Montana's mostly intact landscape and the resulting widely connected state-wide deer population. Expanded, state-wide testing that is offered free-of-charge to hunters, while demanding a significant investment in resources, staff and technician time, was successful in detecting positives in areas where targeted surveillance hadn't yet been scheduled. We plan to continue offering free state-wide testing both to meet hunter interest and to improve our sampling coverage across the state.

The town of Libby has one of the highest measured local prevalences within the state (13%). This high prevalence suggests that the disease has been present there for some time (>decade, based on previous modeling work) and has likely been aggravated by high white-tailed deer densities that frequently share localized food sources like birdfeeders, fruit trees, and the town dump. FWP trapped and euthanized over 100 white-tailed deer within the Libby Management Zone and is working with the city of Libby to develop a formal urban deer management plan to further reduce deer densities. Furthermore, while the lower prevalence (4%) outside of Libby suggests that the bulk of the problem is within town, the detections in moose, including one on the periphery of the management zone boundary, suggests broader surveillance is needed to establish the outer boundaries of the disease's distribution.

By contrast, the Moffat Bridge Special CWD Hunt detected only one additional CWD positive animal, despite significant sampling throughout the hunt area. The low estimated prevalence within the hunt area is consistent with the patterns observed throughout hunting districts 400 and 401, which all seem to be on the periphery of the endemic area spanning the Montana-Alberta border to the east. Connected as they are to the Alberta populations, these are areas where we may have an opportunity to make preemptive changes to management to slow the growth of the disease in the area's deer populations and slow the spread to deer populations further west and south.

A second full year of sampling along the Hi-Line indicated the disease is well-established in white-tailed deer and mule deer throughout the area at relatively low prevalences (mule deer: 0-5%, white-tailed deer: 0-4%). While a few districts require additional sampling to meet our sample size goals, we anticipate achieving this through voluntary hunter submissions rather than a dedicated sampling effort in the coming year.

Additional sampling will be necessary to estimate prevalence and distribution in the eastern, southeastern, and southwestern areas of the state where CWD was detected in 2019. While we did not meet our sampling goals in the Phillipsburg area, the level of sampling to date provides sufficient confidence in the absence of CWD. We plan to move away from that area for the foreseeable future to prioritize sampling in other locations.

To date, our data suggest that mule deer are no more likely to be positive than white-tailed deer where they overlap within Montana. Other western states and provinces have reported that mule deer have higher prevalences than white-tailed deer where they overlap (Miller et al. 2000, DeVivo 2017, Nobert et al. 2016), and indeed Montana used this information in the decision to target mule deer for surveillance. The fact that the patterns in Montana diverge from those reported elsewhere may relate to differences in the way the two species are managed among states and provinces, the relative timing of disease introduction across the two species, or local differences in the ecology, movement and population dynamics of the two species in Montana. FWP has sampled nearly twice as many mule deer (n = 4943) as white-tailed deer (n = 2752) to date, so it is also possible that as we sample more white-tailed deer, we will see a different pattern emerge.

We also found that while adult male mule deer are much more likely to be infected than adult females, there are no significant differences in infection risk among the sexes in white-tailed deer. Male mule deer have been found to have higher prevalences than females in other western states and provinces (Miller et al. 2000, DeVivo 2017, Nobert et al. 2016). However, reported patterns among the sexes in white-tailed deer have been more variable, including evidence for a female bias (Edmunds et al. 2016), a male bias (Grear et al. 2006, Nobert et al. 2016), and no detectable differences in prevalence between the sexes (Miller et al. 2000). Our data suggests that we should continue to emphasize the sampling of adult male mule deer over females for surveillance, but that adult male and female white-tailed deer may be equally valuable for surveillance in Montana. As we continue to collect additional data, we may generate our own weighted surveillance point values (Table 2) that are based on patterns observed in Montana.

Conner et al. (2000) found that the risk of harvesting CWD positive mule deer, particularly mule deer bucks, increased over the harvest season. One hypothesis is that older-aged animals, which are more likely to be positive, are more susceptible to harvest during the rut, which could bias the estimate of prevalence upwards in late vs. early season. Another hypothesis is that CWD-infected deer may be less aware or responsive to hunters, particularly when they are already distracted by the rut. We looked for a similar pattern in Montana's data. We did find support for a general pattern where hunters were more likely to harvest a CWD-positive mule deer and white-tailed deer later in the rut (after November 15th) than earlier. However, when we repeated the analysis within each species' datasets and looked for an interaction with sex, the only significant pattern was that both male and female mule deer harvested later in the season were more likely to be positive.

In 2020, FWP re-ran Russell et al.'s (2015) CWD risk analysis to identify new surveillance areas using updated information on positive animals within Montana and from neighboring states and provinces. The results of this updated risk model emphasized sampling a ~25 mile buffer on known CWD positives. However, the detections in Libby, Sheridan and eastern Montana, all of which have been far afield from previously known positives, have emphasized the need to increase the breadth of our focused sampling across the state. Rather than focusing on smaller, high-risk areas identified through the original risk model, we have decided to shift our surveillance to cover more areas of the state. Thus, we made the decision to select any hunting district intersected by a 40-mile buffer on all known positives as our next set of priority surveillance areas (Figure 5). These will be divided into minimum surveillance units and FWP will survey as many of these units as staffing allows in a given year. In 2020, FWP will conduct surveillance and monitoring in northwestern, eastern and southeastern, and southwestern Montana.

Lastly, we continue to try to improve testing turn-around time. The Montana Department of Livestock Veterinary Diagnostic Lab is preparing to offer in-state testing in time for the 2020 hunting season, although the coronavirus pandemic may cause delays in getting equipment up and running. Furthermore, we hope to move to digital data collection in the field, which should expedite the process of getting samples shipped to the diagnostic lab.

