Impacts of biodiversity on disease risk

Dr. Helen Esser
Wildlife Ecology & Conservation Group
Wageningen University & Research

Zhu et al. (2000) Nature

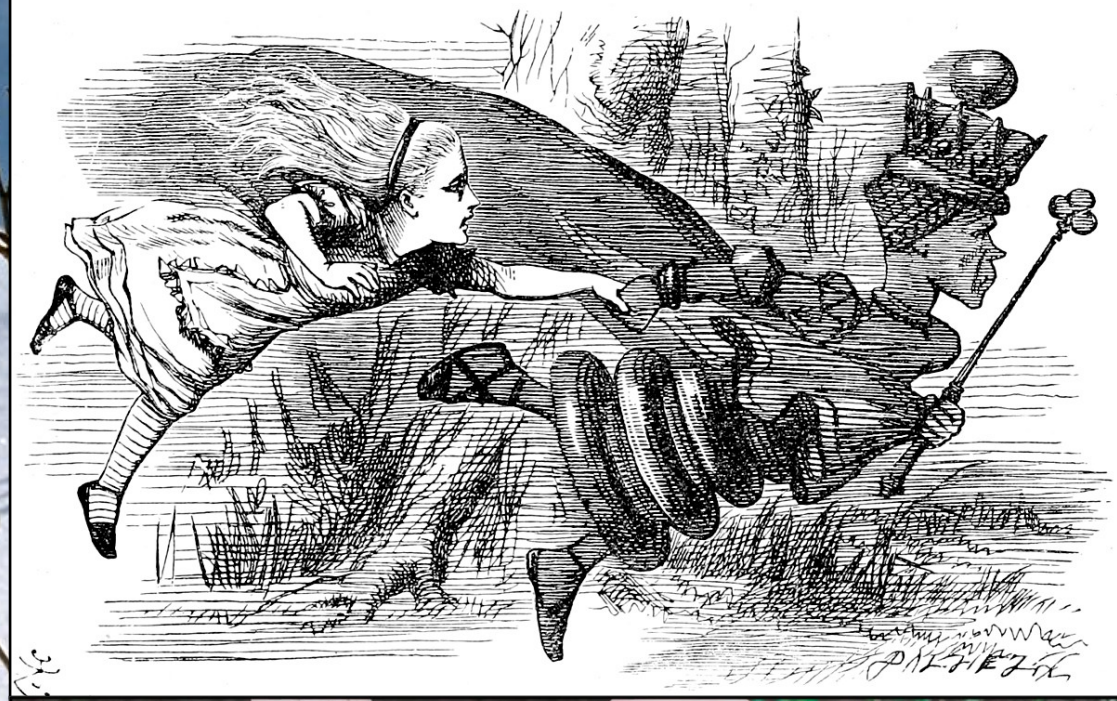
Intercropping of rice varieties:

89% higher yield
94% less severe blast disease

Mechanisms

- Reduced spread
- Improved microclimate
- Induced resistance by other (non-)pathogenic spores

