Cost-benefit analysis for reducing bovine brucellosis prevalence in southern GYA elk

Mandy Kauffman¹, Kari Boroff¹, Dannele Peck¹, Brandon Scurlock², Walt Cook¹, Jim Logan³, Tim Robinson¹, Brant Schumaker¹*

¹University of Wyoming, USA, ²Wyoming Game and Fish Department, USA, ³Wyoming Livestock Board, USA
Background: Management

• Despite ongoing management:
  – Recent cases in cattle/bison traced back to elk
  – Affected area expanding

• Limited $$ available for management
  – No clear scientifically sound method
  – Need for economic evaluation of available management strategies
    • Evaluation of elk prevalence reduction strategies still needed
      – Focus of this study
Background – Bovine brucellosis

• Recent cases in cattle/domestic bison traced back to area elk
• Management strategies
  1. Maintain cattle/elk separation
     - hazing elk
     - fencing haystacks
     - elk feedgrounds
  2. ↓ likelihood of exposed cattle experiencing abortions (RB51)
  3. ↓ disease prevalence in elk
     - T&S
     - low density feeding
     - elk vaccination (S19)
Background – Previous RAs

• Limited elk data
• Relevant findings (elk → cattle):
  – High risk:
    • Abortion risk period → low elevation private ranchlands
    • Parturition risk period → public and private grazing allotments
Overall Project

• Complete cost/benefit analysis for management strategies aimed at reducing brucellosis prevalence in southern GYA elk
  1. Understand how current elk seroprevalence translates to risk to cattle at coarse scale
  2. Model how various management strategies might decrease this risk
  3. Identify costs associated with these strategies
  4. Combine 1, 2 & 3 to understand cost-effectiveness of each strategy
Study Area

• Three counties:
  – Lincoln, Sublette, Sweetwater
  – ~121,000 cattle, ~500 producers
• Site of previous brucellosis cases in cattle
• Portions of 17 EHUs
• 15/23 elk feedgrounds
Methods - Data Collection

• Limited elk collar data → mail survey
• Collect information on:
  – Cattle numbers/locations
  – Elk numbers/locations relative to cattle
• Distributed via National Agricultural Statistics Service (NASS)
  – Early February 2012
  – 486 surveys:
    • 2 options for participation
    • Privacy → scale of modeling
Methods - Survey Data

• 89 responses (50 usable)

• Assign cattle to locations on landscape
  – Winter/spring (Jan-early May)

• Use elk presence/pseudo-absence to estimate resource selection functions (RSFs) for elk relative to cattle
  – Land cover (NLCD)
  – Elevation
    • Slope
    • Aspect
  – Winter precipitation
  – Proximity to:
    • Wolf/human predation pressure
    • Roads
    • Feedgrounds
    • Forest cover
Risk Model

Take home message: risk of elk-cattle overlap higher if:
- ↓ road density
- ↑ cost-distance to feedground
- near feedgrounds
- ↓ elevation

Final Model Results.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>23.97**</td>
<td>9.82</td>
</tr>
<tr>
<td>roaddens</td>
<td>-2.17**</td>
<td>0.93</td>
</tr>
<tr>
<td>feedcostdist</td>
<td>1.39e-04**</td>
<td>5.69e-05</td>
</tr>
<tr>
<td>feuddist</td>
<td>-1.78e-04**</td>
<td>8.07e-05</td>
</tr>
<tr>
<td>elev</td>
<td>-1.06e-02**</td>
<td>4.27e-03</td>
</tr>
</tbody>
</table>

** indicates significance at $\alpha=0.05$
• RSF “risk surface” → where elk-cattle overlap likely
• More elk → bigger problem
• So how many elk?
  – Use seasonal range, EHU populations, and expert opinion to determine
• Current Risk:
  – # years until cattle cases expected
    • # elk overlapping with cattle
    • % female
    • % pregnant
    • seroprevalence
    • probability of abortion (live birth)
  – Compare to reported cases

• Model management strategies
  – Then recalculate risk
    • Benefit
  – Compare to costs
  – Focus on Pinedale EHU
### Management Strategies

(2010 dollars)

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Assumptions</th>
<th>Annual Cost</th>
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<tbody>
<tr>
<td>Test and Slaughter</td>
<td>All 3 feedgrounds ↓ females ↓ population ↓ seroprevalence</td>
<td>$409,111</td>
</tr>
<tr>
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<td>All 3 feedgrounds ↓ seroprevalence</td>
<td>$6,807</td>
</tr>
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<td>Fall and Muddy Creek ↓ seroprevalence</td>
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- Model potential ranges of effectiveness:
  - ↓ by 1%  → 17%
  - ↓ by 5%  → 13%
  - ↓ by 10% → 8%
  - ↓ to 5%
Cost of an Outbreak

- Estimated at $146,299 (Wilson, 2011)
- All costs in 2010 dollars
- Index herd: 400 bred cattle (368 successfully calve), 80 replacement heifers, 280 yearlings, and 23 bulls
- Castrating/spaying non-replacement yearlings
- Twelve-month quarantine
- Three whole-herd tests
- Does not consider changes to markets
Cost-Benefit Analysis