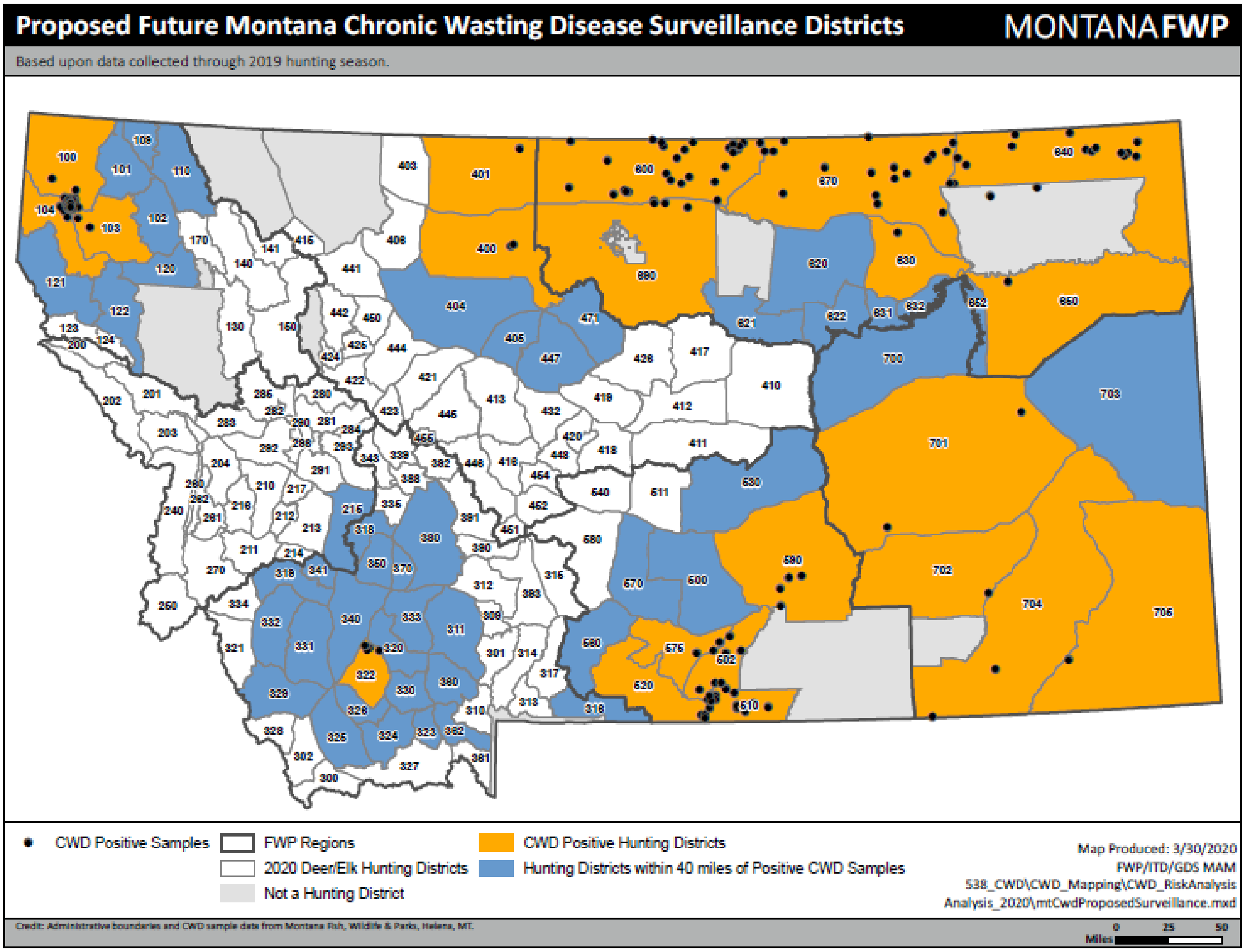


Figure 5. Map of future priority CWD surveillance districts (blue) that are within 40 miles of known CWD positives. CWD-positive hunting districts are in orange.

Management updates

Conversations are underway about how to adjust harvest management to reduce or stabilize CWD transmission across Montana, preferably while following the recommended guidelines for adaptive harvest management proposed by the Western Association of Fish and Wildlife Agencies (2017). In some cases, management has already been changed in response to CWD:

- Region 5: 2019 was the first year of CWD-related season changes in south-central Montana (hunting districts 510, 502, 520, and 575) designed to liberalize both mule deer and white-tailed deer harvest, particularly of bucks. HD 502 went from a buck-only mule deer to an either-sex harvest, and additional antlerless mule deer B licenses were made available. HD 510 went from an unlimited mule deer buck permit to an either-sex general season hunt. HD 520 went to an either-sex mule deer season in that portion of HD 520 lying east of highway 212. HD 575 maintained the antlered buck mule deer season type but doubled the number of antlerless B-licenses issued compared to 2018. Harvest estimates are not yet available for this year to evaluate how these changes influenced harvest.

- Region 6: Managers have actively increased antlerless B-licenses in recent years for both mule deer and white-tailed deer. In 2019, 6,300 mule deer B-licenses were issued region-wide, which was a 90% increase since 2017 (3,300). In 2019, 3,000 limited draw, region-wide white-tailed deer B-licenses were issued, which was a 200% increase over 2018 (1000). The sale of licenses for antlerless white-tailed deer (over-the-counter licenses + 699-licenses) has remained relatively stable from 2018-2019.