- Plant-herbivore interactions
- Red Queen hypothesis
- Hygiene hypothesis



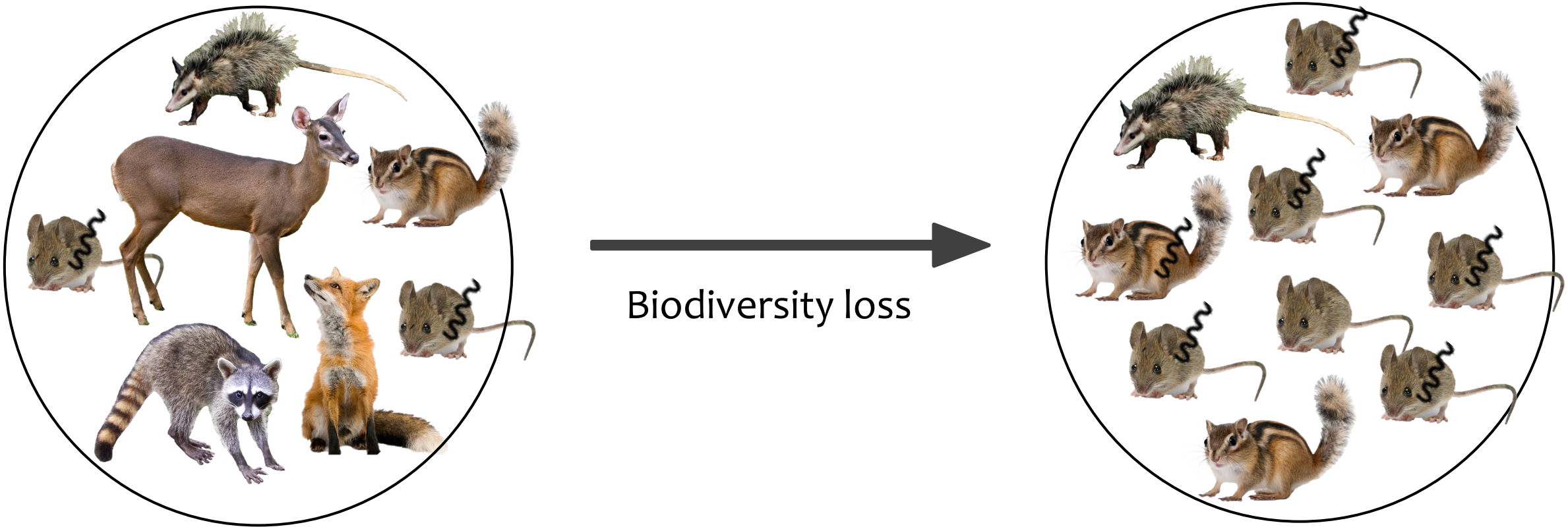
High biodiversity

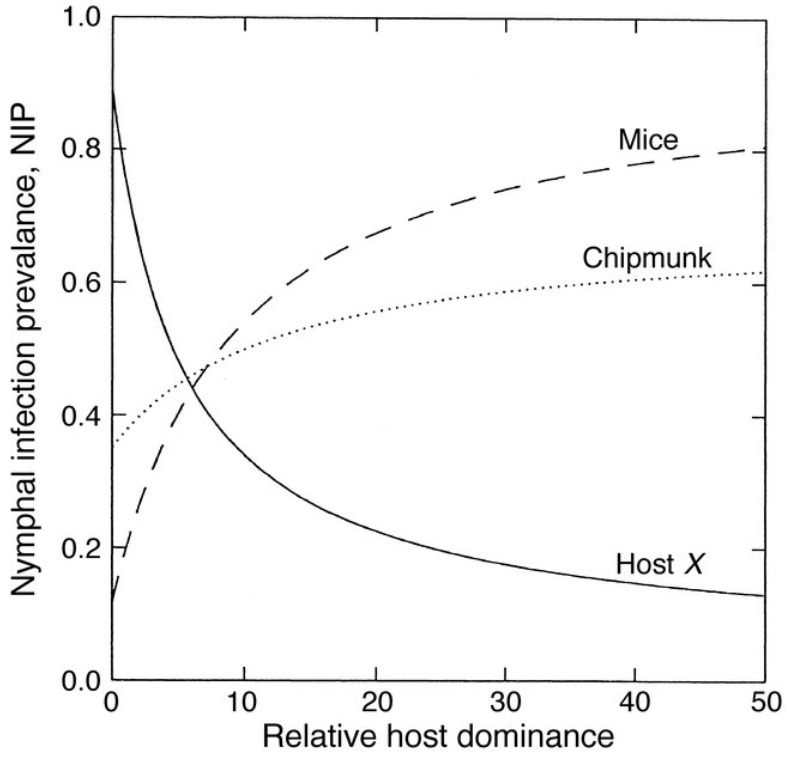
- Many incompetent hosts
- Low disease risk

