Understanding pathogen transmission at the wildlife/domestic animal interface

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1. Multihost pathogens & identification of maintenance population
2. Intervention case study: CDV & rabies in Serengeti Ecosystem
3. Modeling: useful tool - but rarely used. Why?
4. Other gaps/challenges
Why are these important?
• Humans - Emerging infectious disease
• Wildlife - Biodiversity
• Livestock & domestic animals - Welfare, regional & global economics, and livelihoods

How do we control these pathogens?
➢ Identification of maintenance population

Multihost pathogens
Identifying reservoirs in multihost populations

Maintenance community

Maintenance population

Nonmaintenance population

Maintenance community

Target population

Reservoir

Haydon et al. Emerging Infectious Diseases 2002
### Multihost pathogens affect biodiversity

(Cleaveland et al 2002)

<table>
<thead>
<tr>
<th>Threatened population</th>
<th>Pathogen</th>
<th>Maintenance population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chimpanzee</td>
<td>Polio</td>
<td>Humans</td>
</tr>
<tr>
<td>Rainforest toads</td>
<td>Chytridiomycosis</td>
<td>Cane toads</td>
</tr>
<tr>
<td>African wild dog</td>
<td>Rabies, canine distemper virus</td>
<td>Domestic dogs</td>
</tr>
</tbody>
</table>

**Maintenance population**

- species (group of species) in which pathogen *persists*

Can make the same table for humans or domestic animals.
Intervention options

- Focus on maintenance population
- Prevent interactions between reservoir/target
- Control target populations
Serengeti as example of intervention
Why should we care about identifying reservoirs?

In Serengeti...

- **Maintained by domestic animals**
  - Rinderpest
  - Contagious bovine pleuropneumonia
  - CDV
  - Trypanosomiasis
  - RVF

- **Maintained by wildlife**
  - Anthrax
  - CPV
  - BTB
  - Brucellosis
  - Rabies
  - Foot-and-mouth disease
  - East coast fever
  - African swine fever

Lembo, Auty, Hampson, Craft, et al, 2015
RABIES

Domestic dog with rabies

Domestic cow with rabies

Human with rabies

Serengeti National Park

Rabies
Potential rabies reservoir system

(a) Maintenance population/community (size > CCS)
(b) Nonmaintenance population (size < CCS)
(c) Target population
(d) Reservoir

Rabies

Lembo, Hampson, Haydon, Craft et al., *J Appl Ecol* 2008
Canine Distemper Virus
Potential CDV reservoir systems

- Maintenance population/community (size > CCS)
- Non maintenance population (size < CCS)
- Target population
- Reservoir

(a) Other carnivore populations
- Lions
- Dogs

(b) Other carnivore populations
- Lions
- Dogs

(c) CDs
- Other carnivore populations
- Lions
- Dogs
Intervention trial: Mass dog vaccination

2003-present: 30-50,000 dogs vaccinated /yr
Viana et al PNAS, 2015
Rabies results

• Vaccination works and is affordable!
  (Hampson et al., PLoS Bio 2009, Kaare et al., Vaccine 2009)

• “Spillover” from dogs to other hosts
  (Lembo, Hampson, Haydon, Craft et al., J Appl Ecology 2008)

• Rabies is controllable; each rabid animal only infects ~1.2 others.
  (Hampson et al., PLoS Bio 2009)
Rabies results

(a) Maintenance population/community (size > CCS) → Humans → Other carnivore populations (Other carnivore populations → Dogs → Humans)

(b) Nonmaintenance population (size < CCS) → Humans → Other carnivore populations (Other carnivore populations → Dogs → Humans)

(c) Target population → Humans → Other carnivore populations (Other carnivore populations → Dogs → Humans)

(d) Reservoir (Other carnivore populations → Dogs → Humans)

Lembo, Hampson, Haydon, Craft et al., *J Appl Ecol* 2008
CDV results

• Lions not maintenance population  
  (Craft et al ProcRoySocB 2009)

• Multiple wild hosts needed to replicate 1994 fatal outbreak  
  (Craft et al Journal of Animal Ecology 2008)

• Virus may be maintained by broader carnivore community  
  (Viana et al PNAS 2015)
Maintenance population/community (size > CCS)
Non maintenance population (size < CCS)
Target population
Reservoir

Other carnivore populations
Dogs
Lions

(a) Other carnivore populations
Dogs
Lions

(b) Other carnivore populations
Dogs
Lions

(c) Other carnivore populations
Dogs
Lions

CDV results
Modeling: Dynamic disease models

- Ask questions that are ethically or logistically unfeasible
- Conduct ‘what if’ experiments
- Inform data collection
How clustered are different disciplines? How unified are modeling approaches? Any change through time with the “One Health” approach?

- 2258 papers, then eliminated those not directly referencing disease transmission
- 1605 papers remained, from 108 journals, 4219 authors
• Constructed paper citation network (which journals cite which journals)

• Identified community structure and found 3 communities with clear disciplinary structure: veterinary journals, ecological journals, and general biology/public health journals.
Differences: study system
Data incorporation
Model implementation
## Journal Communities

<table>
<thead>
<tr>
<th>Community</th>
<th>Number of Journals</th>
<th>Number of Papers</th>
<th>Median Number of Authors (2.5th, 97.5th quantiles)</th>
<th>Most common lead author affiliation (%)</th>
<th>Citations within community / citations between communities</th>
<th>Citation to Human-focused epi</th>
<th>Citation to Ecology</th>
<th>Citation to Vet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human-focused Epidemiology</td>
<td>42</td>
<td>1043</td>
<td>4, (1, 15)</td>
<td>Math / Stat / Epi (48.2%)</td>
<td>2504 / 421</td>
<td>NA</td>
<td>251</td>
<td>170</td>
</tr>
<tr>
<td>Ecology</td>
<td>30</td>
<td>310</td>
<td>4 (1, 12.275)</td>
<td>Ecology / Evolution (55.9%)</td>
<td>378 / 366</td>
<td>352</td>
<td>NA</td>
<td>14</td>
</tr>
<tr>
<td>Veterinary</td>
<td>7</td>
<td>198</td>
<td>4 (1, 9.075)</td>
<td>Veterinary / Animal Health (63.6%)</td>
<td>311 / 120</td>
<td>106</td>
<td>14</td>
<td>NA</td>
</tr>
</tbody>
</table>
Wildlife/Livestock interface implications?

• Concerning that vet and ecology communities are pretty isolated from each other
  – Do not generally cite (read?) each other
  – Different model objectives and approaches
• What challenges does this pose for working together?
• Or solving challenges at the wildlife/livestock interface?
Other gaps/challenges

- Knowledge of host range and distribution (WL)
- Diagnostic assays that apply to pathogen systems at the interface
- The dynamics of pathogen transmission at the interface
- Host population impacts of interface diseases (WL)
- Appropriate mitigation efforts

- New tools (beyond interventions and modeling)?
Thanks!

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