- Region 4: Based on CWD surveillance findings in 2019, FWP Region 4 managers proposed a change from a 3-week general deer season to a 5-week general deer season in HD's 400, 401, 403, and 406. Due to significant public resistance and direction from the Fish & Wildlife Commission, the Department proposed an alternative of limited species-specific antlered buck permits valid for 2 weeks after the 3-week general season in these 4 hunting districts. This change was approved by the Commission on February 13, 2020.

- Region 1: Following the detection of CWD in Libby, the region focused on increasing the accuracy and precision of prevalence estimates. Efforts were made to increase signage and/or public messaging throughout the Libby CWD Management Zone about 1) not feeding/aggregating deer, 2) discouraging carcass dumping, and 3) informing hunters of carcass transport restrictions associated with the Management Zone. FWP is currently working with the Libby City Council to assist the City with drafting an Urban Deer Management Plan. Lastly, the Commission approved an either sex B-license valid within the Libby CWD Management Zone. There are no limits on the number of B-licenses that can be sold, but there is a limit of one license per person.

In addition, after considerable discussion with the internal CWD Action Team and the CWD Citizen's Advisory Council, FWP is considering moving to a mandatory carcass disposal rule in lieu of within-state carcass transportation restrictions associated with CWD Management Zones. It was extremely difficult to message and enforce the carcass transportation restrictions associated with CWD Management Zones, and if hunters properly dispose of carcass waste in a class II landfill, the risk of human-assisted environmental transmission is minimized. Hunters are still allowed to leave boned-out carcasses in the field at the site of harvest, but if they transport the carcass from the original harvest site, the head and spinal column must be properly disposed of in a class II landfill. Final decisions will be made by the Fish & Wildlife Commission in the spring or summer of 2020.

Acknowledgements

CWD surveillance required significant involvement from FWP regional enforcement staff, biologists, communication and education staff, administrative staff, the Wildlife Health Lab, and hired technicians. A special thank you to the 27 technicians that worked check stations and regional offices during the general season. We greatly appreciate their help for making this effort a success. We would like to extend a special thank you to Kathi Wilson and the staff at Colorado State University's Veterinary Diagnostic Lab for analyzing all our samples as quickly as possible. We would also like to thank hunters, landowners, supportive residents and communities, vigilant wildlife watchers, and State, Federal and Tribal agency partners. A special thank you to the "rock stars" of lymph node collection: Julie Herrick (464), John Randolph (460), Chrissy Webb (457), Samantha Treece (436), Glen Doubek (403), Robbie Seykora (384), Elizabeth Wyatt-Pescador (317), Aaron Groves (289), Scott Hemmer (262), and Brad Oen (240) who collectively took over 50% of our 7025 cervid samples. Funding for this project came from deer and elk auction license sales, Federal Aid in Wildlife Restoration Grant W-171-M to Montana Fish, Wildlife and Parks, and generous donations from the Rocky Mountain Elk Foundation and the Mule Deer Foundation.

