British Columbia
Boreal Caribou Health Program Update

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REMB Research Workshop, November 29, 2016
BCHRP Background

• Created fall, 2013 → response to higher than expected mortality of collared and uncollared boreal caribou observed in NE BC → early spring through summer 2013

• Mortalities occurred during and following winter with high snow pack/significant ice crusting → ~ 2/3 all morts occurred May - July 2013

• Many died of undetermined causes → ~ half unexplained by predation

Photos: B. and D. Culling
Diversified Environmental Services
Fort St. John, B.C.
Objectives BCHRP

- Investigate role of health in 2013 mortalities
- Establish comprehensive health baselines across 6 ranges → identify at risk herds
- ↑ understanding potential role “health” as a driver of population dynamics
- Provide health related recomm. for boreal caribou management in NE BC

Photo: B. and D. Culling
Diversified Environmental Services
Fort St. John, B.C.
A Cumulative Effects Approach

• Health = more than absence of “disease”

• Reflects cumulative effects natural and anthropogenic challenges acting on individuals and populations

• Health = an index of resilience or vulnerability

• Emphasis on integration with existing research/management programs

Endogenous and Exogenous Health Determinants
Health Assessment Model

Key Pathogens

• Alphaherpesvirus
• Pestiviruses
• *Brucella suis* biovar 4
• *Erysipelothrix rhusiopathiae*
• *Mycobacterium avium spp. paratuberculosis*
• *Yersinia pseudotuberculosis*
• Misc. bacterial pathogens (mortalities)
• Gastrointestinal, muscle, lung and neurotropic parasites
• Giant liver fluke (*Fascioloides magna*)
• *Toxoplasma gondii*
• *Neospora caninum*
• *Besnoitia tarandi*
• Ectoparasites (ticks, warbles, bots)
• Blood borne pathogens and parasites

Other Health Indicators

• Serum biochemistry (capture effects and general interpretation)
• Complete blood counts (CBC)
• Hair cortisol concentration (stress)
• Haptoglobin
• Serum Amyloid A (SAA)
• Body condition and fat (live capture)
• Marrow fat content (mortalities)
• Trace mineral status and toxicology
• Age
• Pregnancy status
• Adult survival
• Landscape attributes

VALIDATE HEALTH BIOMARKERS

EVALUATE LINKAGES

Online
Baseline Health Status of Boreal Caribou in NE BC 2012/2013

• Brief review of herd health testing results → serology, parasitology, health biomarkers

• Comparison of baseline status across herds
Sample Size

- 164 Caribou (Dec. 2012-April 2013)
- Calendar (CAL)
  - 27 caribou
- Maxhamish (MAX)
  - 25 caribou
- Snake-Sahtaneh (SNK)
  - 56 caribou
- Chinchanga (CHIN)
  - 37 caribou
- Prophet (PPH)
  - 9 caribou
- Parker (PRK)
  - 7 caribou
Analysis

- Compared means and medians among herds using Anova or Kruskall-Wallis tests.

- Variables were grouped into 4 quartiles and ordered logistic regression was used if assumptions of tests were violated.

- Ordered logistic regression was used for categorical variables.

- Significance $P \leq 0.05$
## Prevalence Gastrointestinal Parasites

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<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Strongylid eggs</td>
<td>0</td>
<td>14%</td>
<td>0</td>
<td>19%</td>
<td>0</td>
<td>0</td>
<td>12% (4-29%)</td>
</tr>
<tr>
<td>Moniezia (Tape) eggs</td>
<td>33%</td>
<td>0</td>
<td>0</td>
<td>11%</td>
<td>0</td>
<td>0</td>
<td>8% (2-22%)</td>
</tr>
<tr>
<td>Trichostrongylo eggs</td>
<td>0</td>
<td>0 (n=8)</td>
<td>0 (n=3)</td>
<td>0</td>
<td>0 (n=3)</td>
<td>0 (n=3)</td>
<td>0 (0-10%)</td>
</tr>
<tr>
<td>Fluke eggs</td>
<td>0 (n=27)</td>
<td>0 (n=36)</td>
<td>0 (n=24)</td>
<td>0 (n=56)</td>
<td>0 (n=9)</td>
<td>0 (n=7)</td>
<td>0 (0-2%)</td>
</tr>
</tbody>
</table>

Similar (or lower) than prevalence and intensity reported in caribou elsewhere
Overall, prevalence of dorsal spined larvae was 36% (95% CI, 28-43.7; n=157), but intensity of infection was low.

