Parasite community ecology and epidemiological interactions at the wildlife/domestic/human interface

Can we anticipate emerging infectious diseases in their hotspots?

Caron A., de Garine-Wichatitsky M., Morand S.

1st International One Health Congress – 14-16th of February 2011, Melbourne, Australia

« One Health » at the wildlife/domestic Interface

- 70% of emerging diseases with a link with wildlife, a lot are zoonosis
- Sanitary issue where wildlife & domestic systems are in interaction

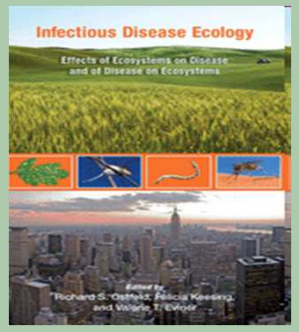
⇒ Hot spots of Emergence in tropical and sub-tropical ecosystems

- Complex multi-host systems
- How do we anticipate the next emergence? How do we survey something not yet there?

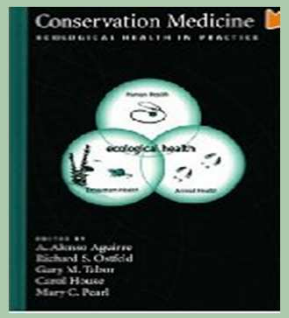
⇒ **Ecology of disease transmission in multi-host systems**

Describe and anticipate the emergence at this interface

- Needs expertise from:
  - **Epidemiology** (classical, risk analysis, molecular epidemiology, etc.)
  - **Ecology** (evolutionnary biology, community ecology, landscape ecology, etc.)
  - **Social sciences**
- Already multidisplinary work exists

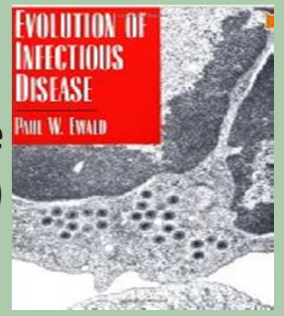


Infectious Disease Ecology:
Effects of Ecosystems on Disease and of Disease on Ecosystems
Ostfeld R.S. et al. (2008)

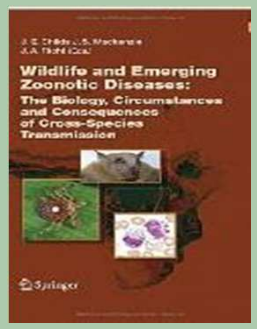


Conservation Medecine:
Ecological Health in Practice
Aguirre A.A. et al. (2002)

Disease Ecology:
Community structure and pathogen dynamics
Collinge S.K. (2006)



Evolution of Infectious Disease
Ewald, P.W. (1994)



Wildlife and Emerging Zoonotic Diseases
Childs J.E. et al. (2007)

Necessity to develop
new operational framework
for early detection and surveillance adapted to
multi-host systems
at the wildilfe/domestic/human interface

New concepts

Which host do we survey?

- Usually empirical decision-making
- Define concept of:
  - Epidemiological Functional Groups (EFGs)

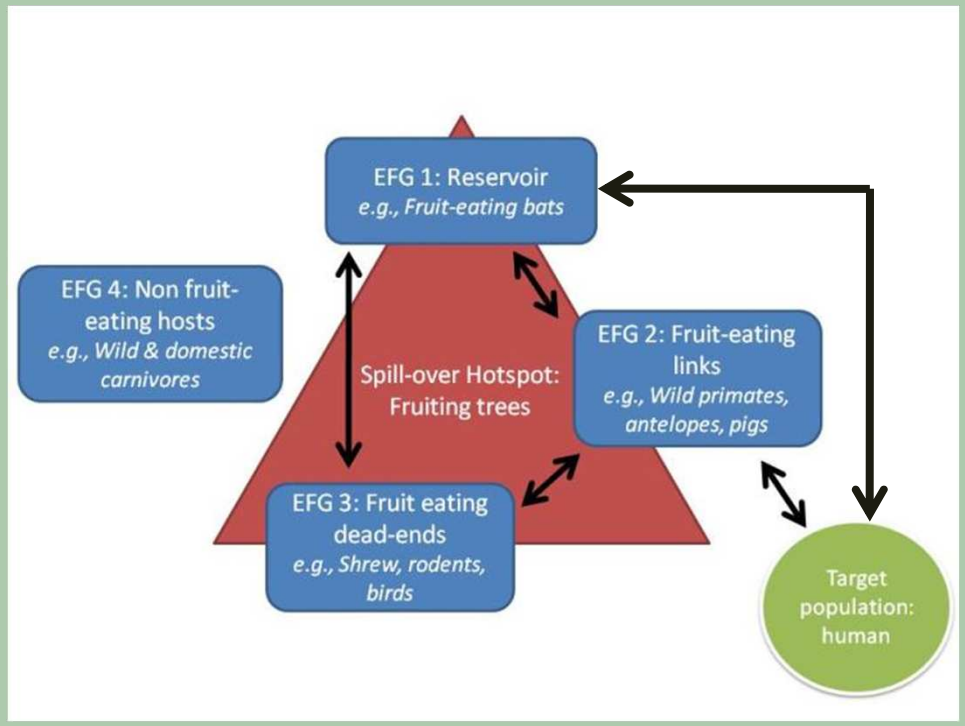
"allocate the species coexisting in a given ecosystem into EFGs according to their specific life-history traits and the role they play in the transmission of a parasite, or a group of parasites, in this ecosystem"

