Johne’s disease in mixed species farming systems

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The Bacterium

• Cause of Johne’s disease (JD) or ‘Paratuberculosis’ (PTB)

Mycobacteria

\[ \text{Type ‘bovine’} \quad \text{Type ‘avium’ (birds)} \quad \text{Type ‘tuberculum’ (human)} \]

Cross-reactivity

\[ \text{Mycobacterium avium subspecies paratuberculosis} \]

“MAP”
Clinical Johne’s disease

Cattle: >3 years

Deer: 1-2 years

Sheep: >1 year
NZ-specifics

who is at risk?

• **Species:**
  – deer, sheep, beef/dairy cattle, wildlife

• **Breed:** Jersey, Merino

• **Age:**
  – cattle (0-12m >> heifer >> cow)
  – sheep (lamb > weaner > hogget > ewe)
  – deer (calf > weaner > yearling)

• **Genotype:** assumed large individual variation in susceptibility/resistance

• **Immune status:** vaccination → reduction of clinical disease

• **MAP bacteria:** Is every bug equal? → strain variability
From exposure to disease

- Not all get infected, few get diseased
From exposure to disease

- Not all get infected, few get diseased

BUT!
Outbreaks: deer
Problem farms: sheep, dairy
Why bother about Johne’s disease?

- Public health → Crohn’s disease no conclusive evidence yet
- Animal welfare
- Production loss

Whittington 2010
Website

http://www.jdrc.co.nz
Paratuberculosis in New Zealand

- Prevalence and Economic Impact?
- Does MAP cause human disease?
- Evidence is mounting but not proven
- Infection widespread, Clinical disease low
- How best to control?
- Eradication impractical
- No silver bullet
- "Best practice guidelines"
- Look for & remove clinical animals
- How best to test?
Agenda

- JD in New Zealand
- Diagnosis
- Transmission across species
- Farm-to-farm transmission
- Production effects
- Control
MAP Infection

- Flock/herd infection prevalence
  - 238 commercial farms
  - 107 Landcorp Ltd. Farms
  - 20 animals/species mob
  - Pooled FC
  - Individ. ELISA of neg. mobs
  - Random + low-BCS suspects

PTB status of 238 commercial properties
How many are infected in NZ?

<table>
<thead>
<tr>
<th>Species</th>
<th>Herd True Prevalence</th>
<th>Animal True Prevalence in infected herds/flocks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Herds</td>
<td>HTP</td>
</tr>
<tr>
<td>Deer</td>
<td>Survey</td>
<td>99</td>
</tr>
<tr>
<td>Landcorp</td>
<td>16</td>
<td>63%</td>
</tr>
<tr>
<td>Abattoir*</td>
<td>57</td>
<td>59%</td>
</tr>
<tr>
<td>Sheep</td>
<td>Survey</td>
<td>162</td>
</tr>
<tr>
<td>Landcorp</td>
<td>61</td>
<td>48%</td>
</tr>
<tr>
<td>Beef</td>
<td>Survey</td>
<td>99</td>
</tr>
<tr>
<td>Landcorp</td>
<td>49</td>
<td>43%</td>
</tr>
<tr>
<td>Dairy</td>
<td>Landcorp</td>
<td>41</td>
</tr>
<tr>
<td>LIC**</td>
<td>3,923</td>
<td>21%</td>
</tr>
</tbody>
</table>

* Abattoir prevalence not adjusted for Se/Sp; ** Bulk tank testing, unadjusted
## How many get diseased?

<table>
<thead>
<tr>
<th>Animal</th>
<th>Infected farms</th>
<th>Infected animals</th>
<th>Infected farms reporting cases</th>
<th>% clinical cases/year</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheep</td>
<td>76%</td>
<td>22%</td>
<td>54%</td>
<td>0.16% (0.09-0.24%)</td>
<td>1:625</td>
</tr>
<tr>
<td>Beef</td>
<td>43%</td>
<td>16%</td>
<td>24%</td>
<td>0.04% (0.01-0.08%)</td>
<td>1:2500</td>
</tr>
<tr>
<td>Deer</td>
<td>50%</td>
<td>39%</td>
<td>55%</td>
<td>0.32% (0.05-0.60%)</td>
<td>1:312</td>
</tr>
<tr>
<td>Dairy</td>
<td>21% (Voges et al. 2014)</td>
<td>9%</td>
<td>35%</td>
<td>0.3 (0.1 – 0.6)</td>
<td>1:333</td>
</tr>
</tbody>
</table>
Diagnosis
Diagnosis

