Use of citizen science to develop a cost-benefit analysis for bovine brucellosis seroprevalence reduction in southern Greater Yellowstone Area elk
Background – Bovine brucellosis

- Bacterial disease
  - History in US
  - Elk, bison, cattle (humans)
  - Cattle → wildlife
  - Causes abortions
  - Environmental contamination
  - Potential transmission to cattle
    - $$$$
    - Management implications
Background – Bovine brucellosis

Management:

1. Maintain cattle/elk separation
   - Fencing haystacks
   - Hazing elk
   - Elk feedgrounds

2. ↓ likelihood that exposed cattle abort
   - RB51 vaccination

3. ↓ seroprevalence in elk
   - Test and Slaughter
   - S19 vaccination
   - Low-density feeding
Background – Management

• Continued spillover
• Expanding interface
• Limited $$
• No scientific answer

• Bang-per-buck
  – Optimize use of available strategies
    • Cost
    • Benefit
Objectives

1. Model current risk
   - No bison
   - Elk feedgrounds

2. Simulate management and observe how risk changes (benefit)

3. Consider costs associated with management strategies
How does current elk seroprevalence translate to risk to cattle?

• For elk → cattle brucellosis transmission to occur:
  – Cattle must be present
  – Elk must be present
  – Elk must:
    • Be female
    • Be pregnant
    • Be infected
    • Experience infectious event
      – (winter/spring)
Where is elk-cattle overlap likely during risk period?

• Elk locations:
  – Limited GPS collar data available for elk
    • Mainly feedground elk
    • Expensive/time-consuming

• Cattle locations:
  – How to acquire?
Study Area

• Three counties:
  – Lincoln, Sublette, Sweetwater
  – ~121,000 cattle
  – ~500 producers

• Previous brucellosis cases in cattle

• Portions of 17 EHUs

• 15/23 elk feedgrounds
Methods - Data Collection

- Survey of cattle producers (tri-county):
  - Cattle #s/locations during winter/spring
  - Elk +/-

- Mail survey (late winter/spring 2012):
  - Distributed via National Agricultural Statistics Service (NASS)
  - 2 options for participation
    - Survey
    - Herd Plan Questionnaire
  - 486 surveys: 89 responses (50 usable)

- Telephone/in person follow-up (late winter/spring 2014):
  - Agricultural-type landowners with registered brand
  - 22 usable responses
Methods - Processing Survey Data

• Assign cattle to locations on landscape

• Elk presence/pseudo-absence → estimate RSFs for elk relative to cattle
  – Land cover (GAP)
  – Elevation
    • Slope
    • Aspect
  – Winter precipitation
  – Proximity to:
    • Wolves/hunting pressure
    • Roads
    • Feedgrounds
    • Forest cover
Risk Model

- Risk of elk-cattle overlap higher where:
  - ↑ distance from road(s)
  - Cost distance to feedgrounds relatively low or high**
  - Higher slope **
  - ↓ hunter density **
  - Far from forest boundary in areas wolves are present**

- Combine with EHU population and seasonal range → expected # elk
How does current elk seroprevalence translate to risk to cattle?

- For elk → brucellosis transmission to occur:
  - *Cattle must be present*
  - *Elk must be present*
  - *Elk must:*
    - Be female
    - Be pregnant
    - Be infected
    - Experience infectious event
      - (winter/spring)
How does current elk seroprevalence translate to risk to cattle?

# elk infectious events expected in proximity to cattle per year

\[
= \left[ \left( \text{#ELK OVERLAPPING} \right) \times \left( \%FEM \right) \times \left( \%PREG \right) \times \left( \text{SEROPREV} \right) \times \left( P(\text{ABORT} | \text{SERO+}) \right) \right] + \left[ \left( \text{#ELK OVERLAPPING} \right) \times \left( \%FEM \right) \times \left( \%PREG \right) \times \left( 1 - \text{SEROPREV} \right) \times \left( P(\text{ABORT} | \text{SERONEG}) \right) \right]
\]
How does current elk seroprevalence translate to risk to cattle?