- Based on the concept of ecological functional groups (borrowed from community ecology)

- After defining target species (according to definition by Haydon et al. 2002)

⇒ Selection process for host populations

e.g. Ebola in Central Africa



Arrows in the figure represent epidemiological interactions between host populations.

Based on Leroy et al. 2005, Gonzales et al. 2007 :

EFG1: fruit-eating bats reservoir but not in direct contact with the target species, human populations;

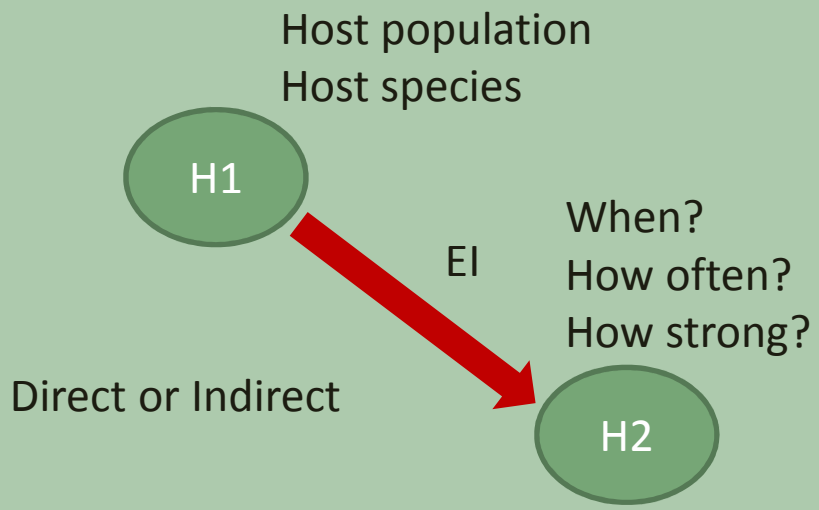
EFG2: fruit-eating links in contact with humans; (e.g., wild primates, some antelopes and livestock such as pigs)

EFG3: fruit-eating dead-ends not in contact with the target species; (e.g., shrew, rodents or birds which are not hunted and consumed by human

EFG4: non fruit-eating animals with no role in the epidemiology of the virus.
(e.g., wild and domestic carnivores)

Concept of Epidemiological Interactions (EIs)