Appendix I. Additional Figures

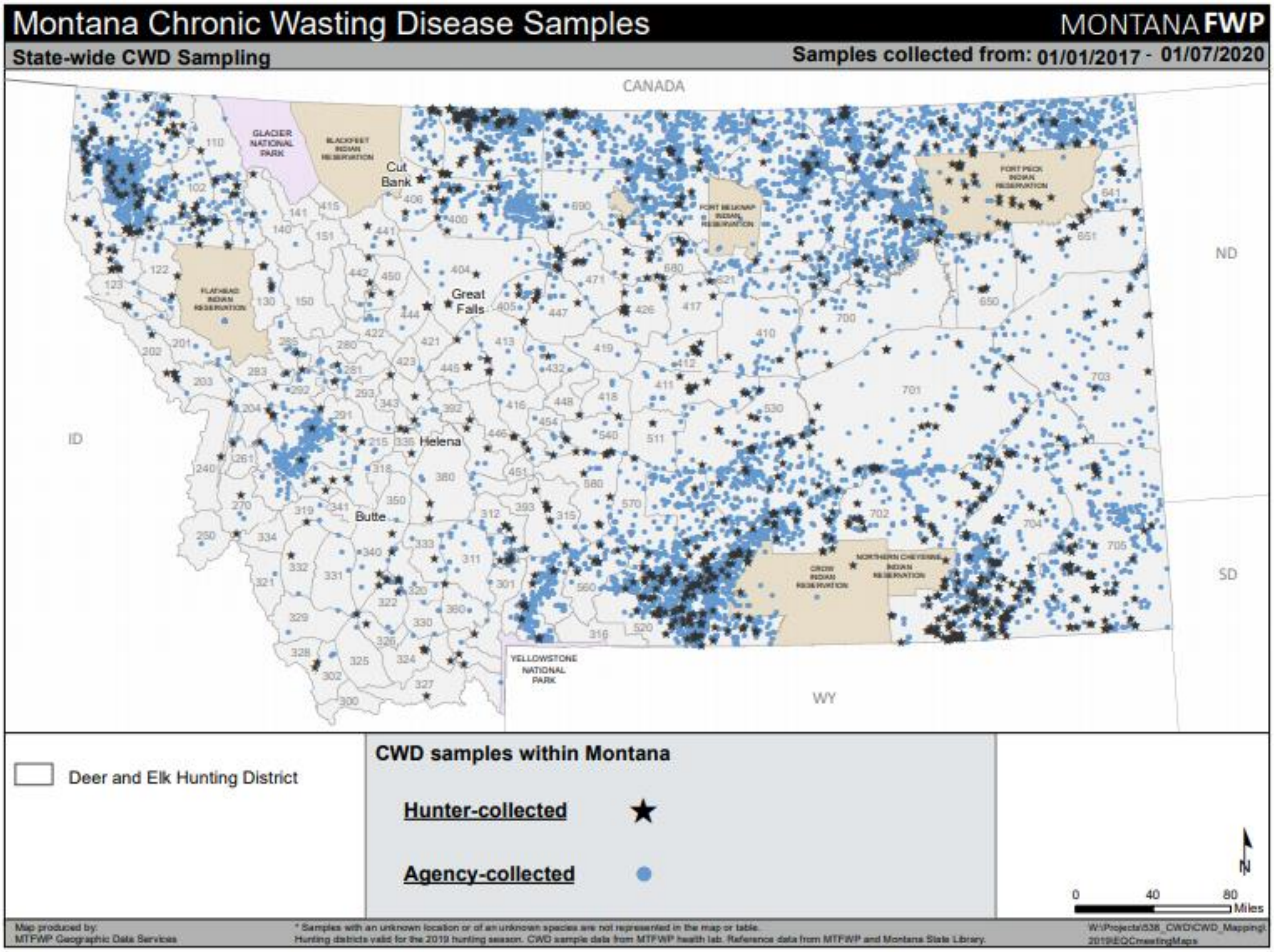


Figure A1. Sampling locations for deer, elk, or moose that were tested for CWD, color-coded by whether they were collected by agency staff or by hunters, 2017-2020.

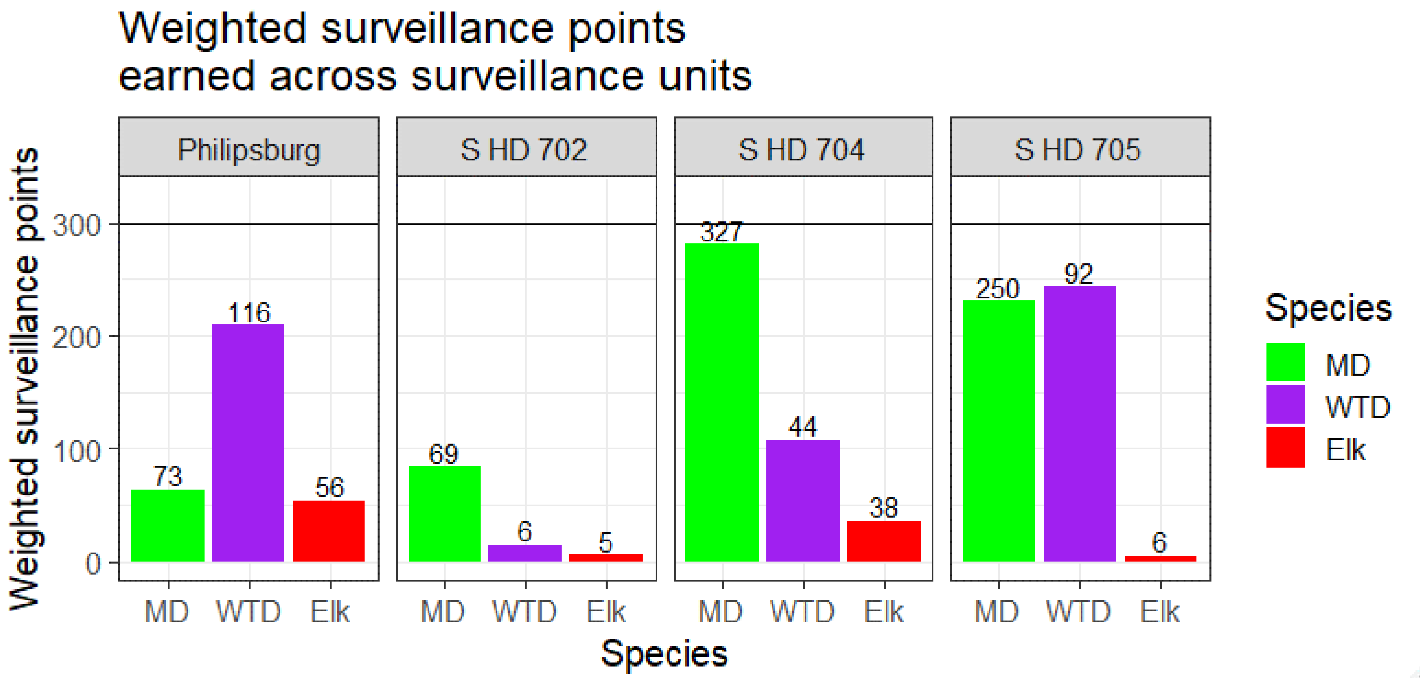


Figure A2. Weighted surveillance points earned for mule deer (MD), white-tailed deer (WTD), and elk within each of the four minimum surveillance units in Montana, using data collected from 2017-2019. Under the weighted surveillance framework, different demographic groups (age, sex, or cause of death categories) of a species are assigned different point-values based on their relative risk of being infected and summed to a total point value. Our goal was to reach 300 weighted surveillance points in mule deer to detect ≥ 1% prevalence with 95% confidence. The sample size of individual animals that we tested for each species is displayed above each bar. We detected CWD in hunting districts 702, 704, and 705, but not in the Philipsburg area.