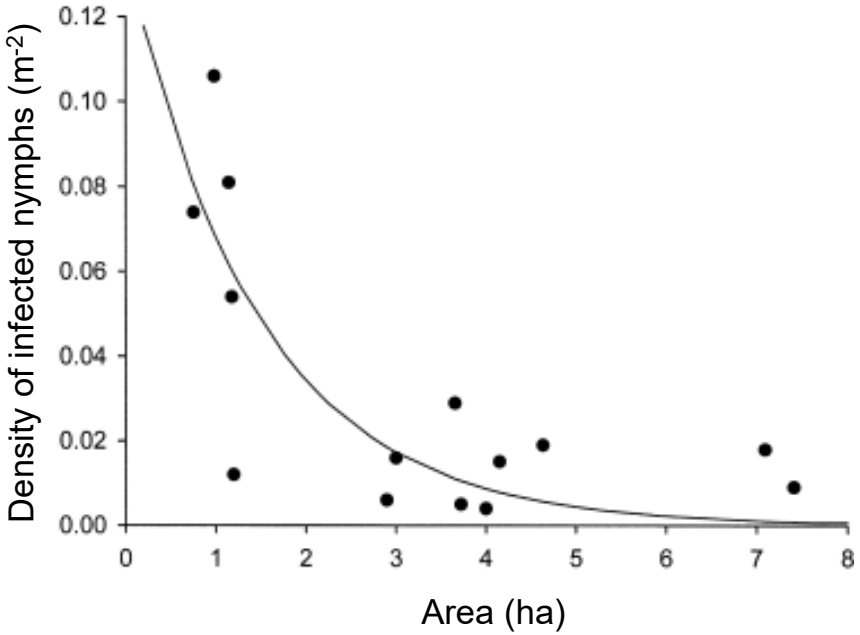
Low biodiversity

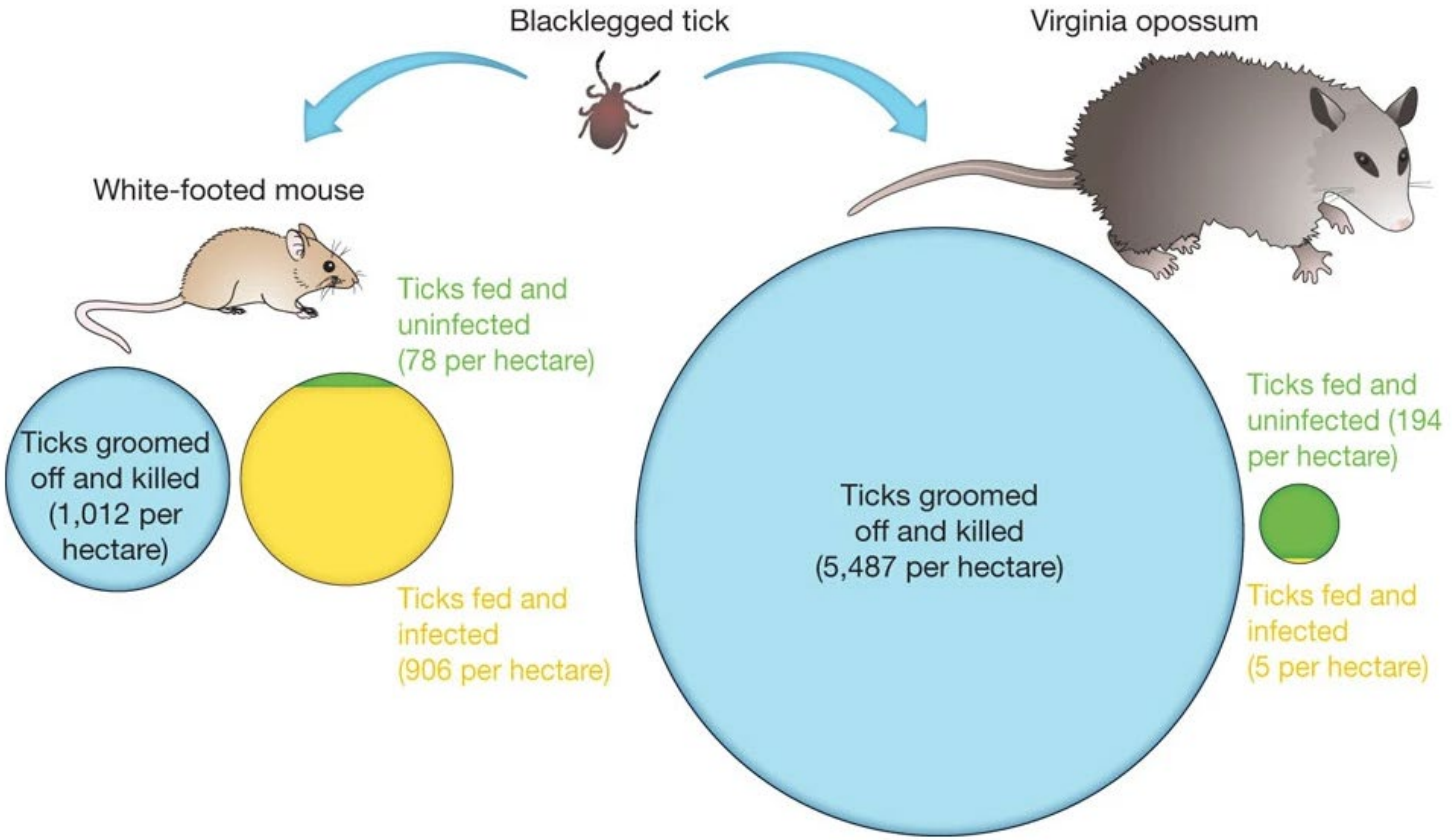
- Many competent hosts
- High disease risk