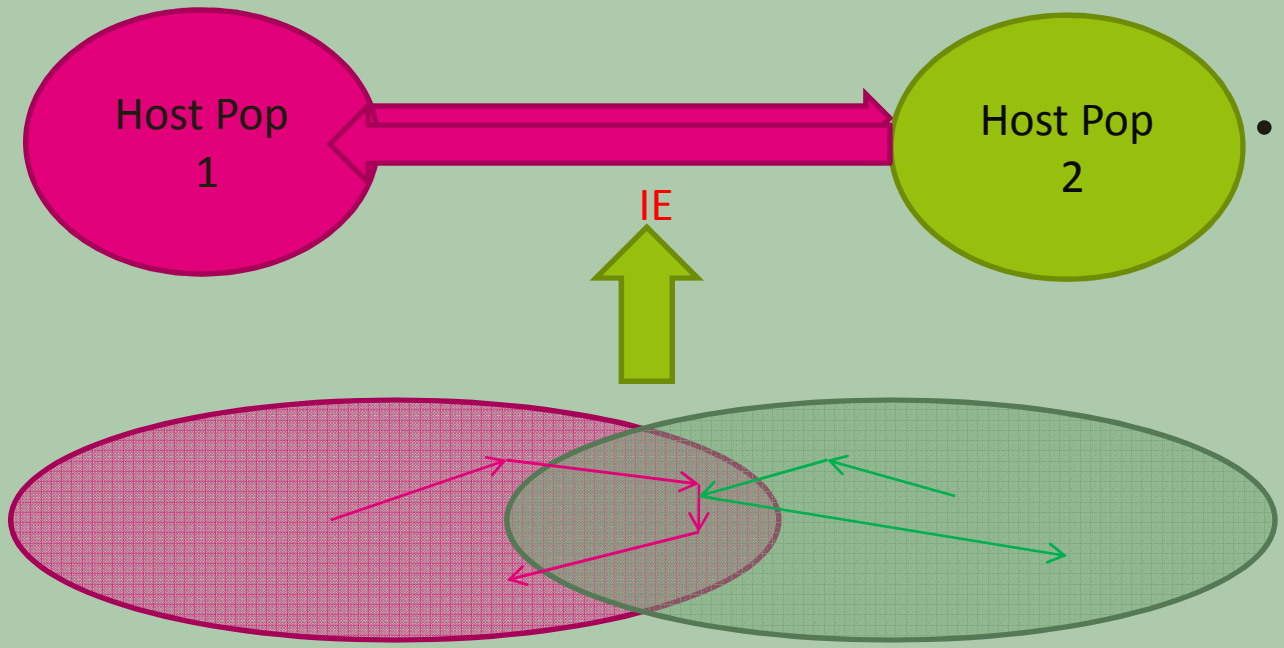
- « Any ecological interaction between 2 hosts which may result in the transmission of one or more pathogens »