- Clinical signs:
- Necropsy:

- Faecal culture:
- Faecal ‘real time polymerase chain reaction’ (PCR) → detection of shedders
- Blood serology: ELISA/Parelisa® → poor in ‘normal’, good in clinical stage
- Other, rarely used tests:
  - Johnin skin test
  - Gamma interferon
  - Gel diffusion
  - Complement fixation test (CMT)
  - Liver biopsy [currently investigated for sheep at Massey; Smith et al. 2014]
Transmission across species
NZ mixed species farming

- **JDRC Survey 2008**: 1,934 farms (2,972 species mobs)

(Verdugo et al. 2009)
## Single- vs multi-species

<table>
<thead>
<tr>
<th>Species</th>
<th>Risk factor</th>
<th>Clinical disease</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheep</td>
<td>Co-grazing with deer</td>
<td>2-fold lower</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Co-grazing with beef</td>
<td>1.2-fold higher</td>
<td>0.01</td>
</tr>
<tr>
<td>Dairy</td>
<td>no data</td>
<td>no effect (sparse data)</td>
<td>0.26</td>
</tr>
<tr>
<td>Beef</td>
<td>Co-grazing</td>
<td>no effect (sparse data)</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>Co-grazing with beef</td>
<td>2.2-fold higher</td>
<td>0.01</td>
</tr>
<tr>
<td>Deer</td>
<td>Co-grazing with sheep</td>
<td>1.4-fold lower</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Co-grazing with beef</td>
<td>2.2-fold higher</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Co-grazing with sheep</td>
<td>1.4-fold lower</td>
<td>0.01</td>
</tr>
</tbody>
</table>
Strain type

- **Type C (Type II)**
  - ‘*Found in infected cattle and most infected deer*’

- **Type S (Types I and III)**
  - ‘*Found in most infected sheep and occasionally in infected deer*’

*O’Brien, Mackintosh, Griffin (2006), DeLisle, Collins*
VNTR + SSR typing  Des Collins et al. 2010

- **VNTR** = variable number of tandem repeats
- Based on repetitive DNA sequences that can be amplified by PCR (polymerase chain reaction)
- Refined by **SSR** (sequencing short repetitive base pair sequences)

**C-type:**
65 isolates: 25 types

**S-type:**
58 isolates: 8 types
15 STs in 2 clusters (n=168):

- Type C:
  - Deer, Dairy (S, C)
  - 8 types, 48 farms
  - 89 isolates (53%)
  - 12% NI – 88% SI

- Type S:
  - Sheep (C, D, Dairy)
  - 7 types, 48 farms
  - 79 isolates (47%)
  - 75% NI – 25% SI

- 1–62 isolates/ST
Strain types: transmission between species

No contact

Limited to species with direct pasture contact

similar
dissimilar
Farm-to-farm transmission

- Social Network Analysis (SNA)
180 Farms:
   112 LandCorp. Ltd.
   68 other properties
   3,531 Movements
    July 2006 – June 2010

Network-Analysis:
   7 Genotypes
   45 Isolates
   33 Farms
Visualization: 2 common strains
Probability of sharing same ST $\sim$ path length + \textbf{path length}²

The shorter the movement path, the more likely are they sharing the same strain
Production effects in sheep

- **Premature mortality:** NZ: <1%  
  AUS: 2-15%  
  $\Rightarrow$ reduced productive life (NZ: -6m)
- **Growth rates:** McGregor 2009 (AUS)
- **Tailing rates** NZ: JD-neg 136%, JD-affected 130% (-6%)

