Chronic wasting disease: a jurisdictional scan of advice for hunters and cervid meat-processors in CWD affected areas

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Abstract: Chronic wasting disease (CWD), a prion disease affecting wild and farmed cervids such as deer, elk, moose, and reindeer, has increased significantly in some areas of North America over the past two decades. Many jurisdictions have now developed wildlife management strategies for controlling the spread and advice on minimizing human exposures to infected wild game. While there have been no known cases of CWD causing prion disease in humans, CWD has the potential to infect humans, warranting caution in handling and consumption of CWD-infected meat. This paper presents the findings of a jurisdictional scan of North America for advice on handling and processing wild cervid meat in jurisdictions affected by CWD. We reviewed publicly available state, provincial, territorial, and federal agency guidance on identifying sick animals, precautions during the processing of cervid meat, and best practices for cleaning and disinfection of meat processing tools and surfaces. Advice was found to vary widely across jurisdictions in the level of detail and in the application of some practices.

Key words: chronic wasting disease, CWD, hunter, meat-processor, cervid, prion.

Introduction

Prions are infectious agents that cause normal proteins in the brain, spinal cord, lymph nodes, and other tissues to misfold. These misfolded proteins can trigger diseases such as transmissible spongiform encephalopathies (TSEs) or other fatal neurodegenerative illnesses in humans and animals. Examples include Creutzfeldt-Jakob disease (CJD) in humans and bovine spongiform encephalopathy (BSE or mad cow disease) in cattle. Chronic wasting disease (CWD) is a TSE that specifically affects animals in the Cervidae family (cervids), such as deer, elk, moose, and reindeer.

Some TSEs can cross the species barrier. For example, variant CJD (vCJD) cases in humans in the 1990s were linked to consuming BSE-contaminated beef in the United Kingdom (UK). The incubation period for these vCJD cases was lengthy, on average 10 years after BSE exposure, highlighting a key difficulty in tracing exposures that lead to disease (Osterholm et al., 2019). There are no known cases of human prion disease that have been determined to be caused by CWD-prion exposure. However, the species barrier for CWD between cervids and humans is may not be absolute (National Academies of Sciences Engineering and Medicine, 2024).

Since the 1990s, there has been an upward trend in reported cases of CJD in humans globally (Gao et al., 2024), including in regions of North America where CWD is endemic. This increase is likely due to improved surveillance and reporting (Public Health England, 2018). CJD remains a rare disease, with fewer than 100 cases reported annually in Canada (Public Health Agency of Canada, 2025) and 500–600 in the US (Centers for Disease Control and Prevention, 2024). The majority of CJD cases (>85%) are sporadic, with no clear infectious source. Further research is needed to identify the drivers and origins of sporadic CJD in humans (National Academies of Sciences Engineering and Medicine, 2024).

Some studies have examined possible links between CWD exposure and human diseases like CJD. One report described degenerative neurological illnesses in three men who participated in wild game feasts in Wisconsin, one of whom was confirmed to have died from CJD. No definitive link to CWD was established (Centers for Disease Control and Prevention, 2003). Another study tracked the health outcomes of 81 individuals over 6 years, following consumption of CWD-infected venison at a game feast in New York. No adverse health effects were linked to this single exposure event (Olszowy et al., 2014).

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A 2024 article reported on the occurrence of sporadic CJD in two deer hunters affiliated with the same hunting lodge who consumed venison from a CWD-infected deer population (Trout et al., 2024). No definitive cause for CJD in these individuals could be established, but exposure to CWD could not be conclusively ruled out (Snider, 2024). There are currently no laboratory tests that can detect CWD in humans and identifying spillover events could be difficult without a clear idea of how such an illness would present in humans. Identifying epidemiological links or novel neuropathologies in sporadic CJD cases or carrying out cohort studies of highly exposed individuals could facilitate a better understanding of spillover potential or diagnostic approaches (Center for Infectious Disease Research and Policy [CIDRAP], 2025).