Two approaches

Host Approach

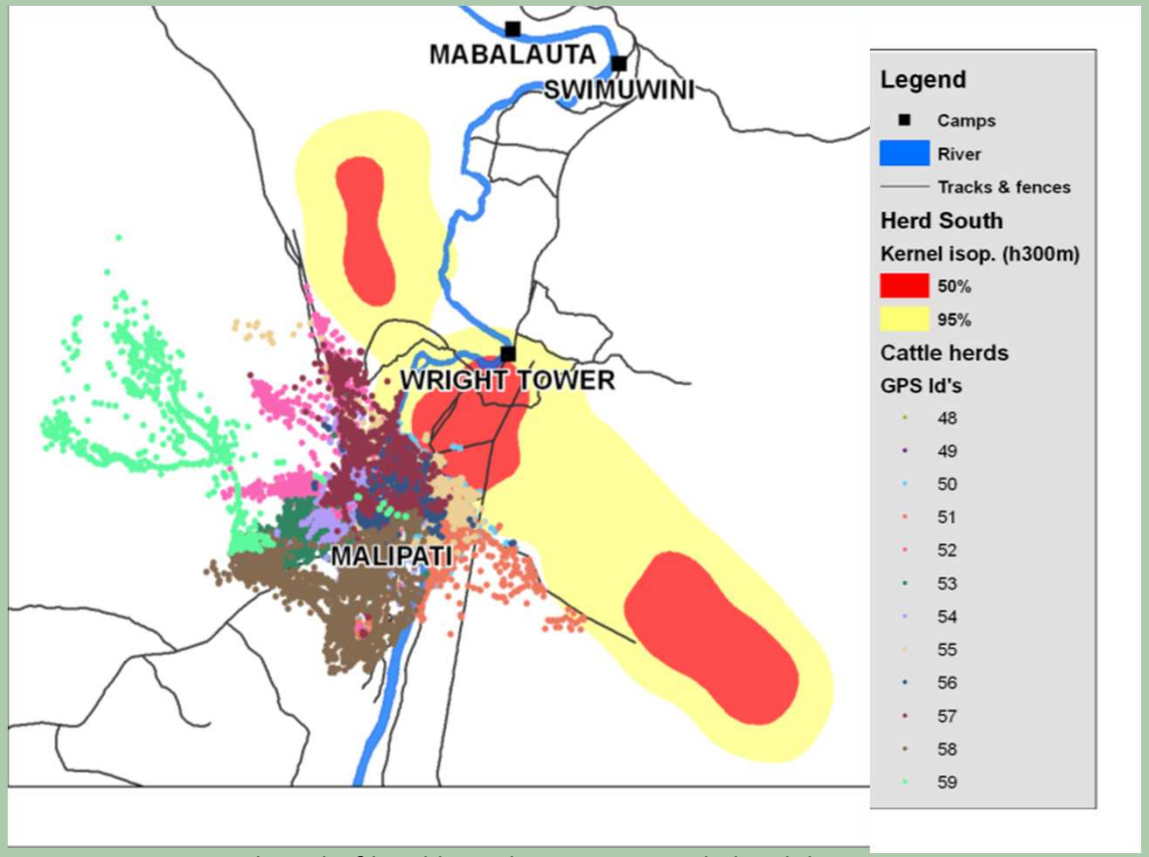
Principle



- **Host approach**: *A priori*
  - Movements of hosts
  - Contacts of hosts

Determine the potential for pathogen transmission

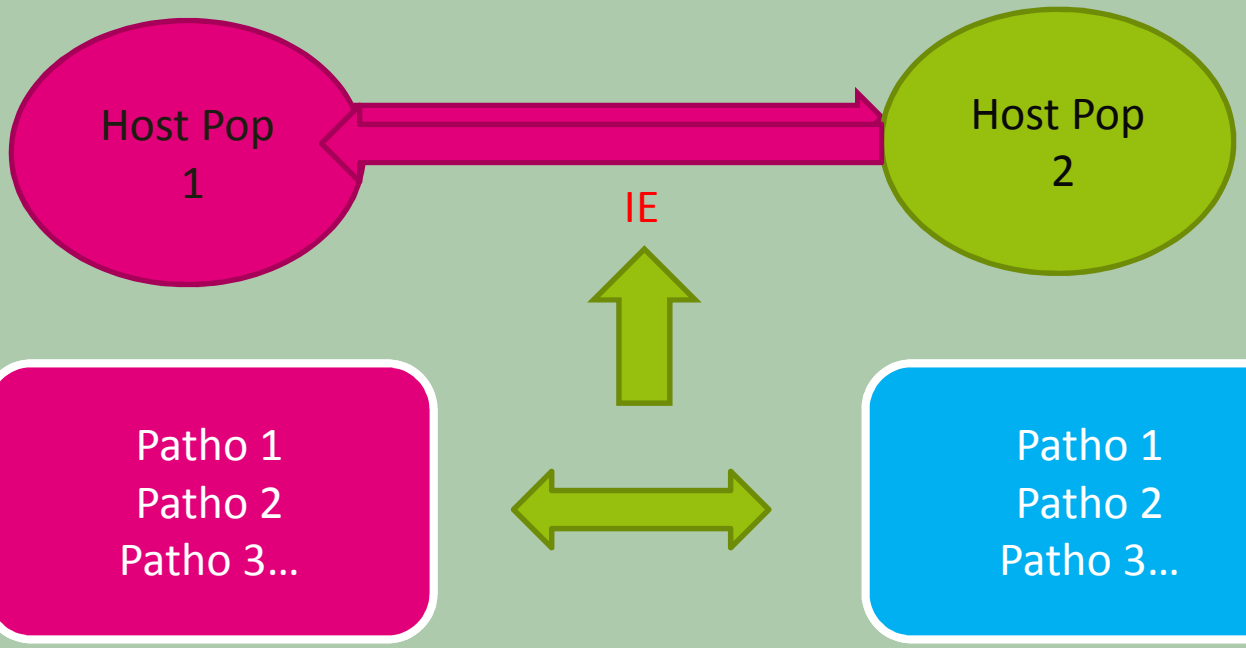
Buffalo/cattle Interaction using telemtry in Zimbabwe



Southern buf herd kernel map + 12 cattle herd locations

Pathogen Approach

Principle



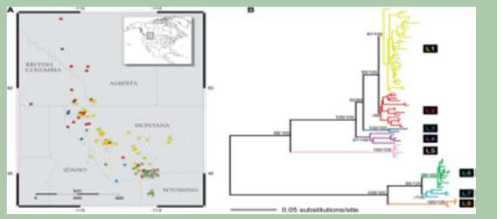
- **Pathogen approach**: *A posteriori*
  - Observed pathogens in hosts
  - Shared community of pathogens