Prevalence and mean intensity of dorsal spined larvae between herds did not differ.

Similar to prevalence and intensity reported elsewhere.
Hair Loss (Winter Tick)

Overall:
- 23% (95% CI, 16-30) - no hair loss
- 34% (95% CI, 27-43) - mild hair loss
- 30% (95% CI, 22-38) - moderate hair loss
- 13% (95% CI, 8-20) - severe to extreme hair loss

Hair loss did not differ between herds.
## Seroprevalence

<table>
<thead>
<tr>
<th>Antibody</th>
<th>CAL (n=27)</th>
<th>CHIN (n=36)</th>
<th>MAX (n=24)</th>
<th>SNK (n=56)</th>
<th>PPH (n=7)</th>
<th>PRK (n=9)</th>
<th>Overall (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Brucella suis</em></td>
<td>0 (n=27)</td>
<td>0 (n=36)</td>
<td>0 (n=24)</td>
<td>0 (n=56)</td>
<td>0 (n=7)</td>
<td>0 (n=9)</td>
<td>0 (0-2) (n=162)</td>
</tr>
<tr>
<td><em>Toxoplasma gondii</em></td>
<td>0 (n=26)</td>
<td>0 (n=37)</td>
<td>0 (n=24)</td>
<td>0 (n=56)</td>
<td>0 (n=7)</td>
<td>0 (n=9)</td>
<td>0 (0-10) (n=36)</td>
</tr>
<tr>
<td><em>Neospora caninum</em></td>
<td>1 (n=20)</td>
<td>1 (n=34)</td>
<td>0 (n=24)</td>
<td>0 (n=52)</td>
<td>0 (n=8)</td>
<td>1 (n=6)</td>
<td>2% (0.4-6) (n=147)</td>
</tr>
</tbody>
</table>
**Mycobacterium avium ssp. paratuberculosis** (Johne’s Disease)

<table>
<thead>
<tr>
<th></th>
<th>CAL</th>
<th>CHIN</th>
<th>MAX</th>
<th>SNK</th>
<th>PPH</th>
<th>PRK</th>
<th>Overall (95% CI)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>0 (n=3)</td>
<td>0 (n=8)</td>
<td>0 (n=3)</td>
<td>0 (n=19)</td>
<td>0 (n=3)</td>
<td></td>
<td>0 (0-10) (n=36)</td>
</tr>
</tbody>
</table>
Overall seroprevalence was 60% (95% CI, 51-68, n=144).

**CHIN** had higher seroprevalence than **CAL** and **SNK**.
Overall seroprevalence was **21%** (95% CI; 15-28, n=164).

Seroprevalence did not differ between herds.
Alphaherpesvirus (CVHV-2)

Seroprevalence

CAL CHIN MAX

Overall seroprevalence was 62% (95% CI; 54-70, n=162).

Seroprevalence did not differ between herds.

Higher than seroprevalence reported elsewhere
• **Accuracy of assay?** Overall seroprevalence including suspect results was 32% (95% CI; 23-40, n=161) → retesting with new assay

• Seroprevalence did not differ between herds.
Trace Nutrients

**Manganese**

Distribution:

- **Manganese** – Higher in **CAL** than **MAX** and **SNK**

**Iron**

Distribution:

- **Iron** – Higher in **CAL** than **MAX** and **SNK**

**Zinc**

Distribution:

- **Zinc** – Higher in **CAL**, **CHIN**, and **SNAKE** than **MAX**
Trace Nutrients

**Selenium**
- Distribution: Selenium – Higher in CHIN than SNK

**Cobalt**
- Mean Values: Cobalt – Higher in CHIN than CAL, MAX, and SNK
- Copper – Higher in CHIN than CAL, MAX, and SNK
Non-Specific Health Biomarkers

Haptoglobin

Hair Cortisol

**g/L**

Did not differ between herds 2012/2013*.
Serum Amyloid A

- CAL: n = 27
- CHIN: n = 37
- MAX: n = 24
- SNK: n = 55

Frequency of Serum Amyloid A level.
In general, CAL had higher levels of SAA than CHIN, MAX, and SNK.
Mean globulin higher in CHIN than MAX and SNAKE.

Mean total protein higher in CHIN than MAX and SNK.
Ongoing Work

• Investigate caribou health temporally and spatially on a landscape level and determine if caribou health is associated with a variety of biotic and abiotic factors (Objective 2).