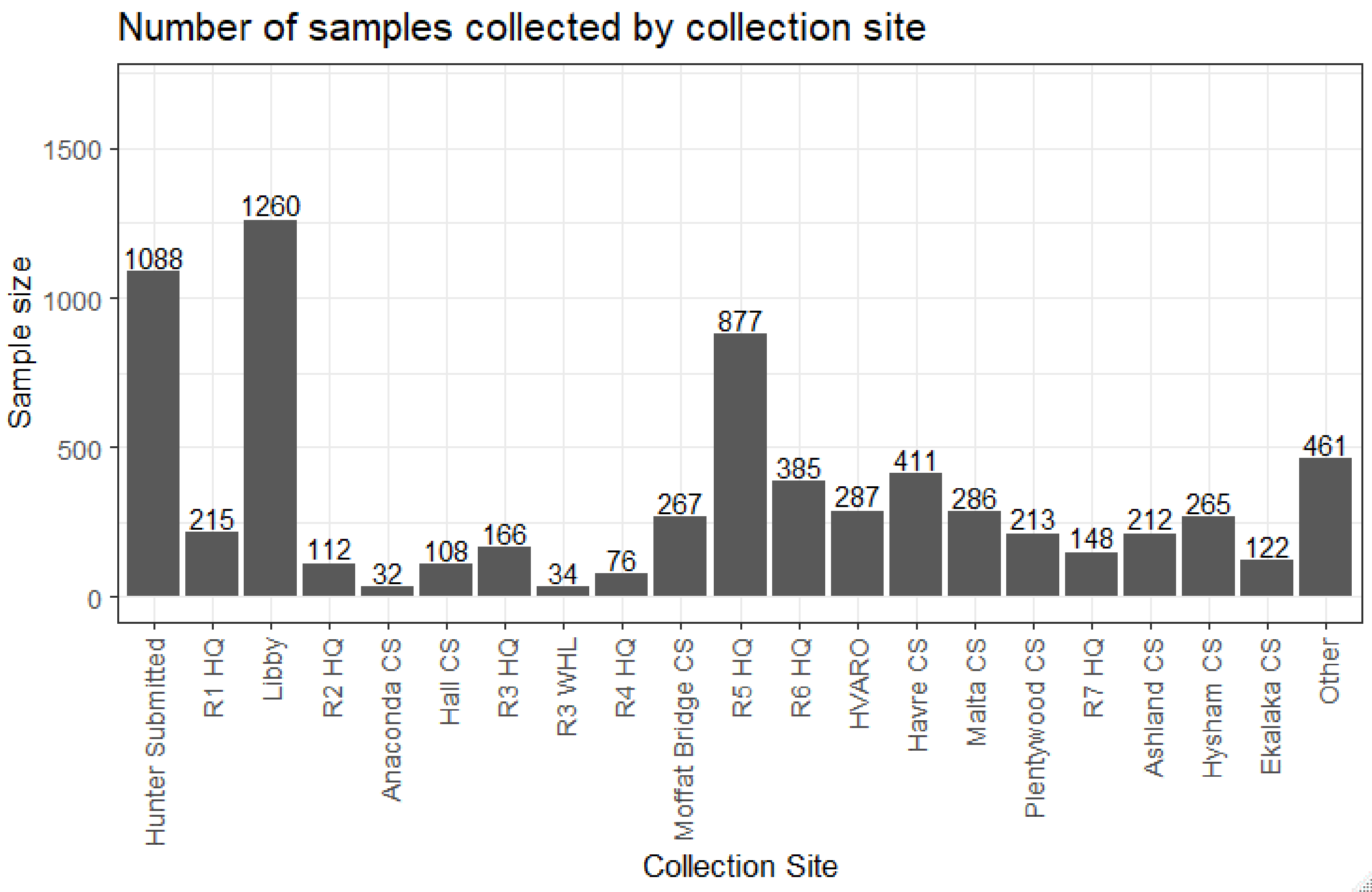


Figure A3. Number of samples collected at various sampling locations, or collection sites, around the state. "Hunter submitted" is the number of sampled collected and submitted by hunters. "HQ" and "CS" stand for headquarters and check station, respectively. "R3 WHL" stands for the Region 3 Wildlife Health Lab. "HVARO" stands for Havre Area Resource Office.

Appendix II. Table of estimated CWD prevalence by hunting district (HD) and species, using data from 2017-2020 from hunter-harvested or agency removed (i.e. in Libby) animals. The lower (LB) and upper (UB) 95% confidence intervals are provided along with sample size (N) and total number of positives by species in each HD.

HD	Species	N	Positives	Prevalence	LB 95%CI	UB 95%CI
100	MD	57	1	0.02	0	0.09
100	WTD	421	26	0.06	0.04	0.09
100	Elk	19	0	0.00	0	0.17
100	Moose	11	1	0.09	0.02	0.38
101	MD	5	0	0.00	0	0.43
101	WTD	35	0	0.00	0	0.1
101	Elk	1	0	0.00	0	0.79
102	MD	2	0	0.00	0	0.66
102	WTD	13	0	0.00	0	0.23
102	Elk	1	0	0.00	0	0.79
103	MD	51	0	0.00	0	0.07
103	WTD	405	4	0.01	0	0.03
103	Elk	8	0	0.00	0	0.32
103	Moose	3	1	0.33	0.06	0.79
104	MD	14	0	0.00	0	0.22
104	WTD	306	15	0.05	0.03	0.08
104	Elk	6	0	0.00	0	0.39
109	MD	4	0	0.00	0	0.49
109	WTD	5	0	0.00	0	0.43
110	WTD	7	0	0.00	0	0.35
110	Elk	1	0	0.00	0	0.79
110	Moose	1	0	0.00	0	0.79
120	WTD	25	0	0.00	0	0.13
120	Elk	2	0	0.00	0	0.66
121	MD	3	0	0.00	0	0.56
121	WTD	22	0	0.00	0	0.15
121	Elk	1	0	0.00	0	0.79
122	MD	2	0	0.00	0	0.66
122	WTD	13	0	0.00	0	0.23
122	Elk	1	0	0.00	0	0.79
123	WTD	1	0	0.00	0	0.79
130	WTD	7	0	0.00	0	0.35
132	WTD	8	0	0.00	0	0.32
140	WTD	3	0	0.00	0	0.56
170	MD	1	0	0.00	0	0.79
170	WTD	18	0	0.00	0	0.18
200	WTD	4	0	0.00	0	0.49
201	WTD	6	0	0.00	0	0.39

