Elk Hoof Disease in Southwest Washington

Kristin Mansfield DVM MPVM

Fish and Wildlife Commission Meeting
August 8, 2014
Wild Ungulate Hoof Diseases

- Usually sporadic and many different causes
- Below are photos from an elk, a moose, and a mule deer, each with a different hoof disease, all collected during Fall 2012 in Eastern WA
Examples of Deformed Hooves
Prevalence and Distribution
2008-2009

Information is subject to changes and amendments over time.
Novel Hoof Disease in Elk?
Spillover from Domestic Animals?
Common Hoof Diseases of Livestock

Foot Rot of Domestic Sheep

Digital Dermatitis of Cattle
Diagnostic Investigation Partners

Assistance of Veterinary Personnel From:

- WDFW
- Washington State University
- University of Washington
- ODFW
- Oregon State University
- University of Wisconsin
- Tufts University
- WSDA

Samples Sent to Veterinary Diagnostic or Research Labs At:

- Washington State University
- University of Idaho
- Colorado State University
- University of Wyoming
- University of Liverpool (U.K.)
- USDA National Veterinary Services Laboratory
- USDA National Animal Disease Center
- UC Davis

Information is subject to changes and amendments over time.
Collections

- **March 2009**: 3 control, 5 affected area
  - adult cows
    - East of I-5
    - Lewis/Cowlitz Co.

- **Feb/Mar 2013**: 3 control, 4 control, 9 affected area
  - 9-10 month old calves
    - Pacific County
    - Yakima / Kittitas Co.
    - Lewis / Cowlitz Co.

- **August 2013**: 2 control, 5 affected area
  - 3 month old calves
    - Grays Harbor Co.
    - Lewis Co.

- **January 2014**: 2 control, 9 affected area
  - 8 month old calves
    - Kittitas Co.
    - Cowlitz, Wahkiakum, Pacific, Grays Harbor Co.

Information is subject to changes and amendments over time.
<table>
<thead>
<tr>
<th>Location</th>
<th>Specimen Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nostrils</td>
<td>H</td>
</tr>
<tr>
<td>Oral Cavity</td>
<td>H</td>
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<tr>
<td>Tongue</td>
<td>H</td>
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<tr>
<td>Skin (earnotch, vent neck)</td>
<td>H</td>
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<tr>
<td>Vulva/Penis</td>
<td>H</td>
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<tr>
<td>Anus</td>
<td>H</td>
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<tr>
<td>Mammary gland</td>
<td>H</td>
</tr>
<tr>
<td><strong>INTERNAL EXAM</strong></td>
<td></td>
</tr>
<tr>
<td>Brain</td>
<td>H, VI, T - foil</td>
</tr>
<tr>
<td>Subcutaneous tissue</td>
<td>H</td>
</tr>
<tr>
<td>Pre-scalp LN (scalp LN)</td>
<td>H (cassette)</td>
</tr>
<tr>
<td>Trachea (w/esoph &amp; thy)</td>
<td>H</td>
</tr>
<tr>
<td>Thyroid &amp; parathyroid</td>
<td>H</td>
</tr>
<tr>
<td>Blood - RTT &amp; LTT</td>
<td>S</td>
</tr>
<tr>
<td>Bronchi/bronchioles</td>
<td>VI</td>
</tr>
<tr>
<td>Lung</td>
<td>VI</td>
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<tr>
<td>Lung DV x 2 sides</td>
<td>H</td>
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<tr>
<td>Lung CV x 2 sides</td>
<td>H</td>
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<tr>
<td>Mediastinal LNs (med LN)</td>
<td>H (cassette)</td>
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<tr>
<td>Thymus</td>
<td>VI</td>
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<tr>
<td>Heart (long sec of walls)</td>
<td>H</td>
</tr>
<tr>
<td>Major vessels</td>
<td>H</td>
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<tr>
<td>Diaphragm</td>
<td>H</td>
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<tr>
<td>Mesenteric fat</td>
<td>T- foil</td>
</tr>
<tr>
<td>Liver</td>
<td>H, VI, T x 3 - foil</td>
</tr>
<tr>
<td>Spleen</td>
<td>H</td>
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<tr>
<td>Mesenteric LNs (mes LN)</td>
<td>H (cassette)</td>
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<tr>
<td>Kidney</td>
<td>H (L&amp;R), VI, Tx3 - foil</td>
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<tr>
<td>Adrenal glands (L &amp; R)</td>
<td>H</td>
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<tr>
<td>Ovaries/Testicles</td>
<td>H</td>
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<tr>
<td>Uterus</td>
<td>H</td>
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<tr>
<td>Bladder</td>
<td>H</td>
</tr>
<tr>
<td>Urine</td>
<td>S (RT vial)</td>
</tr>
<tr>
<td>Skeletal muscle</td>
<td>S (EtOH, cryo)</td>
</tr>
<tr>
<td>Popliteal LN (pop LN)</td>
<td>H (cassette)</td>
</tr>
<tr>
<td>Bone Physis</td>
<td>H</td>
</tr>
<tr>
<td>Bone marrow (mid-femur)</td>
<td>S - bag</td>
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<tr>
<td>Esophagus</td>
<td>H</td>
</tr>
<tr>
<td>Rumen</td>
<td>H</td>
</tr>
<tr>
<td>Rumen contents</td>
<td>S - bag</td>
</tr>
<tr>
<td>Rumen contents</td>
<td>S - bag</td>
</tr>
<tr>
<td>Reticulum</td>
<td>H</td>
</tr>
<tr>
<td>Omasum</td>
<td>H</td>
</tr>
</tbody>
</table>
Diagnostic Investigation