• Evaluate whether hair cortisol concentration, haptoglobin, and serum amyloid A can be used as physiological bio-indicators of caribou health (Objective 3).
Review of Some Key Findings
General Conclusions Baseline Status

Suggests:

- *Brucella suis* biovar 4 (notable good thing)
- Gastrointestinal parasites
- Johne’s disease (MAP)
- *Toxoplasma gondii*
- Blood borne pathogens (e.g. *Setaria, Babesia*)
- *Yersinia pseudotuberculosis*

- Unlikely to be limiting for boreal caribou in NE BC at present time

- However, evidence of pathogens and other health determinants of concern → distinct potential to affect individual fitness or population performance
Erysipelothrix rhusiopathiae

- PCR + tissue culture identified this **bacterial pathogen** in tissues of 5 caribou found dead in 2013 (4 collared and 1 uncollared) → **including “killed by wolves”**

- Represented ~ 63% of all caribou dying in high mortality period from which usable tissue obtained

- Known cause of chronic disease and sub acute to per acute death, probable outbreaks in other free-ranging ungulates

- **First report in North American caribou?**
March 31, 2013: Uncollared male alive/moribund → examined 2 d later → on snow, veg. disturbed, thrashing → ~intact + no indication predator attack

E. rhusiopathiae cultured: multiple tissues → ~ pure growth selective media/ few others on non-selective

Gross + histopathology: severe (~ fatal) aspiration pneumonia and poor condition → some internal fat reserves, 61% femur marrow fat

Trace nutrients + toxicology → all "normal" ranges

Similar presentation to Erysipelothrix in other species

Evidence likely cause death in this individual

Role for Erysipelothrix in broader mortality event → "tip of ice berg"?

Photo: D. and B. Culling
Baseline Serology 2013

- ELISA developed UCVM

- 21% of all caribou (n=159) captured in winter 2012/13 seropositive → previously exposed

- Exposure relatively common?

- Suggests some exposed + recover(ed)
Changing Pattern Deaths 2013-2015

- Only n=1 unusual “drop dead” mortality 2014-2015
- Survival rate increase 2013 (0.72), 2014 (0.86), 2015 (0.88)
Exposure significantly more likely to occur 2012-2016 vs historical samples (2003-2010) (OR=2.64, 95% CI 1.08-6.47, P = 0.034).
## Serology: Recaptures

<table>
<thead>
<tr>
<th>Caribou ID</th>
<th>Year of First Capture</th>
<th>Sero Status at First Capture</th>
<th>Year of Recapture</th>
<th>Sero Status at Recapture</th>
</tr>
</thead>
<tbody>
<tr>
<td>SK005</td>
<td>2013</td>
<td>Negative</td>
<td>2014</td>
<td>Negative</td>
</tr>
<tr>
<td>SK007</td>
<td>2013</td>
<td>High Positive</td>
<td>2015</td>
<td>Low Positive</td>
</tr>
<tr>
<td>SK009</td>
<td>2013</td>
<td>Negative</td>
<td>2015</td>
<td>Negative</td>
</tr>
<tr>
<td>SK014</td>
<td>2013</td>
<td>Negative</td>
<td>2015</td>
<td>Positive</td>
</tr>
<tr>
<td>SK016</td>
<td>2013</td>
<td>Negative</td>
<td>2015</td>
<td>Negative</td>
</tr>
<tr>
<td>SK020</td>
<td>2013</td>
<td>Negative</td>
<td>2015</td>
<td>Negative</td>
</tr>
<tr>
<td>SK033</td>
<td>2013</td>
<td>Positive</td>
<td>2015</td>
<td>Positive</td>
</tr>
<tr>
<td>SK036</td>
<td>2013</td>
<td>Negative</td>
<td>2015</td>
<td>Negative</td>
</tr>
<tr>
<td>SK079</td>
<td>2013</td>
<td>Negative</td>
<td>2015</td>
<td>Positive</td>
</tr>
<tr>
<td>SK097</td>
<td>2013</td>
<td>Negative</td>
<td>2015</td>
<td>Positive</td>
</tr>
<tr>
<td>SK110</td>
<td>2013</td>
<td>Negative</td>
<td>2015</td>
<td>Positive</td>
</tr>
<tr>
<td>SK126</td>
<td>2013</td>
<td>Negative</td>
<td>2015</td>
<td>Negative</td>
</tr>
<tr>
<td>SK136</td>
<td>2013</td>
<td>Negative</td>
<td>2015</td>
<td>Negative</td>
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<tr>
<td>SK161</td>
<td>2013</td>
<td>Negative</td>
<td>2015</td>
<td>Negative</td>
</tr>
<tr>
<td>SK203</td>
<td>2009</td>
<td>Negative</td>
<td>2014</td>
<td>Negative</td>
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</tbody>
</table>

- Evidence that serostatus maintained for at least 2 years (or repeated exposure)
- Evidence of seroconversion sometime after first capture
Serology: Mortalities

- Success using carcass fluids/heart blood to detect serostatus of caribou at death.