Much remains unknown about the causes of sporadic CJD, prompting recommendations to take a precautionary approach by limiting prion exposures (Tranulis & Tryland, 2023). For example, Health Canada's Health Products and Food Branch considers that "CWD could have the potential to infect humans" and supports measures to limit exposure. This aligns with World Health Organization (WHO) recommendations to prevent parts or products from TSE-infected animals from entering the human or animal food chain, and European Food Safety Authority recommendations to limit exposure to prions in the food chain (EFSA Panel on Biological Hazards et al., 2019; Health Canada, 2020). Unlike with some bacteria, viruses, and parasites, normal cooking temperatures or other food processing methods do not destroy CWD-causing prions in infected meat (Benavente et al., 2025). To limit exposure, advice may include avoiding consuming meat from TSE-infected animals and reducing contact with infected animals, their bodily fluids, and tissues. In CWD-endemic zones, hunters and meat processors face a higher risk of exposure to CWD prions than the wider public and may benefit from increased awareness of strategies to minimize exposure (Nemani et al., 2020). This paper aims to summarize current guidance for hunters and meat processors on minimizing exposure to CWD prions and examine the suitability of these recommendations considering existing evidence in the wider literature.

Methodology

We reviewed grey literature and websites from public agencies in Canada and the United States for recommendations, guidelines, and best practice documents related to the handling and processing of harvested cervid meat. National agencies such as Health Canada, and the US Centres for Disease Control were included in this search. Guidance was also reviewed from 41 North American jurisdictions with confirmed detections of CWD in cervids, identified through the Chronic Wasting Disease Alliance website (Chronic Wasting Disease Alliance, 2025). Jurisdictions with no detections of CWD were excluded. Each jurisdiction was scanned for recommendations, guidelines, and best management practices for hunters and meat processors on testing, safe handling, personal protective equipment (PPE), cleaning and disinfection practices, or additional relevant recommendations. Findings were synthesized narratively summarizing common approaches, overarching strategies, and key recommendations, rather than an exhaustive enumeration.

Supplemental searches of scholarly peer-reviewed and grey literature were performed using Google, Google Scholar, and Science Direct to gain additional evidence on the effectiveness of recommendations on exposure reduction, cleaning, and disinfection of equipment and tools. Boolean operator combinations of search terms related to prions, TSEs, and meat handling. Additional references were identified through forward and backward citation chaining. Finally, we compared available guidance to evidence from the wider literature and reflected on key findings.

Results

Jurisdictional scan of advice relevant to hunters and meat processors

All North American jurisdictions with positive detections of CWD provide advice to hunters or meat processors on CWD. Wildlife management agencies are the primary source of advice on testing, harvesting, and processing of cervids, and public health agencies or university extension services working with agricultural, veterinary, or wildlife agencies provide supplemental information in some geographic areas. The following sections provide a synthesis of the guidance and advice identified in this scan. An alphabetized table in the Supplemental Information lists all scanned jurisdictions and their associated websites that provide key CWD information. Reported findings are based on recurring recommendations across jurisdictions, while jurisdiction-specific guidance is explicitly named where relevant.

Guidance on identification of sick animals

Guidance for hunters on identifying sick animals was usually focused on deer only and is consistent across jurisdictions in stating that infected animals can appear healthy and asymptomatic until several years after infection. Jurisdictions vary somewhat in the description of symptoms observed in sick animals; however, most list symptoms associated with changes in appearance, behaviour, and bodily functions:

- **Appearance**: Sick deer appear thin, may have diminished tone of facial muscles, and the coat can appear rough, dull, pale, or spiky.
- **Behaviour**: Sick deer may show lack of awareness, concern, or fear of humans, reduced activity levels, aggression, panic, confusion, nervousness, trembling, teeth grinding, walking in circles or set patterns, paralysis or reluctance to move, and separation from other animals in the herd.
- **Loss of bodily functions**: Sick deer may display weakness, lethargy, or listlessness, standing with very poor posture, splayed legs, or unable to stand. They may also display a drooping head and ears, excessive thirst, salivation, drooling or difficulty swallowing, loss of coordination, stumbling, or loss of balance, excessive urination and dehydration, pneumonia, loss of appetite and progressive weight loss.

Some of the symptoms listed could be related to other diseases or conditions and most agencies advise hunters to avoid harvesting

and consuming meat from animals that appear sick. Many agencies also suggest reporting sick or dead animals to wildlife officials.

For meat processors, there are few visual indicators of CWD in carcasses submitted for butchering, and processors are unlikely to be able to identify a sick animal without a CWD test result.