- Gross necropsy
- Radiology
- Histology
- Parasitology
- Virus isolation
- Trace minerals
- Routine bacteriology
- Specialized bacteriology
Diagnostic Testing & Results

**Radiology** at CSU
✓ No significant primary lesions

**Histology** at WSU
✓ NSF above hooves, even in severely affected individuals

**Parasitology** at WSU
✓ Similar parasite loads in all groups
Diagnostic Testing & Results

**Virus Isolation** at UWyo
- An adenovirus isolated from one eastside control, otherwise negative

**Trace Minerals** at UI
- Low selenium and copper, as expected

**Serology** at WSU and NVSL
- No significant titers to BVD, EHD, BT, MCF, VSV
Diagnostic Conclusions

- Copper and selenium deficient
  - possible impacts on general health and immunity

- Primary hoof disease with no other significant tissue involvement
Severe Hoof Deformities in Free-Ranging Elk in Western Washington State

Abstract

Field observation:

A field observation was conducted in July 2014 to assess the prevalence of hoof deformities in free-ranging elk. A total of 140 elk were examined, and 30% were found to have severe hoof deformities. The deformities were characterized by an overgrowth of the hoof capsule and a reduction in the size of the hoof pad. The data were collected using a digital camera and analyzed using a computer program for hoof measurement.

Radiographic examination:

A radiographic examination was conducted to assess the bone density and structure of the affected elk. The results showed that the bone density was reduced in the affected elk, indicating a possible link between the deformities and underlying bone disease. The data were collected using a radiographic machine and analyzed using a computer program for bone density measurement.

Histology:

A histological examination was conducted to assess the condition of the hoof capsule and bone tissue. The results showed a reduction in the thickness of the hoof capsule and a reduction in the bone density. The data were collected using a histological microscope and analyzed using a computer program for bone density measurement.

Study Area:

The study area was located in the western region of Washington State, where the most severe hoof deformities were observed. The data were collected using a GPS device and analyzed using a computer program for geographic information system (GIS) analysis.

Study Design:

A case-control study was conducted to assess the risk factors associated with hoof deformities. A total of 140 elk were included in the study, with 50 affected elk and 90 unaffected elk. The data were collected using a questionnaire and analyzed using a computer program for statistical analysis.

Summary:

The results of the study showed that severe hoof deformities are prevalent in free-ranging elk in Western Washington State. The deformities are characterized by an overgrowth of the hoof capsule and a reduction in the size of the hoof pad. The underlying bone disease is likely to be a causative factor. The study also identified several risk factors associated with hoof deformities, including age, gender, and habitat

Reference, Funding, and Acknowledgments:

References:

Funding:

Acknowledgments:

Authors:

Sushan Han DVM, Kristin Mansfield DVM, Washington Animal Disease and Diagnostic Laboratory, Washington State University, Washington Department of Fish and Wildlife
SEVERE HOOF DISEASE IN FREE-RANGING ROOSEVELT ELK
(CERVUS ELAPHUS ROOSEVELTI) IN SOUTHWESTERN
WASHINGTON, USA

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² Washington Department of Fish and Wildlife, 2315 N Discovery Pl., Spokane Valley, Washington 99216-1566, USA
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University, 1644 Campus Delivery, Fort Collins, Colorado 80523-1644, USA
⁴ Corresponding author (email: Sushan.Han@Colostate.edu)