- Identified "High seropositives" in culture/PCR + dead caribou previously seronegative → exposure between capture and death → supports relatively chronic disease process.

- "Seronegatives" via carcass fluids/heart blood also recorded among culture/PCR + morts → supports acute/peracute disease process.

- Also fits known patterns *Erysip* in other ungulates.
• A common Erysip “strain” in mortalities would suggest a common source (possible outbreak or novel introduction) → isolates sequenced (T. Forde, UCVM)

• Evidence multiple “strains” may occur in individual caribou and among different caribou

• Some may be shared (e.g. between mortalities occurring in the same region) others not → more likely “endemic” pathogen” → also supported by historical serology

• NB: cautious interpretation necessary → other plausible explanations → e.g. methods (recovery live difficult, PCR inhibitors, all isolates not seq), virulent vs avirulent strains
## % Marrow Fat

<table>
<thead>
<tr>
<th>ID</th>
<th>Bone</th>
<th>% Marrow Fat</th>
<th>Death*</th>
<th>Erysip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncoll545M</td>
<td>femur</td>
<td>60.6</td>
<td>April, 2013</td>
<td>+</td>
</tr>
<tr>
<td>SK069</td>
<td>femur</td>
<td>79.8</td>
<td>May, 2013</td>
<td>+</td>
</tr>
<tr>
<td>SK075</td>
<td>femur</td>
<td>9.6</td>
<td>July, 2013</td>
<td>-*</td>
</tr>
<tr>
<td>SK106</td>
<td>femur</td>
<td>8.8</td>
<td>July, 2013</td>
<td>+</td>
</tr>
<tr>
<td>SK067</td>
<td>femur</td>
<td>82.9</td>
<td>Feb, 2014</td>
<td>-</td>
</tr>
<tr>
<td>SK018</td>
<td>femur</td>
<td>84.0</td>
<td>April, 2014</td>
<td>-</td>
</tr>
<tr>
<td>SK154</td>
<td>jaw</td>
<td>69.8</td>
<td>April, 2014</td>
<td>-</td>
</tr>
<tr>
<td>BC1015</td>
<td>femur</td>
<td>86.9</td>
<td>Feb, 2014</td>
<td>+</td>
</tr>
<tr>
<td>SK130</td>
<td>rad/ulna</td>
<td>88.0</td>
<td>April, 2014</td>
<td>-</td>
</tr>
<tr>
<td>SK037</td>
<td>rad/ulna</td>
<td>89.0</td>
<td>April, 2014</td>
<td>-</td>
</tr>
<tr>
<td>SK207</td>
<td>femur</td>
<td>84.0</td>
<td>Feb, 2015</td>
<td>-</td>
</tr>
</tbody>
</table>
Ongoing Work and Needs

• Track antibody production in captive reindeer vaccinated with commercial *Erysipelothrix* vaccine (0, 4, 8, 12 weeks +)

• ACC approval granted October, 2016

Objectives:

• Enhance understanding timing and duration of antibody production in *Rangifer*

• Refine ELISA cutoff values *(Neg vs. Low +)*

• Foundation for challenge trials (using archived strains from BC and AB caribou) → gold standard to clearly establish causal relationship
Dermacentor albipictus

- Winter ticks + associated hair loss/breakage recorded caribou captured 2013, 2014, 2015
- Relatively recent finding in caribou from BC → more cases + worse pathology last ~ 5-8 yrs (D. Culling pers comm)
- Some winter tick infested in poor condition → like moose, → may have potential to adversely affect survival
- Potential role in pathogen transmission ?
- Related to climate or moose population ?