• Combine risk output with cost information
  – Cost of outbreak estimated at $146,299
  – Expected benefit (EB) = \( \frac{\$146,299}{\text{median years to cattle case (current)}} - \frac{\$146,299}{\text{median years to cattle case (strategy)}} \)
  – Net benefit = EB – expected annual cost of given strategy

• Compare net benefits across strategies/implementations levels
## Cost-Benefit Results

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<td>-$406,296</td>
<td>-$406,110</td>
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<tr>
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<td>-$5,462</td>
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<td>Low-Density Feeding</td>
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## Costs of an outbreak necessary to break even

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<td>Test and Slaughter</td>
<td>$107.1M</td>
<td>$37.1M</td>
<td>$21.3M</td>
<td>$19.9M</td>
</tr>
<tr>
<td>S19 Vaccination</td>
<td>$8.0M</td>
<td>$1.8M</td>
<td>$846K</td>
<td>$740K</td>
</tr>
<tr>
<td>Low-Density Feeding</td>
<td>$4.9M</td>
<td>$1.3M</td>
<td>$562K</td>
<td>$489K</td>
</tr>
</tbody>
</table>
Conclusions

• At coarse scale, cattle-elk overlap risk highest in winter/spring in areas of:
  – Low elevation
  – Near feedgrounds
  – High feedground cost distance
  – Low road density
• Currently, in Pinedale EHU: expect ~1 cattle case/16 years
• Can increase time between expected cattle cases via management activities, but costs high relative to benefits
• Survey method affordable (time/$$) alternative to collecting/analyzing collar data
  – For coarse scale model
  – Possible extension to other areas
Challenges

• Small sample size (18%, 10% usable)
• Poor representation of small producers
  – Impossibility of follow-up
  – Improvement via alternative sampling strategies
  – Weighting of responses
• Lack of adequate ground-truthing data
  – Other research groups working on fine-scale RSFs to identify overlap
    • Individual producer level
University of Wyoming  Cattle producers
Stephen Bieber
Benjamin Rashford
Todd Cornish

Wyoming Livestock Board
Jim Logan

Wyoming Game and Fish Department
Brandon Scurlock
Hank Edwards

USDA-APHIS-VS
<table>
<thead>
<tr>
<th>Elk Herd Unit</th>
<th>True Cases Since 1989(^1)</th>
<th>Minimum # Years to True Case(^1)</th>
<th>Modeled Median # Years to Expected Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afton</td>
<td>0</td>
<td>0</td>
<td>9.0</td>
</tr>
<tr>
<td>Fall Creek</td>
<td>0</td>
<td>0</td>
<td>17.14</td>
</tr>
<tr>
<td>Hoback</td>
<td>0</td>
<td>0</td>
<td>4.7</td>
</tr>
<tr>
<td>Pinedale</td>
<td>1</td>
<td>23</td>
<td>6.96</td>
</tr>
<tr>
<td>Piney</td>
<td>1</td>
<td>23</td>
<td>4.09</td>
</tr>
<tr>
<td>South Rock Springs</td>
<td>0</td>
<td>0</td>
<td>554,011.0</td>
</tr>
<tr>
<td>South Wind River</td>
<td>0</td>
<td>0</td>
<td>95.0</td>
</tr>
<tr>
<td>Steamboat</td>
<td>0</td>
<td>0</td>
<td>719</td>
</tr>
<tr>
<td>Upper Green River</td>
<td>0</td>
<td>0</td>
<td>16.09</td>
</tr>
<tr>
<td>West Green River</td>
<td>0</td>
<td>0</td>
<td>32.5</td>
</tr>
</tbody>
</table>
Test and Slaughter

• Basic premise:
  – Capture elk on all 3 feedgrounds, test adult females, remove if positive

• Assumptions for modeling:
  – All 3 feedgrounds receive management
  – Management “applied” via:
    • ↓ female proportion
    • ↓ population
    • ↓ seroprevalence
Vaccination of Elk with S19

• Basic premise:
  – Vaccinate calf elk on feedgrounds with S19

• Assumptions for modeling:
  – All three feedgrounds receive management
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Low-Density Feeding

• Basic premise:
  – Alter spacing of feed to avoid mass congregation of elk

• Assumptions for modeling:
  – Two feedgrounds receive management (not feasible on Scab Creek)
  – Management “applied” via:
    • ↓ seroprevalence
Costs of Management Strategies: Assumptions

• Test-and slaughter - $346,147
  • On all 3 feedgrounds, annually
  • Assume constant variable costs

• Vaccination - $7,674
  • On all three feedgrounds, annually

• Low-Density Feeding - $1,358
  – Assume applied:
  • On 2 feedgrounds (not Scab Creek)
  • As additional time spent by feeder
Example...