Identify most probable transmission pathways in the ecosystems

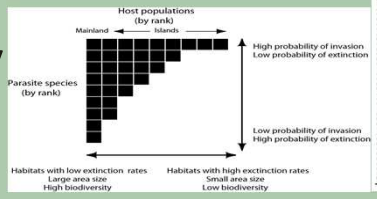
Pathogen Approach

Recent Advances in:

- Molecular epidemiology
  - *A Virus Reveals Population Structure and Recent Demographic History of Its Carnivore Host*, Biek et al., Science, 2006



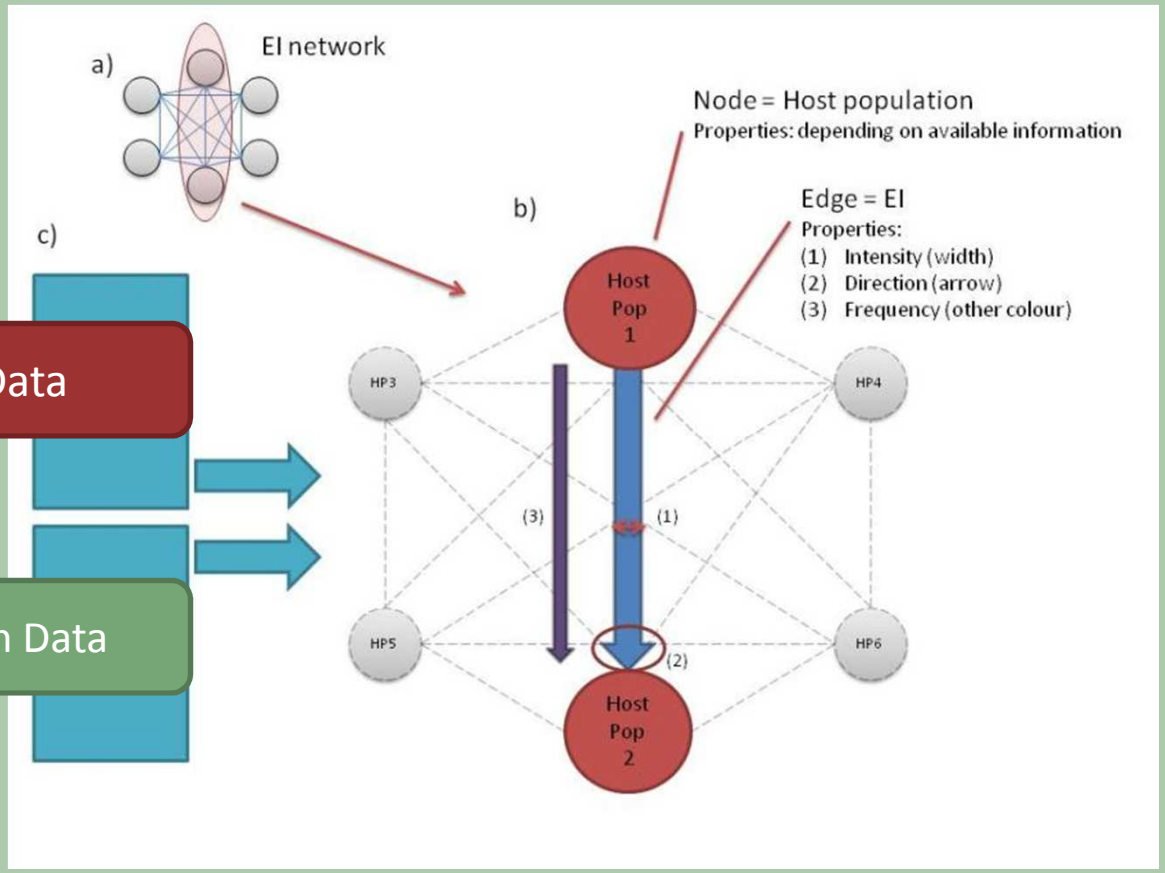
- Community ecology
  - Presence/absence – Prevalence – Molecular data
  - Statistical tools e.g., controlling for host phylogeny