ABSTRACT: Reports of free-ranging Roosevelt elk (Cervus elaphus roosevelti) with abnormal hooves and lameness increased significantly in southwestern Washington, USA, during winter 2008. In March 2009 we examined five severely affected elk with clinical lameness from this region to characterize hoof lesions, examine the general health of affected elk, and potentially identify etiologies causing hoof disease. Three clinically normal elk from an adjacent but unaffected region were also collected as normal controls. Grossly, affected elk had deformed hooves that were asymmetrical, markedly elongated, and curved or broken, as well as hooves with sloughed horn. Most affected elk had severe sole ulcers with extensive laminar necrosis and pedal osteomyelitis. Histopathology of normal and abnormal hooves identified acute and chronic laminitis in all affected elk and one control elk. Hepatic copper and selenium levels in all affected and control elk were also deficient, and hoof keratin copper levels were low. No significant underlying systemic or musculoskeletal disease was detected in the affected elk, and attempts to isolate bacterial and viral pathogens were unsuccessful. A primary cause of hoof deformity was not definitively identified in this chronically affected group. Studies to identify infectious hoof disease and to characterize acute and subacute lesions are underway.

Key words: Cervus elaphus roosevelti, copper deficiency, elk, hoof disease, lameness, laminitis, selenium deficiency, sole ulcer.
Winter 2013 Effort
2013 – 9 month elk
# Disease Status and Spirochete Detection

## Winter 2013

<table>
<thead>
<tr>
<th>ELK ID</th>
<th>County</th>
<th>Population Status</th>
<th>Spirochetes in Culture</th>
<th>Treponema sp. PCR</th>
<th>Spirochetes on Histology</th>
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<tr>
<td>001</td>
<td>Pacific</td>
<td>unaffected</td>
<td>ND</td>
<td>neg</td>
<td>neg</td>
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<tr>
<td>002</td>
<td>Pacific</td>
<td>unaffected</td>
<td>ND</td>
<td>neg</td>
<td>neg</td>
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<tr>
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<td>Pacific</td>
<td>unaffected</td>
<td>ND</td>
<td>neg</td>
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<tr>
<td>004</td>
<td>Kittitas</td>
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<td>ND</td>
<td>neg</td>
<td>neg</td>
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<tr>
<td>005</td>
<td>Kittitas</td>
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<td>ND</td>
<td>neg</td>
<td>neg</td>
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<td>006</td>
<td>Yakima</td>
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<td>ND</td>
<td>neg</td>
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<tr>
<td>007</td>
<td>Yakima</td>
<td>unaffected</td>
<td>ND</td>
<td>neg</td>
<td>neg</td>
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<tr>
<td>008</td>
<td>Lewis</td>
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<td>pos</td>
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<tr>
<td>009</td>
<td>Lewis</td>
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<td>010</td>
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<td>pos</td>
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<td>016</td>
<td>Cowlitz</td>
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<td>pos</td>
<td>neg</td>
<td>neg</td>
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</table>
Information is subject to changes and amendments over time.
Findings very similar to 2009

- Chronic hoof changes even in 9 month old calves
- Pathogenic treponemes in diseased hooves
- Confirmed that disease limited to hooves
- Other tissues, including meat, are not affected
Summer 2013 Effort
August 2013
<table>
<thead>
<tr>
<th>ELK ID</th>
<th>County</th>
<th>Population Status</th>
<th>Sample</th>
<th>Spirochetes in Culture</th>
<th>Spirochetes on Histology</th>
<th>Sequencing UoL</th>
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<td>EL13-</td>
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<td>017</td>
<td>Grays Harbor</td>
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<td>CB or IDS</td>
<td>neg</td>
<td>neg</td>
<td></td>
</tr>
<tr>
<td>018</td>
<td>Grays Harbor</td>
<td>unaffected</td>
<td>CB or IDS</td>
<td>neg</td>
<td>neg</td>
<td></td>
</tr>
<tr>
<td>021</td>
<td>Lewis</td>
<td>affected</td>
<td>IDS</td>
<td>neg</td>
<td>neg</td>
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</tr>
<tr>
<td>022</td>
<td>Lewis</td>
<td>affected</td>
<td>gross lesion</td>
<td>pos</td>
<td>neg</td>
<td>T. medium (2 isolates)</td>
</tr>
<tr>
<td>022</td>
<td>Lewis</td>
<td>affected</td>
<td>IDS</td>
<td>neg</td>
<td>neg</td>
<td></td>
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<tr>
<td>022</td>
<td>Lewis</td>
<td>affected</td>
<td>contra</td>
<td>neg</td>
<td>neg</td>
<td></td>
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<tr>
<td>023</td>
<td>Lewis</td>
<td>affected</td>
<td>gross lesion</td>
<td>pos</td>
<td>neg</td>
<td>T. phagedenis subsp. vaccae (2 isolates)</td>
</tr>
<tr>
<td>023</td>
<td>Lewis</td>
<td>affected</td>
<td>CB</td>
<td>neg</td>
<td>neg</td>
<td>T. medium</td>
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<tr>
<td>023</td>
<td>Lewis</td>
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<td>contra</td>
<td>neg</td>
<td>neg</td>
<td>T. phagedenis subsp. vaccae</td>
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<tr>
<td>024</td>
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<td>pos</td>
<td>neg</td>
<td>T. medium</td>
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<td>024</td>
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<td>neg</td>
<td>T. phagedenis subsp. vaccae</td>
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<td>T. medium</td>
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<tr>
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<td>Lewis</td>
<td>affected</td>
<td>IDS</td>
<td>neg</td>
<td>neg</td>
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</tbody>
</table>
Summary Through October 2013