**Weight change relative to controls**

- Paucibacillary
- Multibacillary
- Clinical multibacillary

McGregor 2009

**Bush et al (2006)**

- 12 farms in southern NSW
  - 3,500 to 20,000 sheep
  - measured over 3 years
- mortality 2 to 15% p.a.
- gross margin decline 6.4 to 8.5%
  amounts to $13,715 per farm per year
PTB-mortality in sheep in NZ

- **Problem farms**, high mortalities due to JD

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**Scientific Article**

*The effect of Johne’s disease on production traits in Romney, Merino and Merino x Romney-cross ewes*

CA Morris*§, SM Hickey* and HV Henderson*

Research station, intensive monitoring 1975-1982:
8 yrs, 3633 ewes, all deaths or culled for emaciation → PM, histo

**Results:** clinical incidence of JD = **1%**
Model outcomes: cost of Johne’s based on (1.8%) mortality

Prices 2012 (/head):
Prime lamb: $113.5
Mutton: $93

Source: Beef+Lamb Economic service

Annual cost of JD (2012)
NZD 3.2 / ewe

Estimate for 2013:
NZD 2.64

Mortality 93.5% of OJD cost

- Lower LWT 0.5%
- Sub-fertility 6%
- Lamb meat 11.5%
- Mutton meat 82%
Control
OJD epidemiology and control

1. Increase herd immunity - vaccination of lambs

2. Avoid contact - cull infected adults - risk based trading

3. Manage grazing
Control

Options:
• Co-grazing ?
• Test & cull
• Early detection of ill-thrift → testing → removal of shedders
• Vaccination
• Biosecurity: prevent infectious contacts with other herds

Approximations:
• Interventions (sheep, sheep&beef, deer)
• Benefit-cost of vaccination (sheep)
Sheep OJD Model
Sheep & Beef model Verdugo, PhD 2013

- Cattle (left) and sheep (right) with grazing contact (centre)
- Environment subdivided in paddocks
Effect of vaccination (sheep)

- We vaccinate 30% of the weaners at 3 months of age
- We keep only vaccinated animals for replacement

Infection dynamics
Cost effectiveness of vaccination

- Vaccine efficacy: **90% drop** in shedders and JD mortality
  
  Reddacliff 2006

Annual cost of JD $3.20/ewe

Cost of vaccine per head 3 $:
Vaccinate replacement: $0.37 \times 3 = 1.11$

![Graph showing shedding and mortality](image_url)

- Shedding (%)
- Mortality (%)
- Time post vaccination (years)
Cost effectiveness of vaccination

JD mortality 1.8%

JD mortality 0.75%
Test and cull strategy

• Drafting ewes in low BCS once a year (prior to lambing):
  ➢ tail end selected and subjected to OJD testing (Elisa)
    ➢ If ELISA negative: treat (anthelminthics) and keep in the herd (subject to similar culling pressure as other MA ewes)
    ➢ If Elisa positive: cull

• Assumption:
  ➢ 80% of MB and 20% PB ewes are drafted
  ➢ Sensitivity of ELISA: 65.1% for MB ewes
    32.3% for PB ewes

(Sergeant 2003, Elisa cutoff 2.4)
Test and cull strategy

In the MA ewes flock, only few animals are in low BCS and likely to be drafted for testing

<table>
<thead>
<tr>
<th>categories</th>
<th>PB</th>
<th>MB</th>
</tr>
</thead>
<tbody>
<tr>
<td># of ewes/100 lambing ewes*</td>
<td>5</td>
<td>1</td>
</tr>
</tbody>
</table>

*numbers at the beginning of the culling period

→ limited impact on OJD. Not cost-effective (prelim. results)
Conclusions so far

• Vaccination:
  • cost–effective when OJD-mortality >1%
  • Long term process

• Selective Test&Cull unlikely to be cost-effective
  • Unless targeted to high risk groups

• Cost effectiveness: not the only incentive for control:
  • Perception (stigma)
  • Food safety & public health (Crohn’s disease)
  • Animal welfare

• Lack of robust data on true impact of JD on farm
Acknowledgements

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- Samples tested at AgRes. (Wallaceville), NZVP (Palm. Nth.) and DRL Otago (Dunedin)
Questions?

Nelly Marquetoux