Information on: *Intensity & Direction of EIs*

Integrating tool

Network analysis as an integrative tool



Health et al. 2008
Bansal et al. 2007
Luke et al. 2007

Example

Pathogen Approach

e.g., Rodent community and their pathogens in SE Asia

- Theoritical example based on collected and literature data
- Ecosystems of South East Asia (Laos, Cambodge, Thailand)
- Target species: Human species
- Host populations: rodent community in SouthEast Asia
  - Presence-Absence data for:

    - Rodents in particular ecosystems
    - 34 macroparasites of rodents, pres/abs in humans from literature
    - 8 microparasites of rodents, , pres/abs in humans from literature

    (Chasiri et al. 2010, Herbreteau et al. Unpublished)

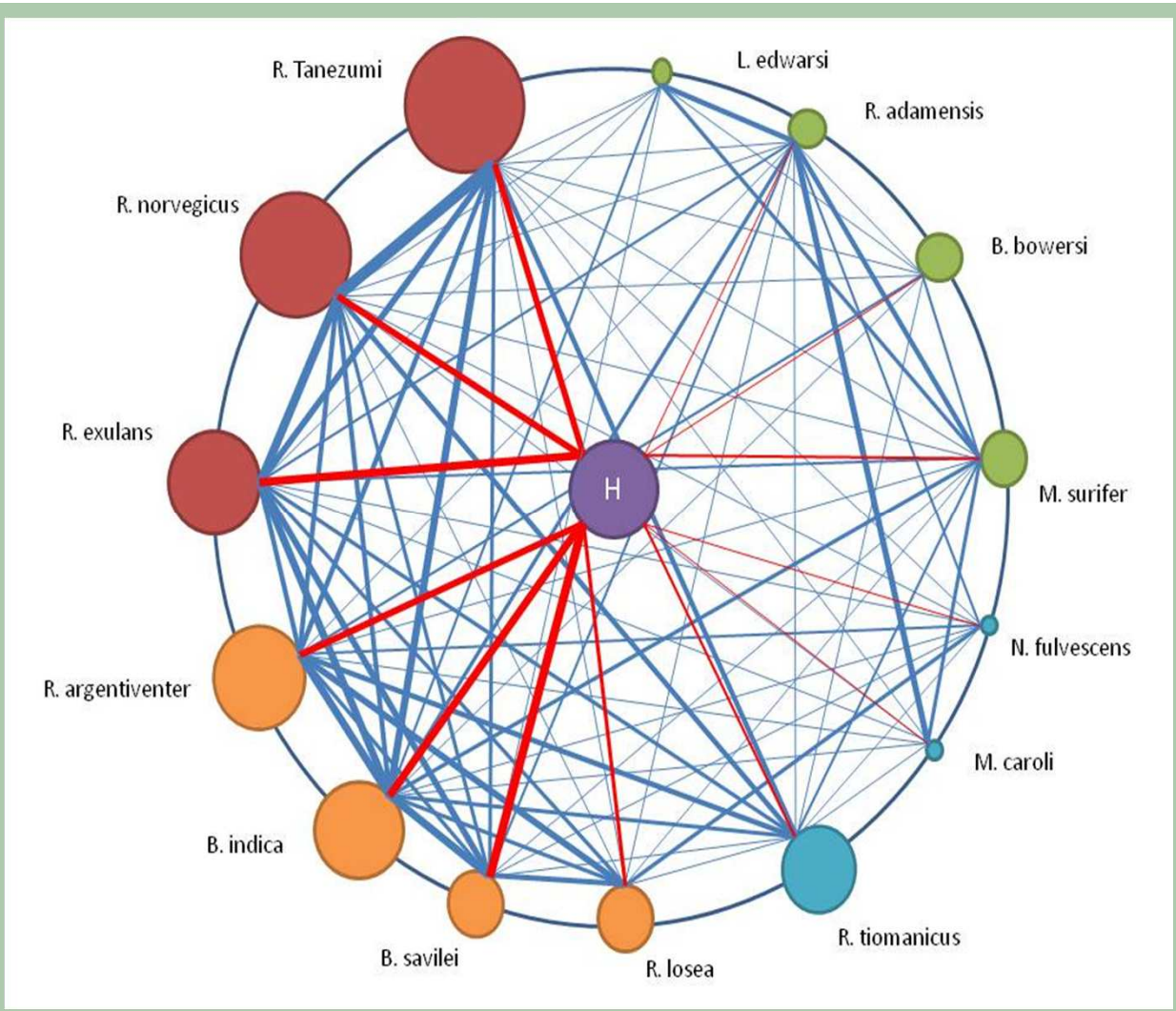
Pathogen Approach

Matrix of EIs

Target sp.	*Homo sapiens*
Rodent sp.	*Bandicota indicata (Bi), Bandicota savilei (Bs), Verylmys bowersi (Bb), Leopoldamys edwardsi (Le), Maxomys surifer (Ms), Mus caroli (Mc), Niviventer fulvescens (Nf), Rattus andamanensis (Ran), Rattus argentiventer (Rar), Rattus exulans (Re), Rattus losea (Rl), Rattus norvegicus (Rn), Rattus tanezumi (Rta), Rattus tiomanicus (Rti)*
Macroparasite sp.	*Hymenolepis nana, Rodentolepis sp., Taenia sp., Taenia taeniaeformis, Ascaris sp., Gnathostoma malaysiae, Ganguleterakis spumosa, Citellina levini, Syphacia muris, Physaloptera sp., Rictularia sp., Rictularia tani, Gongylonema neoplasticum, Mastophorus muris, Protospiura-Mastophorus sp., Cyclodontostomum purvisi, Strongyloides ratti, Strongyloides sp., Nippostrongylus brasillensis, Nippostrongylus sp., Orientostrongylus tenorai, Echinostoma ilocanum, Echinostoma malayanum, Notocotylus sp., Quinqueseralis quinqueseralis, Gastrodiscoides hominis, Centrocestus sp.*
Microparasite sp.	Leptospira, scrub typhus, Bartonella, hanta virus, herpes virus, LCM virus, Trypanosoma, rabies virus.

	Nb Para	Bi	Bs	Bb	Le	Ms	Mc	Nf	Ran	Rar	Re	Rl	Rn	Rta	Rti	Hs
Bi	**16**															
Bs	**9**	0,47														
Bb	**7**	0,15	0,00													
Le	**3**	0,12	0,09	0,11												
Ms	**8**	0,20	0,06	0,15	0,22											
