STRATEGIC SURVEILLANCE PLAN FOR TREPONEME-ASSOCIATED HOOF DISEASE IN CALIFORNIA

June 2020

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Suggested citation: Munk, B.A., Lantz, E.L., and Denryter, K. 2020. Strategic surveillance plan for treponeme-associated hoof disease in California. California Department of Fish and Wildlife, Sacramento, CA.

Executive Summary

Treponeme-associated hoof disease (TAHD), also known as elk hoof disease, was confirmed in California for the first time in April 2020 in a Roosevelt elk harvested from Del Norte County in December 2019. Subsequently, TAHD was been confirmed in two additional elk from the same area. This plan outlines the Department's strategy to determine geographic distribution, estimate prevalence when feasible, and inform research and management actions to better understand and mitigate risks this disease may pose to California's elk populations. Having and maintaining robust demographic data will be vital to the understanding of this disease in California's elk populations and continuing to prioritize Population Monitoring objectives, outlined in the 2018 Elk Conservation and Management Plan and detailed in specific Elk Management Unit (EMU) plans, will be critical.

As the name implies, TAHD is associated with one or more species of spiral-shaped bacteria, or spirochetes, in the genus *Treponema*. The disease was first described in 2009 following increasing reports of limping or lame Roosevelt elk in southwestern Washington the year prior. Since then, it has been detected in Roosevelt and Rocky Mountain elk in other parts of Washington, Oregon, Idaho, and now California. While much has been learned about this disease, much more remains unknown, including what factors lead to disease in individuals and what the potential impacts may be to affected elk populations. These unknowns make planning response and management actions and predicting outcomes to California's elk populations challenging. As such, the Department's immediate priorities for this disease are to determine its distribution in California and to better understand the ecology, epidemiology, and pathophysiology of this disease to better advise the Department's management actions.

Acknowledgments

We are grateful for the support, advice, and input of many individuals in the preparation of this strategic surveillance plan for treponeme-associated hoof disease in California. Several individuals from the Washington Department of Fish and Wildlife (WDFW), Oregon Department of Fish and Wildlife (ODFW), and Washington State University (WSU) generously shared their time and invaluable insights with us before and during the drafting of this plan. We are especially grateful to Kyle Garrison and Dr. Kristin Mansfield from WDFW, Dr. Julia Burco (ODFW), and Dr. Margaret Wild (WSU) for their review of this plan and their input. We also are grateful to Dr. Rachel Cook of the National Council for Air and Stream Improvement for providing materials to help standardize collection of nutritional condition indices from deceased elk.

Plan Overview

Plan Purpose and Goals

The Department developed this plan in response to the initial detection of treponeme-associated hoof disease (TAHD) in California. The purpose of this plan is to direct statewide surveillance for TAHD which will, in turn, support or direct research and management efforts related to elk hoof disease.

Surveillance Goal 1: Determine geographic distribution and, where feasible, estimate prevalence of TAHD in California.
Surveillance Goal 2: Inform research and management actions to better understand and mitigate the risk of this disease to California's elk populations.

Surveillance provides the foundation for understanding this disease in California and will both support and direct any proposed research or management objectives and actions by providing the necessary information to inform and adapt management priorities. Robust population monitoring as outlined in Elk Management Unit plans will be required to adequately interpret surveillance data over time and direct management priorities. Specific surveillance and population monitoring objectives will be incorporated into Elk Management Unit plans as disease and management priorities evolve. Surveillance goals may change as our understanding of this disease increases, new tools are developed, management priorities shift, and resources change.

Departmental Jurisdiction and Authority

California Fish and Game Code (FGC) declares various objectives for preservation, conservation, and maintenance of wildlife resources under the jurisdiction and influence of the state, including alleviation of public health or safety problems caused by wildlife (§1801) and establishes the California Department of Fish and Wildlife (hereafter CDFW or Department) as the trustee agency for the conservation, protection, and management of fish and wildlife (§1802). Additionally, California FGC §1001 grants CDFW the authority to take wildlife for prevention or relief of suffering.