• 1/# infectious events per year → # years until cattle case expected

Pinedale EHU:
• 0.0553 infectious events per year
• → 18.1 years until cattle case (median)
• Reality: 1 case between 1987 and 2012 (25yrs)
What are the costs/benefits associated with a given strategy?

- Cost of outbreak estimated at $146,299 (Wilson et al. 2011)
- Expected benefit (EB) = \( \frac{\$146,299}{\text{median years}} - \frac{\$146,299}{\text{median years}} \) (current years) (strategy)
- Net benefit = EB – expected annual cost of strategy
- Compare net benefits
- Focus on Pinedale EHU
Costs of Mgmt Strategies

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Assumptions</th>
<th>Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test and Slaughter</td>
<td>All 3 feedgrounds ↓ females ↓ population ↓ seroprevalence</td>
<td>$601,164</td>
</tr>
<tr>
<td>S19 Vaccination</td>
<td>All 3 feedgrounds ↓ seroprevalence</td>
<td>$6,715</td>
</tr>
<tr>
<td>Low-Density Feeding</td>
<td>Fall and Muddy Creek ↓ seroprevalence</td>
<td>$4,156</td>
</tr>
</tbody>
</table>

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

- Test and slaughter:
  - Reduce seroprevalence to 5%:
  
  \[
  \text{EB} = \frac{\$146,299}{18.1 \text{ yrs}} - \frac{\$146,299}{73.5 \text{ yrs}} \approx \$6,093
  \]

- Expected annual cost: $601,164
- Net benefit = $6,093-$601,164 = -$595,071
## Cost-Benefit Results

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Reduce by 1%</th>
<th>Reduce by 5%</th>
<th>Reduce by 10%</th>
<th>Reduce to 5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test and Slaughter</td>
<td>-$600,556</td>
<td>-$598,072</td>
<td>-$595,472</td>
<td>-$595,071</td>
</tr>
<tr>
<td>S19 Vaccination</td>
<td>-$6,403</td>
<td>-$5,125</td>
<td>-$3,588</td>
<td>-$2,984</td>
</tr>
<tr>
<td>Low-Density Feeding</td>
<td>-$3,882</td>
<td>-$2,806</td>
<td>-$1,448</td>
<td>-$981</td>
</tr>
</tbody>
</table>
Cost of an outbreak necessary to break even

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Reduce by 1%</th>
<th>Reduce by 5%</th>
<th>Reduce by 10%</th>
<th>Reduce to 5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test and Slaughter</td>
<td>$144.8M</td>
<td>$28.5M</td>
<td>$15.5M</td>
<td>$14.4M</td>
</tr>
<tr>
<td>S19 Vaccination</td>
<td>$3.2M</td>
<td>$618K</td>
<td>$314K</td>
<td>$263K</td>
</tr>
<tr>
<td>Low-Density Feeding</td>
<td>$2.2M</td>
<td>$450K</td>
<td>$223K</td>
<td>$192K</td>
</tr>
</tbody>
</table>
Conclusions

• Citizen science can be used to estimate wildlife distribution (coarse scale)
  – Stakeholder participation

• Pinedale EHU:
  – Expect ~1 cattle case/18.1 years
  – Can delay via management
    • Costs >>> benefits
      – Society’s risk attitude?
Future Directions

• Additional mgmt strategies
  – Contraception
  – Habitat improvements
  – Fencing elk “out” of cattle WFAs

• Seeking funding to:
  – Expand study area
  – Explore additional ground-truthing methods
    • Trail cameras?
    • Pellet counts?
University of Wyoming
Stephen Bieber
Benjamin Rashford
Todd Cornish

Wyoming Livestock Board
Jim Logan

Wyoming Game and Fish Department
Brandon Scurlock
Hank Edwards

Area cattle producers

Funding
USDA-APHIS-VS
WDA - WWLDRP
QUESTIONS?