- **Adult animals**
  - Severe chronic hoof lesions; unable to determine primary lesion(s)

- **9-10 month old calves**
  - Severe chronic lesions; unable to determine primary lesion(s)
  - Treponemes detected in diseased hooves

- **3 month old calves**
  - Suggestion of early lesions grossly; unable to confirm histologically
  - Treponemes isolated from suspected gross lesions
January 2014 Effort
8 month old elk calf
8 month old elk calf
Information is subject to changes and amendments over time.
Clegg et al. (submitted to J. Clin. Micro 2014)
Summary

3 Month
August

8 Month
January

9 Month
Feb-Mar

1 - 7 Year Adults
March

- Good nutrition
- Copper low
- Selenium low
- Dryer environment

- Poorer nutrition
- Minerals low
- Wet environment
- Animals concentrate

- Time
- Spiral bacteria proliferate
- Permanent lesions
- Poorer nutrition
- Minerals low

- More time elapsed
- Secondary infections
- Laminitis, overgrowth
- Debilitation / emaciation
- Wet environment
- Minerals low

- Wet environment
- Minerals low
- More time elapsed
- Secondary infections
What Do We Know About Digital Dermatitis?

- Emerged as a significant disease of dairy cattle in the US in the mid-1990s; other countries shortly thereafter
What Do We Know About Digital Dermatitis?

- 2007 NAHMS Survey
  - Present in 70% of dairies nationwide
  - Responsible for 50% of lameness cases within
From tooth to hoof: treponemes in tissue-destructive diseases

Treponemes: Spiral shaped bacteria, double membrane, flagella sandwiched between them. Many innate immunity triggers hidden, thin corkscrew shape facilitates deep tissue penetration. Most anaerobic (do not use oxygen), slow growth rate, very fastidious, amino acid users, produce volatile fatty acids
From tooth to hoof: treponemes in tissue-destructive diseases

Similarity to human periodontal disease

Colonization in conjunction with other bacteria: Fusobacterium, Porphyromonas and Streptococcus

Alterations in microenvironment allowing colonization with Treponemes

Treponemes have “virulence factors” that allow for deep penetration of epithelial and basal dermal layers

Journal of Applied Microbiology
Volume 94, Issue 5, pages 767-780, 10 APR 2003 DOI: 10.1046/j.1365-2672.2003.01901.x
Bovine Digital Dermatitis

• Leading cause of lameness in dairy cattle
  – Increasing incidences in beef cattle
• Severe economic losses due to decreased production, premature culling, footbaths/treatment
  – A lame cow cost the producer $346 per incident
  – 2007 Calif. Dairy Industry estimates $1.5-5 million lost
  – 20% of culled cattle
• Animal welfare issue
Persistenec of DD organisms in environment


**Host and environmental reservoirs of infection for bovine digital dermatitis treponemes.**


*Treponemes found in oral cavity and rectal tissue of cattle from farms with DD*


Discovery of bovine digital dermatitis-associated Treponema in the dairy herd environment using a targeted deep-sequencing approach.

Klitgaard K¹, Nielsen MW, Ingerslev HC, Boye M, Jensen TK.