Background and Current Understanding of Treponeme-Associated Hoof Disease

History and Known Geographic Distribution

Treponeme-associated hoof disease (TAHD), sometimes referred to simply as elk hoof disease, was first characterized in Roosevelt elk from southwest Washington in 2009, following sporadic reports of limping elk back to the 1990s and a dramatic increase in 2008 (Han and Mansfield 2014, Han et al. 2019). It has since been detected in Roosevelt and Rocky Mountain elk in Oregon (2014), Idaho (2018), and California (April 2020) (Fig. 1). As of May 2020, TAHD is not known to occur in tule elk. The first cases of TAHD in California were

from hooves of two Roosevelt elk harvested by hunters in December 2019. While much has been learned about this multifactorial disease in recent years, still more remains unknown.

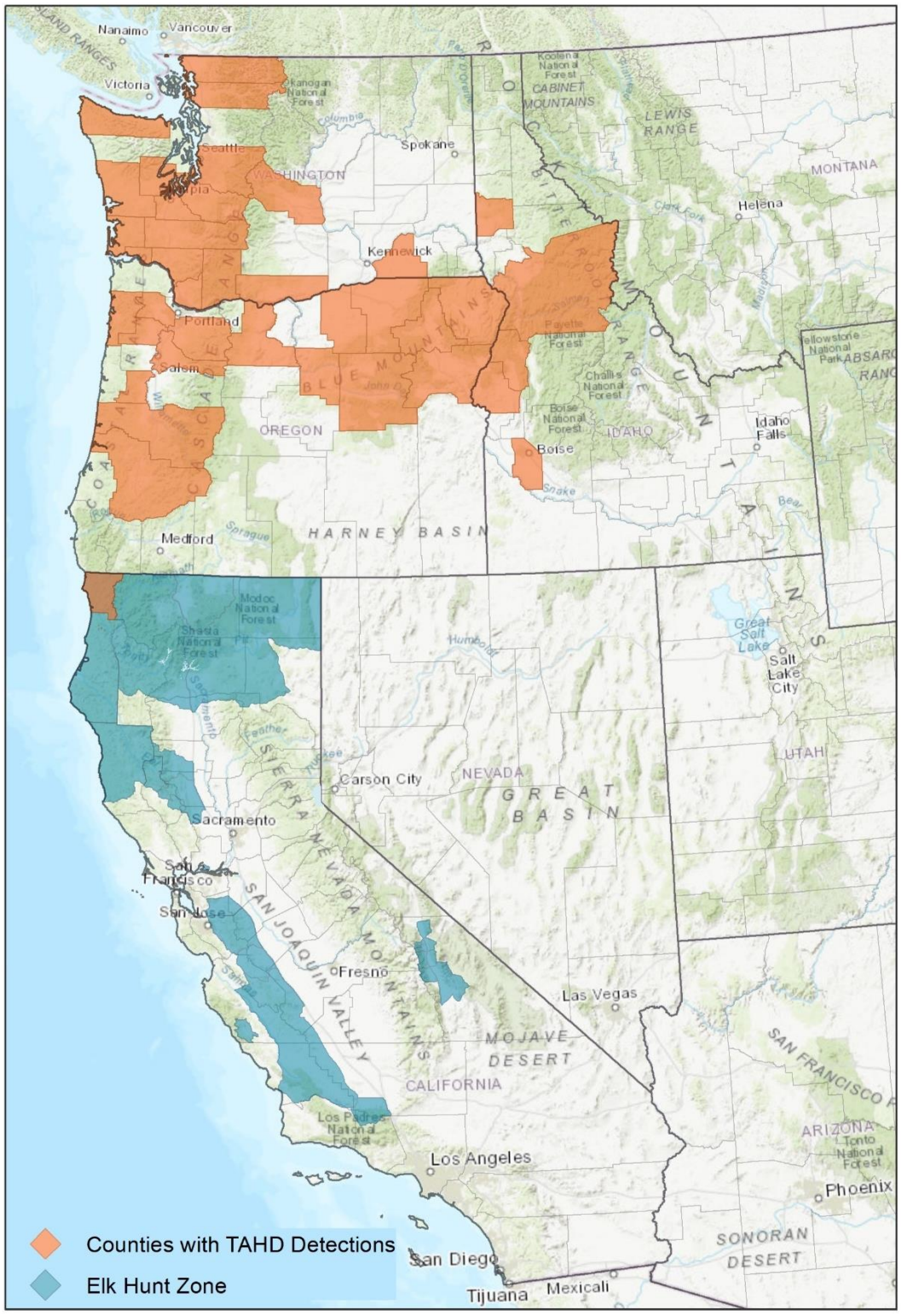

FIGURE 1: KNOWN DISTRIBUTION OF TAHD AS OF MAY 2020. ORANGE SHADING INDICATES COUNTIES WHERE TAHD HAS BEEN CONFIRMED IN FREE-RANGING ELK. NOTE, DEL NORTE COUNTY IS THE ONLY KNOWN AFFECTED COUNTY IN CALIFORNIA BUT SURVEILLANCE FOR TAHD WILL BE PERFORMED WHEREVER ELK ARE PRESENT IN CALIFORNIA.