Testing for CWD in harvested meat

Testing harvested cervids for CWD is voluntary in many jurisdictions but may be mandatory in CWD management zones or at certain times of year. The turnaround times for CWD test results vary widely. One to two weeks was the shortest turnaround time identified, and 8–12 weeks the longest. Turnaround times can be longer at some times of year when demand for testing is high, or in jurisdictions with lower testing capacity. Most jurisdictions report test results online, and many notify hunters via email or phone call only if their animal tests positive. Only a few jurisdictions specifically state that meat processors would also be notified of positive animals.

No jurisdictions were found to prohibit consuming the meat of CWD-positive cervids or those of unknown status, but many advise against it. Positive meat may be barred from meat donations. In Wyoming, all cervid meat in the meat donation program is tested for CWD, regardless of origin, and any CWD-positive animals are disposed of. In Montana meat already donated to a foodbank that subsequently tests positive requires follow-up with the processor and/or the recipient(s) of the meat.

No agencies prohibit processing meat of CWD-positive cervids or those of unknown status, but a few advise waiting until a negative test result is received before processing. For example, Michigan recommends isolating and avoiding cutting or processing carcasses or meat products until a negative CWD result is obtained.

Some jurisdictions advise against handling or eating high-risk tissues or fluids of any CWD-susceptible cervids, regardless of test results. High-risk tissues are usually stated to include the brain, eyeballs, spinal cord, spleen, lymph nodes, and tonsils. North Carolina also specifies avoiding eating the tongue, and New York, the pancreas. Few jurisdictions were found to identify specific organ meats as high-risk tissues or advise against their consumption.

Recommendations for handling and processing of harvested meat

Recommendations for safe handling of carcasses

To reduce opportunities for exposure to CWD during carcass handling, hunters are usually advised to field dress carcasses at the kill site, carefully removing high-risk tissues, organs, fat, connective tissues, and lymph nodes, and leaving these materials behind. Some jurisdictions provide designated waste bins near hunting sites, or signpost to landfills that accept such materials.

Many jurisdictions provide drop-off points in the field for submitting heads of harvested cervids for testing and hunters may remove the head prior to leaving the hunt area. Many jurisdictions recommend caution when cutting through high-risk tissues like the spinal cord to remove the head and to use dedicated equipment for this task. Recommendations also state that dedicated blades, saws, and cutting boards that are used to cut through bone, spinal cord, or brain should not be used to cut through edible portions of meat or for household purposes.

Few jurisdictions provide advice on handling or butchering meat that is specific to meat processors. General advice on using dedicated tools for high-risk tissues also applies to the meat processing environment. Many jurisdictions recommend minimizing the use of a bone saw and avoiding cutting through the brain or spinal cord, except to remove the head. Wisconsin also recommends trimming meat a generous distance away from shattered bone, especially near the skull or spine. Commercial processors that debone meat are further recommended to ensure high-risk tissues are removed and disposed of appropriately, ensuring they are not included in the grinding of any meat.

Personal protective equipment and hand hygiene

The recommended PPE for handling cervid carcasses or meat varies by jurisdiction, with some recommending the same precautions used to protect against other pathogens. Most agencies recommend the use of rubber, latex, or protective gloves during field dressing or processing animals to reduce contact with high-risk tissues. Some specifically recommend disposable gloves (Manitoba and Kentucky). Additionally, Montana, Louisiana, and British Columbia (BC) recommend the use of eye protection, and BC also recommends wearing an apron to limit contact with blood and tissues. Michigan suggests changing gloves between deer carcasses.

The Association of Fish and Wildlife Agencies (AFWA) recommends using dedicated clothing and PPE when hunting in CWD zones, storing them in separate, labelled containers to prevent cross-contamination (Gillin and Mawdsley 2018). The guidance suggests that hunters avoid the use of porous items such as leather gloves or boots, which are difficult to clean, and instead consider using disposable materials like plastic gloves, boot covers, plastic aprons or Tyvek suits. The guidance advises that non-disposable PPE and clothing should be cleaned with detergent and wiped down with 20,000 ppm bleach where it won't damage the item.

Most agencies recommend thorough handwashing after field dressing or meat processing. Most specify using warm water and soap, and Kentucky specifies washing hands for at least 20 s. New York also recommends washing other body parts exposed to animal tissues, blood, urine, or feces. Manitoba was the only jurisdiction to mention the use of alcohol-based hand-cleanser as an alternative to handwashing.

