Modeling transmission of bovine tuberculosis in Uruguay using dynamic cattle movement networks - A potential model for the US

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Acknowledgments

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Minnesota Bovine TB, 2005-2009

- *M. bovis* identified in cow at slaughter plant in Feb 2005 traced to Minnesota beef herd
- 12 infected beef cattle herds
- 27 deer with lesions
- *M. bovis* in positive cattle and deer linked to isolates from cattle in SW US and Mexico
Epidemiologic links between cattle herds in Minnesota Bovine TB outbreak, 2005-2009

Linda Glaser, MN Board of Animal Health
Bovine TB surveillance

- 5 year delay in detection of infected herds through slaughter surveillance alone (Fischer, 2005)
- Impossible to perform cost-effective surveillance in all herds

- How to target surveillance?
- Focus on the strata of the population more likely to have a case of disease as a consequence of their risk profile
Risk-based surveillance

Disease does not behave randomly → underlying risk factors enhance or limit spread.

- Number of cattle introductions and origin of trace-in cattle are known risk factors for Bovine TB (APHIS, 2009)
- 90% of purchased cattle in index herd in 2005 MN BTB outbreak originated in other states (Shaw, 2008)
Social Network Analysis

- Uses **Graph theory** and the **social science** of interactions
- A network of contacts is represented by a graph with “**nodes**” (individuals) connected by “**edges**” (contacts or movements)
- Model the **contact structure** of population based on **behavior** of individuals
From network analysis to risk analysis –
An approach to risk-based surveillance
for bovine tuberculosis in Minnesota, US

• Data 2008 - 2011
  • 3,467 movements with 46,717 cattle moved into MN, between 559 premises
• Network analysis performed
  • Each node represented premises, connections as movements
Network of cattle movements

20% highest risk movements

- "High risk" in-degree
  - Number of movements: 90%
  - Number of cattle: 86%

- "High risk" out-degree
  - Number of movements: 67%
  - Number of cattle: 64%
Risk score for disease introduction

- **Total risk score**
- **Cumulative risk score %**
- **Interquartile range**

The graph shows the cumulative proportion of the total risk score for farms ranked from the BTb area. The risk scores are categorized into three levels: **HIGH RISK**, **MEDIUM RISK**, and **LOW RISK**. The cumulative risk score percentage is shown on the y-axis, and the rank of farms is shown on the x-axis.
Uruguay

- Complete, electronic-based animal traceability system for cattle.
- Since 2011, all cattle uniquely identified with electronic ear tag ID.
- Every cattle movement recorded by date, number animals by type, origin, destination.
- Since 2005, cattle movement database complete and electronically available.
Bovine TB-positive farms in Uruguay
Study objectives

1) Identify Bovine TB risk factors including herd-specific factors and between-herd interactions.
2) Develop simulation model of spread of Bovine TB within and between cattle herds.
TB-positive farms move more cattle

- Total cattle received
- Total cattle sent

**BTB positive herds**

**Graph**

- **Types**:
  - Breeding
  - Growing
  - Complete cycle
  - Fattening
  - Dairy
  - Small farm
  - Overall

**Count**

- 0 to 400
Factors associated with *M. bovis* CCT in Uruguay dairy herds

- Multivariable conditional logistic regression
- **Outcome**
  - CCT herd status (positive vs negative)
- **Controls**
  - 3 dairy controls per case, matched by spatial proximity
### Risk factors for bovine TB in Uruguayan dairy herds

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Level</th>
<th>Odds ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herd size</td>
<td>&lt;116</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>116-360</td>
<td>7.3 (1.9-28.9)</td>
</tr>
<tr>
<td></td>
<td>&gt;360</td>
<td>15.7 (3.8-65.3)</td>
</tr>
<tr>
<td>Number heifers (1-2 yrs)</td>
<td>&lt;4</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>4-27</td>
<td>0.2 (0.1-0.5)</td>
</tr>
<tr>
<td></td>
<td>&gt;27</td>
<td>0.5 (0.2-1.3)</td>
</tr>
<tr>
<td>Number cattle received</td>
<td>&lt;2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2-44</td>
<td>0.8 (0.3-2.1)</td>
</tr>
<tr>
<td></td>
<td>&gt;44</td>
<td>1.6 (0.7-4.0)</td>
</tr>
<tr>
<td>Receive steers</td>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>3.3 (1.2-9.0)</td>
</tr>
</tbody>
</table>
Results from model with control

5 seeded dairies, run for 5 yrs, 100 runs

Moderate skin test Sens = 70%
Results from model with control

5 seeded dairies, run for 5 yrs, 100 runs

Low skin test Sens = 36%
Results from model with control
5 seeded dairies, run for 5 yrs, 100 runs

No skin testing
Future goals

- Develop transmission model of between-farm transmission of bovine TB in US
- Evaluate strategies for targeted surveillance and control in Uruguay and US