HD	Species	N	Positives	Prevalence	LB 95%CI	UB 95%CI
202	WTD	5	0	0.00	0	0.43
203	WTD	2	0	0.00	0	0.66
204	WTD	1	0	0.00	0	0.79
210	MD	25	0	0.00	0	0.13
210	WTD	65	0	0.00	0	0.06
210	Elk	35	0	0.00	0	0.1
211	MD	3	0	0.00	0	0.56
211	WTD	6	0	0.00	0	0.39
211	Elk	3	0	0.00	0	0.56
212	MD	18	0	0.00	0	0.18
212	WTD	12	0	0.00	0	0.24
212	Elk	11	0	0.00	0	0.26
213	MD	1	0	0.00	0	0.79
213	WTD	2	0	0.00	0	0.66
213	Elk	1	0	0.00	0	0.79
214	MD	1	0	0.00	0	0.79
214	WTD	1	0	0.00	0	0.79
214	Elk	1	0	0.00	0	0.79
215	Elk	6	0	0.00	0	0.39
216	MD	5	0	0.00	0	0.43
216	WTD	11	0	0.00	0	0.26
216	Elk	3	0	0.00	0	0.56
217	MD	16	0	0.00	0	0.19
217	WTD	24	0	0.00	0	0.14
217	Elk	8	0	0.00	0	0.32
240	WTD	1	0	0.00	0	0.79
240	Elk	1	0	0.00	0	0.79
250	WTD	1	0	0.00	0	0.79
261	WTD	1	0	0.00	0	0.79
262	MD	1	0	0.00	0	0.79
270	MD	1	0	0.00	0	0.79
270	WTD	2	0	0.00	0	0.66
281	MD	1	0	0.00	0	0.79
281	WTD	6	0	0.00	0	0.39
283	WTD	3	0	0.00	0	0.56
285	MD	2	0	0.00	0	0.66
285	WTD	7	0	0.00	0	0.35
285	Elk	1	0	0.00	0	0.79
290	WTD	4	0	0.00	0	0.49
291	MD	4	0	0.00	0	0.49
292	MD	4	0	0.00	0	0.49
292	WTD	9	0	0.00	0	0.3
293	MD	4	0	0.00	0	0.49

HD	Species	N	Positives	Prevalence	LB 95%CI	UB 95%CI
298	WTD	1	0	0.00	0	0.79
298	Elk	2	0	0.00	0	0.66
301	MD	1	0	0.00	0	0.79
302	MD	3	0	0.00	0	0.56
302	Elk	1	0	0.00	0	0.79
309	WTD	8	0	0.00	0	0.32
309	Elk	2	0	0.00	0	0.66
310	Elk	1	0	0.00	0	0.79
311	MD	3	0	0.00	0	0.56
311	WTD	6	0	0.00	0	0.39
311	Elk	4	0	0.00	0	0.49
312	MD	3	0	0.00	0	0.56
312	WTD	9	0	0.00	0	0.3
312	Elk	2	0	0.00	0	0.66
313	MD	55	0	0.00	0	0.07
313	WTD	3	0	0.00	0	0.56
313	Elk	32	0	0.00	0	0.11
314	MD	21	0	0.00	0	0.15
314	WTD	13	0	0.00	0	0.23
314	Elk	21	0	0.00	0	0.15
315	MD	4	0	0.00	0	0.49
315	WTD	8	0	0.00	0	0.32
315	Elk	1	0	0.00	0	0.79
317	MD	27	0	0.00	0	0.12
317	WTD	29	0	0.00	0	0.12
317	Elk	7	0	0.00	0	0.35
319	MD	1	0	0.00	0	0.79
319	Moose	1	0	0.00	0	0.79
320	MD	1	0	0.00	0	0.79
320	WTD	4	0	0.00	0	0.49
321	Moose	1	0	0.00	0	0.79
322	MD	3	0	0.00	0	0.56
322	WTD	11	2	0.18	0.05	0.48
322	Elk	1	0	0.00	0	0.79
323	MD	1	0	0.00	0	0.79
324	Elk	4	0	0.00	0	0.49
325	WTD	2	0	0.00	0	0.66
325	Elk	1	0	0.00	0	0.79
326	MD	1	0	0.00	0	0.79
326	Elk	1	0	0.00	0	0.79
327	Elk	1	0	0.00	0	0.79
328	MD	1	0	0.00	0	0.79
328	Elk	1	0	0.00	0	0.79