Clinical Findings and Etiology

To date, few studies have been published on TAHD and research efforts have focused largely on describing the disease in individual elk and identifying pathogens associated with the disease (Han and Mansfield 2014; Clegg et al. 2016; Han et al. 2019). Early infections are characterized by superficial changes (e.g. erosions, ulcers, hyperkeratosis) at the coronary band and interdigital space of affected feet and hooves. As the disease progresses, ulcers undermine the coronary band, hoof capsule, and/or heel-sole junction. Further ulceration associated with inflammation and necrosis of deep and superficial tissues leads to increasingly overgrown, broken, or otherwise damaged hoof capsules. In severely affected hooves, the hoof capsule can ultimately break or slough off (Table 1; Appendix A). Hoof capsule overgrowth or deformity may be found at any stage of TAHD (Han et al. 2019). Hoof lesions are painful and can lead to limping or lameness. Secondary bacterial infections, both localized and systemic, may occur and could contribute to disease in affected animals.

TABLE 1. DESCRIPTION AND GRADES OF TREPONEME-ASSOCIATED HOOF LESIONS FROM HAN ET AL. (2019); SEVERITY OF LESIONS INCREASES WITH INCREASING GRADE NUMBER.

Grade of foot lesion	Description
I	Cutaneous only with coronary, interdigital skin, or heel erosions or ulcers with or without hoof capsule overgrowth and deformity
II	Ulceration with undermining of the hoof capsule or heel-sole junction, with or without hoof capsule overgrowth and deformity
III	Sole ulceration with inflammation or necrosis of the epidermal and dermal lamina, with or without hoof capsule overgrowth and deformity
IV	Grade II or III lesions with breakage or sloughage of the hoof capsule, with or without hoof capsule overgrowth and deformity

Spirochete (spiral-shaped) bacteria in the genus *Treponema* are consistently detected in affected hooves (Clegg et al. 2016, Han et al. 2019), though in combination with diverse species of aerobic and anaerobic bacteria, hence the descriptive name treponeme-associated hoof disease (Han et al. 2019). Genetically related treponemes are associated with similar hoof diseases, digital dermatitis (DD), found in domestic livestock including cattle, pigs, sheep, and goats (Clegg et al. 2016). However, the role these treponemes play in the development of TAHD or DD is not fully understood and other species of bacteria routinely identified in association with these diseases may play a role in developing disease (Han et al. 2019). To date, TAHD has not been detected in other wild ungulate species.

Ecology and Epidemiology

Relatively little is known about the ecology and epidemiology of TAHD and much work is needed to describe and understand the various host, pathogen, and environmental factors associated with the disease. Susceptibility of individual elk to TAHD is believed to be multifactorial (Han et al. 2019). Understanding these factors is necessary to effectively manage this (and any) disease in wildlife populations (Wobeser 2007).

Development of TAHD is likely influenced by multiple factors including environmental conditions (e.g., moist soils, bacterial community makeup), population densities, nutritional condition of individual animals, and mineral deficiencies (e.g., selenium, copper) (Han and Mansfield 2014; Han et al. 2019). Preliminary results from a Washington Department of Fish and Wildlife (WDFW) study of the Mount Saint Helen's elk population suggest that affected elk were in poorer nutritional condition in December (usually the time of year of peak body fat levels in temperate environments), had lower pregnancy and lactation rates, and had lower annual survival than unaffected elk. Additionally, WDFW found that more elk affected by TAHD died from general debilitation and predation than unaffected elk (Hoenes et al. 2018). These findings, taken together, suggest that TAHD has the potential to negatively influence susceptible elk populations. However, many risk factors remain unknown and much work remains to understand what effects TAHD may have on elk populations and what effective management strategies may be.