Preventing cross-contamination

Cross-contamination between infected and healthy cervids, or between cervids and other animals can occur during processing via cutting tools, surfaces, or other equipment, or during storage. To minimize this risk, many jurisdictions recommend that cervids are processed and stored individually until their CWD status is known. Meat or carcasses can be labelled, frozen, and stored (processed or unprocessed), until test results are received. California recommends processing all hunter-harvested deer and elk individually at the end of the day, to limit potential

cross-contamination of tools and surfaces used for domestic meat and advises storing cervids separately from other animal submitted for processing. This may include hanging cervids on separate rails or using protective coverings to prevent contact between parts or carcasses. To package securely, Manitoba recommends double-bagging and freezing meat until CWD test results are obtained.

Batch processing where multiple carcasses are processed together, and hunters receive meat from more than one animal, poses a risk of cross contamination. Many jurisdictions advise hunters to request individual cutting and wrapping of their meat to ensure that they only receive meat from their own animal. Montana recommends that batch processing should only be used for meat that is confirmed to test negative for CWD. Missouri advises processors to inform their customers if mixing meat from different animals is a common practice, to enable them to make an informed decision about consumption of meat from mixed sources. To further reduce risks associated with batch processing, some jurisdictions recommend record keeping of animals processed together to enable tracing if a CWD-positive test result is identified as part of a batch.

Recommendations for cleaning and disinfection

Cleaning equipment

Advice on cleaning knives, tools, and other implements varies from basic (wash thoroughly) to more detailed. Most jurisdictions recommend scrubbing to remove visible tissue, blood, fat, or other organic matter from equipment and rinsing before disinfection. Keeping equipment moist between meat processing and cleaning is recommended to prevent residues from drying and sticking to surfaces (Gillin and Mawdsley 2018). Some agencies note that larger pieces of residue should be physically removed and discarded to waste, rather than washed to drains.

Normal dish-washing detergent is typically recommended for cleaning, however a few jurisdictions list other detergents as effective for reducing prion infectivity. Three alkaline detergents mentioned by a small number of agencies are 1.5% CIP 150®, Tergazyme™, and Prolystica® 2X alkaline detergent (Gillin and Mawdsley 2018).

Disinfecting equipment

Advice on disinfection was found to range from basic ("clean and disinfect") to more detailed, with variations in the recommended concentration and contact time between equipment and the disinfectant. Bleach (sodium hypochlorite, NaClO) is the most recommended disinfectant, but there are differences in how it is described. Some jurisdictions refer to bleach in terms of percentages (e.g. 40% or 50%), fractions (e.g. 50/50), or ratios (e.g. 1:1, 1:1.5, 1:2, or 2:3) of household bleach to water. Other agencies refer to the absolute percentage of NaClO (e.g. 2%) or available chlorine concentration (20,000 ppm).

Contact time with bleach is not always stated but either a 5-min or a 60-min soak is commonly recommended for equipment. Some agencies are more specific, stating a 5-min treatment for stainless steel items, and a 60-min treatment for non-steel items. The AFWA and California recommend soaking items for 10 min in 2% bleach solution (based on NaClO concentration), while Tennessee recommends a 20-min treatment using a 50% bleach-to-water mixture.

For surfaces, some jurisdictions recommend simply wiping down or spraying surfaces with a bleach solution, then air drying, whereas others refer to soaking. There was variation in advice on air drying and rinsing, with some recommending rinsing after a bleach soak then air drying, and others (New York and Pennsylvania) recommending air drying after the bleach soak and then rinsing.

Reflections on key findings

The review of current guidance for hunters and meat processors revealed some inconsistencies in recommended control measures across jurisdictions, however clarity on best practices can be gained from a wider review of the grey literature and scholarly sources.

Identifying sick animals and seeking testing

Guidance on recognizing physical symptoms of CWD in cervids aligns with research indicating that infected cervids may remain asymptomatic until reaching a late stage of illness, and only testing can confirm infection (CIDRAP, 2025; National Academies of Sciences Engineering and Medicine, 2024). Further study is needed to identify whether other observable signs or symptoms of disease may be detectable earlier, such as those related to spatial movements or behaviours (Escobar et al., 2020). Hunters, Indigenous communities, or biologists with a more advanced knowledge of wild cervid populations and their habitats could contribute to an improved understanding of how CWD-infection may affect cervid ecology or behaviour (Parlee et al., 2021).