HD	Species	N	Positives	Prevalence	LB 95%CI	UB 95%CI
329	MD	1	0	0.00	0	0.79
329	Elk	1	0	0.00	0	0.79
330	MD	1	0	0.00	0	0.79
330	WTD	4	0	0.00	0	0.49
331	MD	1	0	0.00	0	0.79
332	Elk	2	0	0.00	0	0.66
333	MD	4	0	0.00	0	0.49
335	MD	1	0	0.00	0	0.79
339	Elk	1	0	0.00	0	0.79
340	MD	2	0	0.00	0	0.66
340	WTD	3	0	0.00	0	0.56
343	MD	2	0	0.00	0	0.66
360	MD	1	0	0.00	0	0.79
360	WTD	1	0	0.00	0	0.79
361	Moose	1	0	0.00	0	0.79
362	WTD	1	0	0.00	0	0.79
362	Elk	2	0	0.00	0	0.66
370	MD	1	0	0.00	0	0.79
380	Elk	4	0	0.00	0	0.49
388	WTD	1	0	0.00	0	0.79
390	MD	1	0	0.00	0	0.79
391	Elk	2	0	0.00	0	0.66
392	MD	1	0	0.00	0	0.79
393	MD	3	0	0.00	0	0.56
393	WTD	1	0	0.00	0	0.79
393	Elk	3	0	0.00	0	0.56
400	MD	332	1	0.00	0	0.02
400	WTD	51	1	0.02	0	0.1
400	Elk	1	0	0.00	0	0.79
401	MD	352	1	0.00	0	0.02
401	WTD	162	0	0.00	0	0.02
401	Elk	50	0	0.00	0	0.07
401	Moose	1	0	0.00	0	0.79
403	MD	30	0	0.00	0	0.11
403	WTD	6	0	0.00	0	0.39
404	MD	9	0	0.00	0	0.3
404	WTD	5	0	0.00	0	0.43
405	MD	11	0	0.00	0	0.26
405	WTD	5	0	0.00	0	0.43
406	MD	11	0	0.00	0	0.26
406	WTD	5	0	0.00	0	0.43
406	Elk	2	0	0.00	0	0.66
410	MD	33	0	0.00	0	0.1

HD	Species	N	Positives	Prevalence	LB 95%CI	UB 95%CI
410	Elk	1	0	0.00	0	0.79
411	MD	19	0	0.00	0	0.17
411	WTD	12	0	0.00	0	0.24
411	Elk	3	0	0.00	0	0.56
412	MD	5	0	0.00	0	0.43
412	WTD	3	0	0.00	0	0.56
412	Elk	5	0	0.00	0	0.43
413	MD	4	0	0.00	0	0.49
413	WTD	1	0	0.00	0	0.79
416	Elk	1	0	0.00	0	0.79
417	MD	4	0	0.00	0	0.49
418	MD	2	0	0.00	0	0.66
418	WTD	2	0	0.00	0	0.66
419	MD	3	0	0.00	0	0.56
421	MD	1	0	0.00	0	0.79
422	MD	1	0	0.00	0	0.79
423	MD	1	0	0.00	0	0.79
425	MD	1	0	0.00	0	0.79
426	MD	16	0	0.00	0	0.19
426	WTD	1	0	0.00	0	0.79
432	MD	5	0	0.00	0	0.43
432	WTD	3	0	0.00	0	0.56
432	Elk	1	0	0.00	0	0.79
441	MD	2	0	0.00	0	0.66
441	WTD	2	0	0.00	0	0.66
441	Elk	1	0	0.00	0	0.79
442	MD	1	0	0.00	0	0.79
442	Elk	1	0	0.00	0	0.79
444	MD	1	0	0.00	0	0.79
444	WTD	5	0	0.00	0	0.43
445	MD	6	0	0.00	0	0.39
445	WTD	5	0	0.00	0	0.43
445	Elk	1	0	0.00	0	0.79
446	WTD	2	0	0.00	0	0.66
447	MD	10	0	0.00	0	0.28
447	WTD	5	0	0.00	0	0.43
447	Elk	1	0	0.00	0	0.79
448	MD	1	0	0.00	0	0.79
448	WTD	1	0	0.00	0	0.79
448	Elk	1	0	0.00	0	0.79
449	MD	2	0	0.00	0	0.66
449	WTD	2	0	0.00	0	0.66
449	Elk	1	0	0.00	0	0.79

HD	Species	N	Positives	Prevalence	LB 95%CI	UB 95%CI
450	MD	1	0	0.00	0	0.79
452	MD	2	0	0.00	0	0.66
452	WTD	1	0	0.00	0	0.79
454	WTD	1	0	0.00	0	0.79
454	Elk	1	0	0.00	0	0.79
471	MD	13	0	0.00	0	0.23
471	Elk	1	0	0.00	0	0.79
500	MD	175	0	0.00	0	0.02
500	WTD	14	0	0.00	0	0.22
500	Elk	3	0	0.00	0	0.56
502	MD	375	5	0.01	0.01	0.03
502	WTD	236	4	0.02	0.01	0.04
502	Elk	12	1	0.08	0.01	0.35
510	MD	177	13	0.07	0.04	0.12
510	WTD	20	1	0.05	0.01	0.24
511	MD	2	0	0.00	0	0.66
511	WTD	3	0	0.00	0	0.56
511	Elk	1	0	0.00	0	0.79
520	MD	132	0	0.00	0	0.03
520	WTD	147	1	0.01	0	0.04
520	Elk	28	0	0.00	0	0.12
520	Moose	3	0	0.00	0	0.56
530	MD	40	0	0.00	0	0.09
530	WTD	4	0	0.00	0	0.49
530	Elk	3	0	0.00	0	0.56
540	MD	1	0	0.00	0	0.79
540	WTD	3	0	0.00	0	0.56
540	Elk	3	0	0.00	0	0.56
560	MD	37	0	0.00	0	0.09
560	WTD	12	0	0.00	0	0.24
560	Elk	4	0	0.00	0	0.49
570	MD	38	0	0.00	0	0.09
570	WTD	12	0	0.00	0	0.24
570	Elk	1	0	0.00	0	0.79
575	MD	361	2	0.01	0	0.02
575	WTD	165	0	0.00	0	0.02
575	Elk	5	0	0.00	0	0.43
580	MD	5	0	0.00	0	0.43
580	WTD	10	0	0.00	0	0.28
580	Elk	5	0	0.00	0	0.43
590	MD	358	0	0.00	0	0.01
590	WTD	128	4	0.03	0.01	0.08
590	Elk	25	0	0.00	0	0.13