Surveillance

In their Terrestrial Animal Health Code, the OIE (World Organisation for Animal Health) defines surveillance as the "systematic on-going collection, collation, and analysis of information related to animal health and the timely dissemination of information so that action can be taken." In accordance with this definition, CDFW's surveillance efforts are described below and will be incorporated into existing population assessment efforts across every elk management unit. The Department is responsible for collecting population data which will continue to be critical to help inform potential management actions. Population monitoring will be continuous and disease surveillance intensities will adapt and vary over time as detections are confirmed and our understanding of the disease improves. We anticipate broad interest in the potential implications of the disease so efforts will coordinate with other state and federal wildlife and agricultural agencies, universities, federally recognized Tribes, and the public to monitor and document the distribution of TAHD in California. Surveillance activities are underway where TAHD has been detected and will be expanded to other Elk Management Units (EMU) as we implement this plan.

Determining Geographic Distribution of TAHD

To determine the geographic distribution of TAHD and monitor for changes in that distribution, surveillance will be conducted throughout the range of elk in California. Surveillance intensities will vary between EMUs based on presence/absence of TAHD, presence of risk factors associated with TAHD, and management priorities in each EMU. The Department will work with partners including other state and federal resource agencies and

land managers; federally recognized tribes; hunters; scientific collecting permit holders; law enforcement; CalTrans; private landowners enrolled in Private Lands Management (PLM) or Shared Habitat Alliance for Recreational Enhancement (SHARE) programs; non-governmental organizations; and the general public to facilitate disease surveillance. These efforts will focus on the following surveillance activities:

1. Reporting limping elk or elk with deformed hooves through WIL's online disease/mortality reporting tool:
    a. Used to prioritize populations to sample.
    b. May come from the public, CDFW staff during routine population management activities (surveys, captures, depredation, etc.), or CDFW partners and volunteers.
    c. https://wildlife.ca.gov/Conservation/Laboratories/Wildlife-Investigations/Monitoring/Mortality-Report.
2. Hooves from hunter-harvested elk (removed approximately four inches above the "ankle" joint):
    a. Initial focus on PLM and SHARE program and managed hunts.
    b. Brought to CDFW Regional Offices or hunter check stations, as organized by Regional staff in coordination with the Wildlife Branch (WLB) Elk Species Lead and Wildlife Investigations Lab (WIL).
    c. Visual inspection of hooves by trained CDFW staff, partner, or volunteer to identify lesions consistent with TAHD. Training will be provided by the WIL.
    d. Submit a subset of hooves either directly to the California Animal Health and Food Safety (CAHFS) Laboratory or the WIL for confirmation of TAHD and collection of samples for archive (biopsy interdigital space, coronary band; cryovial; freeze -80ºC).
    e. Hooves not sampled for diagnostics may be stored frozen for ongoing TAHD research collaborations.
3. Sick or debilitated elk may be euthanized by CDFW staff for Animal Welfare or Management purposes.
    a. Collect and submit all four hooves (described above) and a 2" x 2" piece of liver to the WIL or directly to CAHFS in coordination with WIL.
    b. Store on ice or refrigerate for up to 48 hours, otherwise freeze at -20ºC until samples can be submitted.
    c. There may be cases where a full necropsy and postmortem investigation is required. For these cases, a standardized necropsy protocol will be developed in coordination with the WIL.
4. Elk mortalities from other sources may be opportunistically inspected or sampled for TAHD.
    a. Regional staff should coordinate with scientific collection permit holders, CalTrans, and Tribes to facilitate visual inspection and/or sampling.
    b. Hooves and liver samples will be collected and submitted as described in 3(a), if visual inspection suggests TAHD or if samples are from an EMU with negative or unknown disease status.

Surveillance in Elk Herds Following Initial Detection

Following initial detection and confirmation of TAHD in a herd or EMU, the Department may increase surveillance and sample collection intensity in an EMU to accomplish specific objectives that may be developed in response to TAHD or management priorities, otherwise disease monitoring will continue as described in the previous section. The decision to increase surveillance intensity will depend on multiple factors including evolving management, disease, and research priorities, defined as we work with partners and gain a broader understanding of this disease in California, and resource availability. Situations that may require increased surveillance intensity include, for example, confirming disease status of herds with negative or unknown disease status that are adjacent to known positive herds, determining prevalence within an affected population, measuring success of disease management actions, or to support specific research goals.