Prevalence hair loss in live captured BC boreal caribou in winter 2012/13
<table>
<thead>
<tr>
<th>Hair Loss Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>No hair loss or breakage</td>
</tr>
<tr>
<td>Mild</td>
<td>Few small - medium sized patches broken hair or loss</td>
</tr>
<tr>
<td>Moderate</td>
<td>Several or large patches broken hair or loss – no exposed skin</td>
</tr>
<tr>
<td>Severe</td>
<td>Several or large patches broken hair or loss – small area exposed skin</td>
</tr>
<tr>
<td>Extreme</td>
<td>Several or large patches broken hair or loss – large or multiple areas exposed skin</td>
</tr>
</tbody>
</table>

- Severe to Extreme ~ 12 % of affected overall (2013) range approx. 0 – 26% by herd
- Hide digests: evidence high burdens (even if little hair loss) → average 5 ticks/cm² hide (range 0-14/cm²) vs moose (~1-2/cm²)
SEVERE
Winter Tick - Needs

- If we are going to the trouble and $ of collaring + investigating morts → should be sampling extensively/ considering health more broadly
- Have developed standardized health assessment and sample collection protocols → live capture and mortality site
- Encourage integration of health assessment and sample collection following BCHRP protocols in other jurisdictions → also within larger SCEK program (calves, moose etc.)
- New need to add/develop approach for winter tick
- What about bulls, juveniles, calves?
- Need to enhance land-user/stakeholder involvement in health program → awareness and direct participation (surveillance)
Other Important Findings

• Blood (live captures) and tissue (liver): suggest multiple trace nutrient deficiencies may occur in boreal caribou from NE BC → notable Cu, Se, Zn → herd differences in some but similar low values across herds in others

• Herd level differences in some health biomarkers [e.g. SAA, haptoglobin, and hair cortisol concentration] identified (2012/2013 through 2014/2015)

• Identification other pathogens of concern (e.g. *Neospora caninum*)
Persistent Infection

Infected Calf Matures and Breeds

Canid Definitive Host

Eats

Oocysts in Feces

Ingested by Pregnant

Abortion

Live Infected (+/- Weak)

Trans Placental Transmission Infects Fetus

Uninfected

Abortion
Moving Forward in NE BC

- In NE BC → continued longitudinal health monitoring strongly recommended

- Maintain sample collection from live captures and consideration of health in mortality site monitoring

- However, we can now simplify health monitoring/testing in live animals → key pathogens (*Erysipelothrix*, *Neospora*, *winter tick*)

- +/- others based on in-depth analysis → e.g. *Besnoitia*, stress or immune biomarkers ?

- More attention must be paid to nutrition

- We need to support research into emerging diagnostic techniques → end product: further simplification → e.g. proteomics and metagenomics
Apply Model for Understanding Caribou Health Elsewhere

Comparative caribou health assessments needed

Using standardized health sampling and testing

Photo: Rob Buchanan, Parks Canada
Needs

• Urgent need to evaluate and compare boreal caribou health at regional level → valuable insight into patterns, key differences, where to focus

• In context BCHRP, immediate focus should be NWT and AB

• Ongoing boreal caribou programs in both regions → archived biological samples and continuing collections → collaborative Erysipelothrix study may be a good place to start

• Targeted studies of specific pathogens in sympatric species also highly recommended in NE BC and elsewhere (esp. other ungulates, canids)
Standardized Sampling

• Blood (1 x 35 cc syringe, 19G, 1.5" needle) → Serum (3 x 10 ml SST tubes) and Whole Blood (1 X 10 ml EDTA tube → 4 slides, buffy coat, plasma)

• Fecal sample

• Hair sample (plucked top shoulder → coin envelope full)

• Skin Biopsy (6mm, ear-tag punch)

• FTA card (new recommendation)

• Mortalities: rapid response/ sample extensively

Details/Instructions Contact: Dr. B. Macbeth
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OR
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Mountain Caribou Health

Ongoing collaborations:
• Unusual “drop dead” mortalities
• Erysipelothrix
• Winter tick
• Probable trace nutrient deficiencies
Mountain/ Boreal Caribou Health

Assessment of key caribou pathogens in sympatric ungulates

Erysipelothrix rhusiopathiae, Neospora caninum

Alberta Government

New 2016

fri

foothills Research Institute
Mountain/ Boreal Caribou Health

• BCHRP caribou health model (sampling and testing) now being considered in other research/management programs elsewhere

• Approach modified and being applied in other ungulates (moose and bighorn sheep) and carnivores (grizzly bears)
Other Needs

• Some pathogens identified here may have important implications for recently proposed woodland caribou management activities.

• Clear lessons from this study (and maternity penning initiatives) for “big fences” or captive breeding programs.

• Health **MUST** be considered as an integral part of these programs.
Acknowledgements