HD	Species	N	Positives	Prevalence	LB 95%CI	UB 95%CI
600	MD	491	25	0.05	0.03	0.07
600	WTD	123	5	0.04	0.02	0.09
600	Elk	2	0	0.00	0	0.66
611	MD	284	4	0.01	0.01	0.04
611	WTD	59	1	0.02	0	0.09
611	Elk	2	0	0.00	0	0.66
620	MD	116	0	0.00	0	0.03
620	WTD	18	0	0.00	0	0.18
620	Elk	3	0	0.00	0	0.56
621	MD	37	0	0.00	0	0.09
621	WTD	3	0	0.00	0	0.56
621	Elk	4	0	0.00	0	0.49
622	MD	35	0	0.00	0	0.1
622	WTD	2	0	0.00	0	0.66
622	Elk	9	0	0.00	0	0.3
630	MD	181	1	0.01	0	0.03
630	WTD	82	0	0.00	0	0.04
630	Moose	1	0	0.00	0	0.79
631	MD	34	0	0.00	0	0.1
631	WTD	1	0	0.00	0	0.79
631	Elk	1	0	0.00	0	0.79
632	MD	43	0	0.00	0	0.08
632	Elk	3	0	0.00	0	0.56
640	MD	254	9	0.04	0.02	0.07
640	WTD	89	0	0.00	0	0.04
640	Elk	1	0	0.00	0	0.79
641	MD	23	0	0.00	0	0.14
641	WTD	16	0	0.00	0	0.19
650	MD	34	1	0.03	0.01	0.15
650	WTD	14	0	0.00	0	0.22
651	MD	27	0	0.00	0	0.12
651	WTD	5	0	0.00	0	0.43
652	MD	3	0	0.00	0	0.56
670	MD	547	17	0.03	0.02	0.05
670	WTD	138	2	0.01	0	0.05
680	MD	38	0	0.00	0	0.09
680	Elk	1	0	0.00	0	0.79
690	MD	216	2	0.01	0	0.03
690	WTD	54	0	0.00	0	0.07
690	Elk	2	0	0.00	0	0.66
690	Moose	1	0	0.00	0	0.79
700	MD	25	0	0.00	0	0.13
700	WTD	4	0	0.00	0	0.49

HD	Species	N	Positives	Prevalence	LB 95%CI	UB 95%CI
700	Elk	8	0	0.00	0	0.32
701	MD	86	1	0.01	0	0.06
701	WTD	70	1	0.01	0	0.08
701	Elk	4	0	0.00	0	0.49
702	MD	101	0	0.00	0	0.04
702	WTD	19	1	0.05	0.01	0.25
702	Elk	5	0	0.00	0	0.43
703	MD	72	0	0.00	0	0.05
703	WTD	45	0	0.00	0	0.08
703	Elk	2	0	0.00	0	0.66
704	MD	360	1	0.00	0	0.02
704	WTD	44	1	0.02	0	0.12
704	Elk	39	0	0.00	0	0.09
705	MD	296	0	0.00	0	0.01
705	WTD	109	1	0.01	0	0.05
705	Elk	8	0	0.00	0	0.32

Appendix III.

Table A1. Logistic generalized linear mixed models used to evaluate the odds of infection as a function of species (mule deer vs. white-tailed deer), sex, and age class (young of the year, yearlings, adults). Models are ranked from best supported to least supported. All complete deer records were included in this analysis (n=7695).

Model	**AIC**	**Delta AIC**	**Relative model likelihood**	**AIC weight**
Infected~ 1+ Species + Sex + Species*Sex + AgeClass + (1|HD)	1370.48	0.00	1.00	0.98
Infected~ 1+ Species + Sex + Species*Sex + (1|HD)	1377.83	7.35	0.03	0.02
Infected~ 1+ Species + Sex + (1|HD)	1391.99	21.51	0.00	0.00
Infected~ 1+ Species + (1|HD)	1394.45	23.96	0.00	0.00

Table A2. Logistic Generalized Linear Mixed Models used to evaluate the odds of infection for deer as a function of species, sex, age class, and timing of harvest (pre-rut vs. rut/post-rut). Models are ranked from best supported to least supported. All complete deer records from the general rifle season were included in this analysis (October 15-December 5; n=6935).

Model	**AIC**	**Delta AIC**	**Relative model likelihood**	**AIC weight**
Infected~ 1+ Species + Sex + Species*Sex + AgeClass + HarvestTiming + (1|HD)	1138.57	0.00	1.00	0.84
Infected~ 1+ Species + Sex + Species*Sex + AgeClass + (1|HD)	1141.99	3.42	0.18	0.15
Infected~ 1+ Species + Sex + Species*Sex + HarvestTiming + (1|HD)	1148.83	10.26	0.01	0.00
Infected~ 1+ Species + Sex + Species*Sex + HarvestTiming + Species* HarvestTiming + (1|HD)	1149.06	10.49	0.01	0.00
Infected~ 1+ Species + Sex + Species*Sex + HarvestTiming + Sex* HarvestTiming + (1|HD)	1150.07	11.50	0.00	0.00
Infected~ 1+ Species + Sex + Species*Sex + (1|HD)	1152.83	14.26	0.00	0.00
Infected~ 1+ Species + Sex + (1|HD)	1157.03	18.46	0.00	0.00
Infected~ 1+ Species + (1|HD)	1168.19	29.61	0.00	0.00

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