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(307)721-3177
<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>SE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.95</td>
<td>1.25</td>
<td>0.12</td>
</tr>
<tr>
<td>DistanceToRoad</td>
<td>4.5e-04</td>
<td>2.84e-04</td>
<td>0.11</td>
</tr>
<tr>
<td>FeedCostDist</td>
<td>-2.32e-04</td>
<td>7.43e-05</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>FeedCostDist^2</td>
<td>2.18e-09</td>
<td>6.68e-10</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Slope</td>
<td>0.32</td>
<td>0.14</td>
<td>0.02</td>
</tr>
<tr>
<td>HuntersPerSQKM</td>
<td>-3.21</td>
<td>1.44</td>
<td>0.03</td>
</tr>
<tr>
<td>ForestWolf</td>
<td>5.55e-04</td>
<td>3.06e-04</td>
<td>0.07</td>
</tr>
</tbody>
</table>

AIC: 80.13
Se: 0.82; Sp: 0.62
Marginal Effects
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>(Within producer polygon(s))</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAP</td>
<td>Majority land cover type</td>
<td></td>
</tr>
<tr>
<td>Road density</td>
<td>Mean roads/km²</td>
<td></td>
</tr>
<tr>
<td>Distance to road</td>
<td>Mean euclidean distance to road (m)</td>
<td></td>
</tr>
<tr>
<td>Feedground cost-distance</td>
<td>Mean cumulative cost-distance (where cost is derived from slope) to nearest feedground</td>
<td></td>
</tr>
<tr>
<td>Distance to feedground</td>
<td>Mean euclidean distance to nearest feedground (m)</td>
<td></td>
</tr>
<tr>
<td>Winter precipitation</td>
<td>Mean PRISM precipitation for November-April (according to regional SNOTELs, these are the months when precip is likely snow)</td>
<td></td>
</tr>
<tr>
<td>Elevation</td>
<td>Mean elevation (m)</td>
<td></td>
</tr>
<tr>
<td>Slope</td>
<td>Mean slope (degrees)</td>
<td></td>
</tr>
<tr>
<td>Aspect</td>
<td>Majority aspect</td>
<td></td>
</tr>
<tr>
<td>Wolf presence</td>
<td>Maximum probability of wolves from WYNDD deductive model (0/1)</td>
<td></td>
</tr>
<tr>
<td>Distance to forest</td>
<td>Mean euclidean distance (m) to National Forest edge</td>
<td></td>
</tr>
<tr>
<td>Forest x Wolf</td>
<td>Wolf presence x distance to forest</td>
<td></td>
</tr>
<tr>
<td>Hunter density</td>
<td>Mean hunters/km²</td>
<td></td>
</tr>
</tbody>
</table>
## Risk Summary by Herd Unit

<table>
<thead>
<tr>
<th>Elk Herd Unit</th>
<th>True Cases Since 1989</th>
<th>Minimum # Years to True Case</th>
<th>Median Years Until Cattle Case Expected (5%, 95%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afton</td>
<td>0</td>
<td>0</td>
<td>16.4 (6.7, 25.3)</td>
</tr>
<tr>
<td>Fall Creek</td>
<td>0</td>
<td>0</td>
<td>439.7 (170.4, 686.7)</td>
</tr>
<tr>
<td>Hoback</td>
<td>0</td>
<td>0</td>
<td>12.4 (5.5, 18.5)</td>
</tr>
<tr>
<td>Pinedale</td>
<td>1</td>
<td>23</td>
<td>18.1 (5.3, 32.2)</td>
</tr>
<tr>
<td>Piney</td>
<td>1</td>
<td>23</td>
<td>4.3 (1.7, 7.2)</td>
</tr>
<tr>
<td>South Rock Springs</td>
<td>0</td>
<td>0</td>
<td>2292.7 (111.0, 9.1mil)</td>
</tr>
<tr>
<td>Upper Green River</td>
<td>0</td>
<td>0</td>
<td>12.5 (4.4, 22.1)</td>
</tr>
<tr>
<td>West Green River</td>
<td>0</td>
<td>0</td>
<td>312.9 (17.3, 1198.7)</td>
</tr>
</tbody>
</table>
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
    • 23 bulls
  – Castrating/spaying non-replacement yearlings
  – Twelve-month quarantine
  – Three whole-herd tests
  – Does not consider changes to markets