Mc	**2**	0,06	0,00	0,00	0,00	0,25										
Nf	**2**	0,06	0,10	0,00	0,00	0,00	0,00									
Ran	**5**	0,24	0,17	0,09	0,33	0,30	0,40	0,17								
Rar	**17**	0,43	0,24	0,14	0,00	0,09	0,06	0,12	0,10							
Re	**18**	0,48	0,35	0,00	0,11	0,13	0,05	0,05	0,15	0,30						
Rl	**9**	0,19	0,29	0,00	0,00	0,06	0,00	0,22	0,08	0,37	0,23					
Rn	**23**	0,34	0,23	0,03	0,04	0,07	0,04	0,09	0,08	0,33	0,52	0,19				
Rta	**32**	0,45	0,24	0,11	0,06	0,14	0,03	0,06	0,09	0,32	0,47	0,17	0,72			
Rti	**13**	0,26	0,05	0,05	0,00	0,17	0,07	0,07	0,06	0,36	0,24	0,10	0,33	0,36		
Hs	**15**	0,48	0,50	0,05	0,06	0,21	0,06	0,06	0,18	0,28	0,43	0,20	0,41	0,42	0,17	

Matrix of shrared community of pathogens between pairs of hosts
(Jaccard Index=N_{common}/N_{total})



Epidemiological Interaction Network

- EIN skewed on the left
- Rodent Sp with the highest EI have the highest EI with humans
- Other species can be identified as potential link between environments:
  - *R. tiomanicus* could be a bridge species between forest environment and human settlements
- Provide more information than a separate analysis

Human settlement
Rice fields
Modified forest and agricultural areas
Primary forest

Conclusions

- Perspective:
  - New concepts and approaches open new perspective for exploring disease transmission ecology
  - Are there common properties for EIs → across ecosystems
    → across pathogens
  - To which extent can we assume that transmission pathways used by some pathogens will be used by emerging pathogens?
  - How can social sciences be incorporated in this framework?

- From a practical point of view, this operational framework can be used:
  - to select host populations to survey for EIDs (EFG concept)
  - to develop an early detection surveillance based on available knowledge (in resource limited environment) targeting the most probable transmission pathways

Conclusions

We believe that this operational framework could be an integrative tool for “One Health” studies exploring complex processes and systems at the Human/Livestock/Wildlife interface

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