As we learn more about TAHD in California, specific population, management, and disease objectives will be developed and more intensive surveillance strategies may be required to support those objectives. As such, they will be developed as specific Research and Management priorities are developed. Where required, a specific and detailed disease sampling and surveillance plan will be developed collaboratively by WLB, WIL, and Regional staff within Research and/or EMU Plans. These plans will, at a minimum, identify:

1. Specific Research or Management Goal(s) and Objective(s) to be addressed.
2. The specific Surveillance Goal(s) and Objective(s) to accomplish.
3. Population(s) to be sampled.
4. Sampling unit(s) defined.
5. Minimum sample size(s) and, where appropriate, predictive values.
6. Samples to be collected and tests performed.

Confirmation of Treponeme-Associated Hoof Disease

Confirmation of TAHD in an individual animal will be based on identifying one or more gross and microscopic lesions consistent with TAHD and in association with argyrophilic (silver-loving) spirochete bacteria (Han et al. 2019). As understanding of this disease expands additional diagnostic assays like immunohistochemistry (IHC), polymerase chain reaction (PCR), metagenomics, or others may become available and modify or replace this standard for case confirmation.

Sampling, testing, and surveillance strategies may change based on the availability of diagnostic assays or resources, disease detections, and management or research priorities. For example, once TAHD is detected in a herd, identification of additional diseased animals may be based on evidence of lame elk or by visual inspection of affected hooves, and confirmatory testing may be waived.

For continuity, a minimum dataset will be collected from each animal sampled or inspected to include:

- Reporting party or inspector's name and contact information
- Location of affected elk, EMU and GPS (UTM) coordinates.

- Date of observation and/or collection.
- Number of elk affected.
- Age and sex of affected elk.
- Identify and label which hooves have lesion(s) and which were collected.
- Note any antler abnormalities.

Research

Much remains unknown about TAHD and research into the disease, particularly the causes and effects, will be crucial for developing effective management strategies (Wobeser 2007, Han et al. 2019). As such, research into TAHD performed or supported by CDFW will focus on understanding the ecology and epidemiology, causative factors, population level effects, and effective management strategies of TAHD in California's elk populations. This will be accomplished by initially defining the geographic extent of TAHD in California and monitoring trends over time through disease surveillance (described above), continued demographic monitoring (described in CDFW's 2018 Elk Conservation and Management Plan), and working with local and regional partners to develop and implement specific research priorities. We will continue to support already established research collaborations to further understand the pathophysiology, confirm causative relationships between pathogens, and develop additional diagnostic tests for TAHD.

Specific research Objectives and Actions will be developed collaboratively within and among CDFW and CDFW's partners. Research goals, objectives, and actions will be modified or expanded as additional needs arise. As our understanding of the etiology, epidemiology, and ecology of TAHD increase, we will transition to research efforts that prioritize identifying strategies for managing TAHD.

Disease Management

Selecting appropriate methods for managing a disease requires a clear understanding of the cause, ecology, and epidemiology of the disease. Generally, objectives for managing wildlife diseases focus on prevention and reducing the prevalence and spread of disease, rather than eradication which is often not feasible once a disease becomes established in a wild population. In controlled or captive settings, animal disease management can include contact tracing, quarantine, treatment, vaccination, husbandry or habitat manipulation, and culling. However, these tools are often unavailable or ineffective for managing diseases in wildlife.

Contact tracing is generally not feasible in wildlife populations since not all animals are marked to be individually identifiable, individual movements and interactions among individuals cannot be tracked with adequate detail, and it is often impractical, dangerous, or impossible to capture and mark or quarantine all affected animals. Similarly, treatments available for similar hoof diseases in domestic livestock (e.g., topical antibiotics, prophylactic footbaths) are not feasible in free-ranging wildlife as they require repeated treatments and resource prohibitive to implement. There is no vaccine available for TAHD or

similar diseases in livestock. That leaves habitat manipulation and culling as the remaining options to consider, with our current understanding of TAHD.

Lethal removal has been used in Washington and Oregon for management of TAHD and is currently the only tool considered feasible for managing TAHD in California. To the extent feasible, management will focus on disease containment and mitigation, with lethal removals being a tool to help achieve that goal. Where lethal removal is employed, it will be performed to maximize animal welfare and conducted whenever possible in accordance with the American Veterinary Medical Associations guidelines. It is likely that habitat features (moist environments, overlap with livestock) are important risk factors as such habitat manipulation that alters habitat usage patterns by elk may be an option to consider as we learn more about the risk factors and ecology of TAHD. However, much work remains before habitat manipulation is likely to be a viable management action. Surveillance and research will inform TAHD-related management objective and actions. Management objectives and actions will be developed within specific EMU plans.