- Test and slaughter → reduce seroprevalence to 5%
- Expected benefit (EB) = \( \frac{194,627}{16.8} - \frac{194,627}{21.9} \approx 2,698 \)
- Expected annual cost = $346,147
- Net benefit = $2,698 - $345,147 = -$342,449
Test and Slaughter

<table>
<thead>
<tr>
<th>Seroprev. Reduction</th>
<th>Years to Cattle Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>None (current)</td>
<td>16.8 (11.7, 30.0)</td>
</tr>
<tr>
<td>By 1%</td>
<td>19.0 (12.1, 29.7)</td>
</tr>
<tr>
<td>By 5%</td>
<td>19.0 (13.2, 33.2)</td>
</tr>
<tr>
<td>By 10%</td>
<td>21.2 (14.6, 37.2)</td>
</tr>
<tr>
<td>To 5%</td>
<td>21.9 (15.2, 37.7)</td>
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Test and Slaughter Simulation

- Current (18%)
- Reduce by 1% (17%)
- Reduce by 5% (13%)
- Reduce by 10% (8%)
- Reduce to 5%
## S19 Vaccination

### Seroprev. Reduction vs. Years to Cattle Case

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<tr>
<td>By 1%</td>
<td>16.4 (11.8, 28.9)</td>
</tr>
<tr>
<td>By 5%</td>
<td>17.4 (12.1, 29.9)</td>
</tr>
<tr>
<td>By 10%</td>
<td>17.9 (12.4, 31.9)</td>
</tr>
<tr>
<td>To 5%</td>
<td>18.3 (12.5, 32.6)</td>
</tr>
</tbody>
</table>

### S19 Elk Vaccination Simulation

- **Current (18%)**
- **Reduce by 1% (17%)**
- **Reduce by 5% (13%)**
- **Reduce by 10% (8%)**
- **Reduce to 5%**

The graph shows the probability distribution of years to cattle case for different seroprevalence reduction scenarios.
## Low-Density Feeding

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</tr>
<tr>
<td>To 5%</td>
<td>18.1 (12.5, 32.8)</td>
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Pinedale EHU

• For elk-cattle brucellosis transmission to occur:

1. Elk must occur in close proximity to cattle

\[ \Sigma(RSF \times EE) = 1.92 \] elk overlapping with cattle
2. Elk must be infected

• Elk may test positive:
  – Seroprevalence:
    • Weighted average across the three feedgrounds = 18%
  – $P(\text{Culture}+ | \text{Sero}+)$
    • Mean = 53.6%
3. Elk must experience an infectious event

a) Elk must be female
   – WGFD classifies % female annually
     • Mean = 66.8%

b) Elk must be pregnant
   – WGFD data suggests ~78.8% on average
c) Elk must abort

– Given WGFD VIT data:
  • \( P(\text{Abort}|\text{Culture}+) = 20\% \) on average
  • If Sero- \( \rightarrow \) not necessarily uninfected: \( P(\text{Abort}|\text{Sero}-) \approx 1.7\% \) will abort on average
Current Risk* = \# infectious events expected in proximity to cattle per year

\[
\begin{align*}
\text{Current Risk} &= \left[\text{#ELK} \times (\%FEM) \times (\%PREG) \times (\text{SEROPREV}) \times (\text{P(CULTURE+ | SEROPOS)}) \times (\text{P(ABORT | CULTURE+)})\right] \\
&\quad + \left[\text{#ELK} \times (\%FEM) \times (\%PREG) \times (1-\text{SEROPREV}) \times (\text{P(ABORT | SERONEG)})\right]
\end{align*}
\]

* Note that this includes feedground and non-feedground elk
Modeling

- Small size of cattle winter feeding areas $\rightarrow$ contact with infectious materials inevitable
- Management implications same if 1 or more cattle test positive
- $1/(\text{Current Risk}) = \# \text{ of years until cattle case expected}$
  - Pinedale EHU
    - $\sim31$ years until cattle case
  
  (Compare to 1 case since 1987)
Simulate Management Strategies

1. Test and slaughter
2. Elk vaccination with S19
3. Low-density feeding

- Model potential ranges of effectiveness:
  - ↓ by 1% → 17%
  - ↓ by 5% → 13%
  - ↓ by 10% → 8%
  - ↓ to 5%

- Then recalculate risk
Test and Slaughter

• Basic premise:
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• Assumptions for modeling:
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Example...

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- Expected benefit (EB) = \( \frac{194,627}{31.08} - \frac{194,627}{37.84} = \sim 1118 \)
- Expected annual cost = $346,147
- Net benefit = $1,118 - $345,147 = -$345,029
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  – Assume applied:
    • On 2 feedgrounds (not Scab Creek)
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Further Steps...

- Model additional management strategies
  - Habitat improvements
  - Elk contraception
  - Fencing elk “out”
- Consider summer risk as well
  - Late elk abortion/infectious live birth
  - Cattle exposure on summer grazing allotments
  - Smaller role than winter risk
- Ground-truth models
  - Collars?
  - Intensive producer surveys?