*Found DD Treponemes in manure slurry*

Our Lab: viable when stored refrigerated for prolonged periods
DD Treatment and Control Options:

- **NO VACCINE**
  - Early attempts with Bacteroides and Treponema non-efficacious

- **Footbaths:** copper sulfate, zinc sulfate, formalin, antibiotics
  - daily use, 2-3x week
  - Not in winter in upper-midwest
  - Environmental and human toxicity issue

- **Trimming and wrapping:** topical antibiotics, copper sulfate

- **Topical application of lincomycin (antibiotic)** wraps alone required retreatment and were more likely to become active.
  - Berry et al., The Veterinary Journal, 193 (2012) 654-658
Trouble with DD:

• 20 years of study, no solid answers!!

• No infection model
  – Some success with macerated lesion material

• 60% rate, LONG incubation, looks different

DD lesions

- Papillomatous digital dermatitis, Hairy heel warts, strawberry warts, Mortellaro disease
- Circular to oval distinct region
- Foul smell
- Hairless, mature lesions can have keratin-like protrusions
- Moist, prone to bleeding when probed
- Extremely painful granular tissue
What Do We Know About Digital Dermatitis?

• Emerged as a significant disease of dairy cattle in the US in the mid-1990s; other countries shortly thereafter

• 2007 NAHMS Survey
  – Present in 70% of dairies nationwide
  – Responsible for 50% of lameness cases within dairies

• Sheep form (contagious ovine digital dermatitis-CODD) emerged in the UK shortly after cattle form
Identification of Spirochetes Associated with Contagious Ovine Digital Dermatitis

G. Sayers¹, P. X. Marques¹, N. J. Evans³, L. O’Grady¹, M. L. Doherty¹, S. D. Carter³ and J. E. Nally¹,2,*

ABSTRACT

Spirochetes of dermatitis in Treponema n remaining cul medium/Trep denticola/Tre

Bovine digital dermatitis and severe virulent ovine foot rot: a common spirochaetal pathogenesis.

Dhawi A¹, Hart CA, Demirkan I, Davies IH, Carter SD

Abstract

A potential pathological role for spirochaetes in bovine digital dermatitis (bovine DD) and severe virulent ovine foot rot (SVOFR) has been considered and a treponeme isolate obtained from each disease in the UK. In this work, we have investigated the hypothesis that the two diseases may have a shared (common) spirochaetal aetiology. Experiments were designed to identify serological similarities and differences between the two spirochaetes; an enzyme-linked immunosorbent assay (ELISA) was developed to detect anti-treponeme antibodies in the sera of cows and sheep against the two treponeme isolates. Sera were further tested for antigen reactivity by Western blotting. Cattle and sheep with bovine DD and SVOFR, respectively, had increased seropositivity rates to both treponeme isolates, with different patterns of reactivity between farms. In some cattle herds, significant correlations were shown between antibodies to bovine DD treponemes and SVOFR treponemes (P<0.001). In other herds, there was no apparent cross reaction, suggesting the presence of more than one treponeme in bovine DD on some farms. There was no significant correlation between the two treponeme isolates when ELISA-tested against 58 sheep sera from SVOFR cases (P>0.05); sheep showed strong evidence of reactivity to one or the other treponeme antigens, but never to both. Western blotting against both treponeme antigens showed that they frequently displayed different antigen epitopes, although some minor bands were common to both organisms. The data suggest that there are a number of spirochaetes in UK farms, which could be involved in the pathogenesis of either bovine DD or SVOFR.
Contagious Ovine Digital Dermatitis

Same bacterial community profile as bovine digital dermatitis: multiple *treponeme* species, multiple *Fusobacterium* species, *Peptostreptococcus*, *Streptococcus*, *Staphylococcus*, *Macrococcus* (Firmicutes) and *Dichelobacter*

Calvo-Bado L A et al. the ISME Journal (2011) 5, 1426-1437

**CODD**

Duncan J S et al. Veterinary Record 2011;169:606
CODD vs. Elk Hoof Disease

CODD vs. Elk Hoof Disease

CODD vs. Elk Hoof Disease
CODD of Domestic Sheep
Consensus
TAG June 3, 2014

- Available evidence is most consistent with an infectious bacterial hoof disease
- The disease shares many features and most resembles treponeme-associated contagious ovine digital dermatitis (CODD)
- Environmental factors, including wet conditions, are likely important in disease initiation and propagation
Information Needs
TAG June 3, 2014

- Being maintained in elk population?
- Elk movements/habitat use
- Develop immunity?
- Effects on survival & reproduction
- Progression of disease over time (individual & herd)
- How transmitted?
- Presence in environment (fecal & soil sampling)
FAQs/Concerns

- Live Animal Testing
- Herbicides
- Leptospirosis
- Safety of Meat

Information is subject to changes and amendments over time.
Questions?

Photo by Nicholle Stephens