Potential Management Actions, unknown efficacies:

- Identify and cull affected animals (Wildlife Services and/or CDFW staff).
    - Removes sources of transmission and environmental contamination.
    - Decrease or slow disease transmission and spread.
- Lowering population objectives in affected areas.
    - Increase tag limits in affected areas.
    - Decrease density dependent disease transmission.
- Improve habitat conditions and forage quality.
    - Increase nutritional status of elk.
    - Decrease (yet undefined) environmental risk factors.
- Ban translocations of elk into or out of affected populations.
- Increase disease surveillance prior to any translocation from an unaffected herd.
- Habitat management/manipulation to affect habitat use by elk.
    - Fire or mechanical manipulation of habitats.
    - Fencing to exclude elk from certain habitats.
    - Decrease interactions with livestock.

Data Management

Samples will be submitted directly to the WIL or to CAHFS in coordination with WIL. Copies of data sheets (Appendix B) will accompany all samples and be copied to the WLB. The WIL will store, archive, and submit samples for testing; report test results; enter data and maintain an TAHD database. Regional staff will be responsible for providing (and updating quarterly) all available data on elk to the WLB for maintenance in a relational database. The WLB and WIL will develop an TAHD website where we will report and map TAHD surveillance results.

Data will be analyzed, summarized, and reported on annually by July 1. Reports will be prepared collaboratively by WLB, WIL, and appropriate regional staff, and will include

information on surveillance efforts (including number of samples analyzed, maps of geographic distribution of samples, diagnostic results, changes in distribution or prevalence, and other pertinent information).

Communication Strategy

Communication and dissemination of results in a timely manner are integral to successful disease surveillance and management efforts.

Communication Goal 1: Increase public awareness of TAHD in California.

Objective 1.1: Facilitate transparency and timely sharing of information related to TAHD in California.

Action 1.1.1: Communicate important updates using press releases through CDFW's Office of Communication, Education, and Outreach.

Action 1.1.2: Produce and maintain an up-to-date webpage on TAHD and associated surveillance and research activities in California.

Action 1.1.3: Provide information to elk hunters on hoof disease in hunter information documents, including information on reporting hoof abnormalities.

Action 1.1.4: Produce a technical report, with accompanying non-technical summary, of TAHD surveillance and research efforts annually.

Action 1.1.5: Department staff provide updates at public meetings.

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APPENDIX A: Depiction of elk hoof lesions and associated lesion grades from Han et al. 2019. Adapted by permission from Hoenes et al. 2018.

Elk Hoof Disease

Washington Department of FISH and WILDLIFE

Coronary band: where the hair meets the hoof

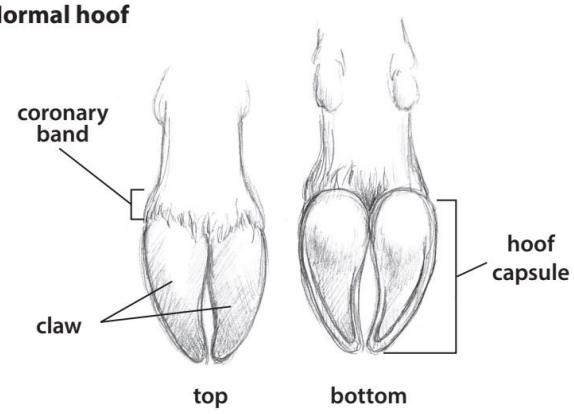
Claw: one of two digits/toes on each hoof

Hoof capsule: the entire structure, made of horn, that covers the digit/toe/claw

More Info:

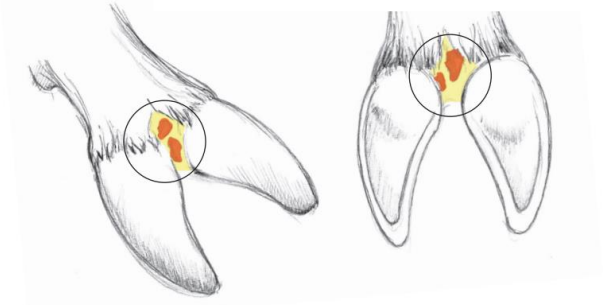
wdfw.wa.gov/conservation/health/hoof_disease/