Handling cervid tissues

Current guidance suggests avoiding handling and consuming high-risk tissues, primarily of the central nervous system (CNS; brain, spinal cord), and the lymph nodes. Advice to field dress animals and leave these tissues at the kill site can reduce additional handling or transport that could lead to exposures or environmental contamination. These recommendations align with evidence that these tissues can concentrate CWD prions; however, CWD prions can be concentrated in a much wider range of tissues (e.g. tonsils, digestive tract, heart, lung, kidney, adrenal, and pancreas, skeletal muscle and bodily fluids) (Angers et al., 2006; Benavente et al., 2025; Escobar et al., 2020; Li et al., 2021; National Academies of Sciences Engineering and Medicine, 2024; World Health Organziation, 2010). Although removal of high-risk tissues of the CNS and lymph nodes can reduce exposure to prions, all cervid tissues should be handled with care, particularly in CWD-endemic zones. The presence of prions across multiple tissues underscores the importance of using PPE during handling, particularly disposable or easily cleaned PPE, and dedicated clothing and equipment in CWD zones.

Handwashing with soap and water to physically remove prions is preferred over alcohol-based hand sanitizer, which are ineffective against TSE prions (World Health Organziation, 1999).

Preventing cross-contamination

Processing cervids individually and keeping cervids and non-cervids separate can reduce opportunities for cross-contamination during meat processing. Limited research on processing facilities suggests that contamination can transfer between animals and equipment. A 2024 pre-print article reported that uncontaminated venison became contaminated when processed in a grinder previously used for CWD-positive venison (5/8 tests) (Milstein et al., 2024). The study also reported contamination of stainless-steel knives and plastic cutting boards after processing CWD-positive meat, reinforcing messages to keep animals separate and the importance of rigorous cleaning protocols.

Cleaning and disinfection

Scrubbing and detergents

Organic matter on equipment and surfaces can shield prions from disinfectants and reduce available chlorine, reducing its efficacy. Keeping tools and surfaces moist prior to cleaning prevents organic matter from drying on surfaces, making removal easier. This aligns with biosafety guidelines for prion decontamination in other settings, informed by evidence from the literature (Centers for Disease Control and Prevention & National Institutes of Health, 2020; Public Health Agency of Canada, 2016). Milstein et al. reported that scrubbing with dish soap and a sponge was effective at removing potentially infectious CWD-prions from knife blades and cast-iron grinders used for cervid meat processing (Milstein et al., 2024). However, this was less effective for cutting boards and stainless-steel grinders. Porous surfaces or complex equipment that can trap organic matter may require more intensive cleaning.

There is limited research on detergent effectiveness for removing CWD-prions, but alkaline products are generally considered more effective than acidic ones (World Health Organziation, 1999; Xu et al., 2014). No specific evidence was identified for the effectiveness of some of the recommended alternatives to dish soap (1.5% CIP 150®, Tergazyme™, and Prolystica® 2X); however, the role of detergents, is primarily for organic matter removal rather than inactivation. Detergents should not be considered an alternative to disinfection steps.

Disinfection of tools and surfaces

Most agencies recommend disinfecting using a solution made from household bleach (5%–6% NaClO or 50,000–60,000 ppm available chlorine) and water. The communication of bleach concentration however (e.g. "40%," "2%," "1:2 dilution") was inconsistent and resulted in variations in recommended NaClO concentrations. Biosafety guidance, supported by evidence from the literature, typically recommends a 2%–2.5% NaClO solution equating to 20,000–25,000 ppm available chlorine. Communicating disinfection concentration in these terms (% NaClO or ppm available chlorine) can facilitate consistency in practice (Centers for Disease Control and Prevention & National Institutes of Health, 2020; Public Health Agency of Canada, 2016).

Contact time with bleach solution was found to vary in the jurisdictional scan from 5 to 60 min. While a 5-min soak could be sufficient for non-porous materials such as stainless-steel wires or knife blades, (Williams et al., 2019) porous surfaces or more complex equipment may require a longer exposure. Standard biosafety guidance advice supported by literature recommends a 60-min contact time for all tools using 2%–2.5% NaClO for prion inactivation. For bleach concentrations lower than 2%–2.5% NaClO, a longer contact time may be required (Groveman et al., 2024). These findings suggest that advice on spraying and wiping down surfaces, with limited contact time, especially porous cutting surfaces, may be insufficient for disinfection.