Normal hoof



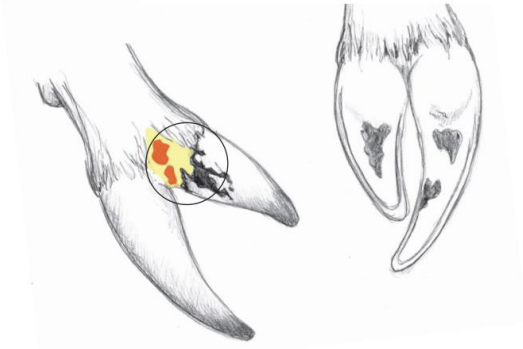
Grade 1

Broken or infected-appearing skin along the coronary band or between the toes/claws/digits. Lesions are limited to the skin with no hoof capsule involvement. Hoof capsule(s) may or may not be overgrown, but are not infected or broken.



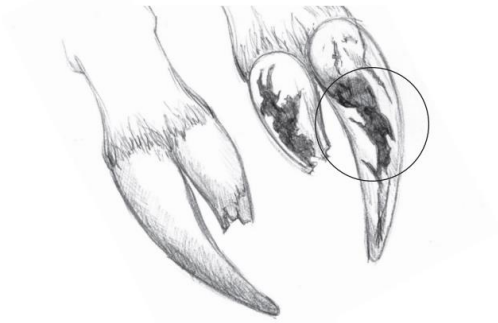
Grade 2

Skin wound is beginning to work its way underneath the hoof capsule. Hoof capsule(s) may or may not be overgrown.



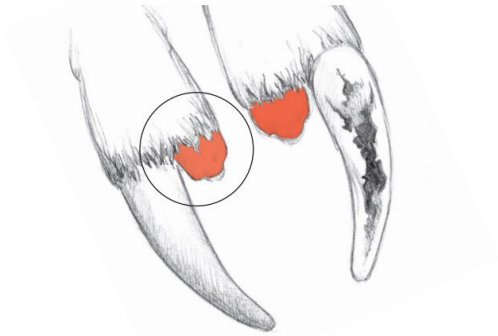
Grade 3

A large cavity or hole in one or both hoof capsules, usually on the bottom of the hoof. May include Grade 2 lesion. Hoof capsule(s) may or may not be overgrown.



Grade 4

Missing one or both hoof capsules. Remaining claw may include Grade 2 or Grade 3 lesions; and remaining hoof capsule is usually overgrown.



APPENDIX B: Sample Datasheet.

ELK HEALTH SURVEILLANCE

ID Number: ____________

Date: ____________
Name: ____________
Source: ____________

Subspecies: Roosevelt ☐ Rocky Mtn ☐ Tule ☐
Age Class: Calf ☐ Yearling ☐ Adult ☐ ____________ (years)
Sex: Female ☐ Male ☐ Unknown ☐

Post-mortem condition: Good ☐ Fair ☐ Autolyzed ☐
Nutritional Status: Good ☐ Fair ☐ Poor ☐
Death via: Hunter ☐ Euthanasia ☐ Vehicular ☐ Predation ☐ Other ☐ Unknown ☐ ____________

Date of death: ____________ Hunter name: ____________ Tag # (or GoID): ____________

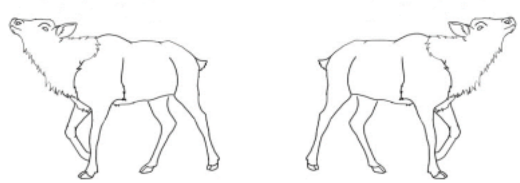
Notes: ____________

GPS coordinates

Latitude: ____________ Longitude: ____________
Easting: ____________ Northing: ____________
Datum: WGS 84 ☐ NAD83 ☐ Zone: ____________

General location (*physical land description, address, hunt zone, etc.*): ____________

Carcass injuries *(Mark general location of injuries on picture and describe below)*



Left side   Right Side

Description of injuries
____

Marked individual: Ear Tag ID ____________ Collar ID ____________ Collar Frequency ____________

Samples Collected

Notes (*description of any abnormalites*)

Hooves:	Right Front ☐	Left Front ☐	Right Hind ☐	Left Hind ☐
Feces:	WhirlPak 1 ☐	WhirlPak 2 ☐		
Liver:	WhirlPak 1 ☐	WhirlPak 2 ☐		
CWD Samples:	WhirlPak RPLN ☐		Formalin RPLN & obex ☐	
GI:	Illeocecal LN ☐	Colon ☐	Mesenteric LN ☐	
Muscle:	WhirlPak 1 ☐			