Alternative disinfectants

Highly alkaline solutions, such as 1–2N NaOH or KOH are known to be effective against prions, and a combination of chemical treatment and heat is likely to be more effective than standalone treatments (Belondrade et al., 2016; Centers for Disease Control and Prevention & National Institutes of Health, 2020; Public Health Agency of Canada, 2016; Spickler, 2016). However, no jurisdictions recommended using NaOH or KOH or heat treatment for cleaning of cervid processing equipment. This may be due to the chemical hazards and potential for severe burns associated with handling concentrated alkaline solutions and the impracticality of applying high temperature treatments to surfaces or managing autoclaving equipment in a meat processing setting.

Environ LpH® is sometimes recommended as an alternative to bleach for use on hard non-porous surfaces; however, this product is no longer available in North America. Wex-cide 128, a similar phenolic product tested alongside Environ LpH® was found to provide a comparable level of CWD-prion inactivation (e.g. 4.0–5.5 log reduction on steel wires) (Baune et al., 2023). Milstein et al. tested additional disinfectants on meat processing equipment. A 5-min soak using Briotech (0.02% hypochlorous acid) removed infectious prions from knives, but only partially from cutting boards (Milstein et al., 2024). A 5-min soak using Virkon®-S (potassium peroxymonosulfate) removed infectious prions from knives and cutting boards but not from meat grinders. Bleach was the most effective treatment, with a 5-min soak using a 5,000–20,000 ppm solution removing infectious prions from all tested equipment. Current evidence suggests that bleach remains an appropriate disinfectant based on effectiveness, availability, and relative safety compared with highly alkaline solutions.

Conclusions

The jurisdictional scan of current advice and guidance for hunters and meat processors on minimizing exposure to CWD prions generally finds that while most jurisdictions with CWD detections provide basic information on safe handling of hunter-harvested cervids, detailed advice for meat processing environments, is often lacking. Guidance on CWD exposure prevention is largely supported by available evidence but in some cases misses important nuances or details that could further reduce risks.

Enhancing communication about the potential for prions to be present in multiple cervid tissues and bodily fluids, not just

Table 1: Key recommendations for reducing exposure to CWD-prions in hunter harvested cervids

Control measure	Recommended actions
Identify sick animals and seek testing	– Avoid harvesting animals that appear sick – Seek cervid testing, especially in CWD management zones
Reduce contact with tissues until CWD status is known	– Remove high risk tissues at the kill site using dedicated equipment; do not use this equipment to cut edible parts – Use disposable PPE and minimize contact with all cervid tissues, blood, and bodily fluids – Handwash using soap and water after handling cervids – If possible, store unprocessed meat until a negative test is received – Do not eat meat that subsequently tests positive
Prevent cross-contamination	– Process cervids separately and keep meat of unknown status labelled and stored separately – Avoid batch processing for animals of unknown CWD-status
Clean and disinfect equipment	– Scrub equipment and surfaces with soap and water to remove all visible organic matter – Disinfect tools and surfaces using a bleach solution (2%–2.5% NaClO), with a preferred contact time of 60 min for all items, particularly porous and hard to clean equipment

high-risk tissues, could reinforce the importance of using PPE, dedicated equipment, and waiting for a negative test result before processing or consuming cervid meat. Faster turnaround of test results could increase the likelihood that hunters and processors will wait for results. Keeping meat from animals of unknown CWD-status separate from other animals and avoiding batch processing can prevent cross-contamination. Where animals of unknown status are processed, clear guidance on appropriate cleaning and disinfection practices, particularly standardizing communication on the appropriate concentration of disinfectants (bleach) and longer contact times for porous materials, could improve the adoption of best practices. The key control measures and recommended actions are summarized in Table 1.

As CWD continues to spread rapidly across North American, opportunities for human exposures are increasing. Many hunters, including within Indigenous communities, rely on hunted cervid meat each year, and the risks that CWD could pose to both food safety and food security should not be underestimated (Parlee et al., 2021). Improved understanding of the human health risks, and strategies to mitigate spread among wild cervid populations and human exposures will help to refine recommendations and strengthen protective measures over time.

Supplementary material

Supplementary data are available with the article at https://doi.org/10.5864/d2025-003.

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