"Dilution effect"









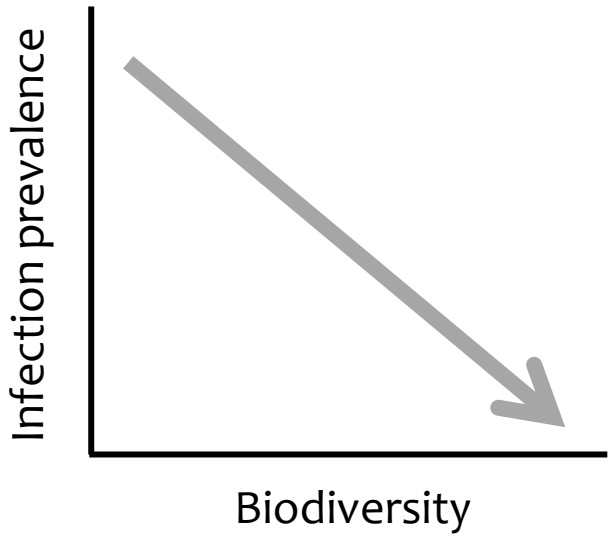
Keesing et al. (2010) Nature

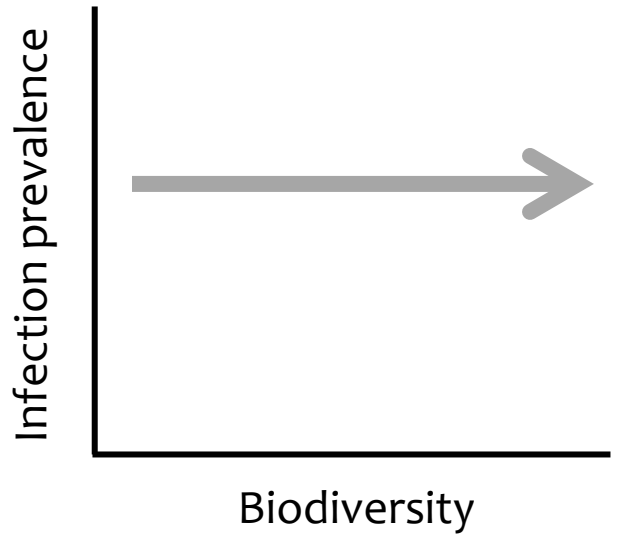
Allan et al. (2003) Conserv. Biol.

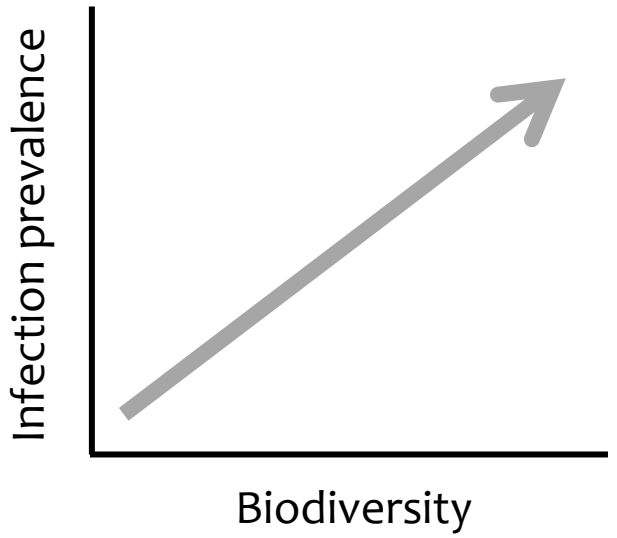
Schmidt & Ostfeld (2001) Ecology

Generality of the dilution effect

Other studies found negative, positive, or no biodiversity-disease relationships







"Dilution effect"

"Amplification effect"

It's a myth that protection against disease is a strong and general service of biodiversity conservation: Response to Ostfeld and Keesing

TREE-1706; No. of Pages 2

Letter

Ecology, 95(4),
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Do

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[3]*U.S. Geologi*

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proach for diseas
in this controversy
mission of LD (wh
Borrelia burgdorf

Institute, University of California, Santa Barbara,

536–545
l Society of America

versity protect humans
ectious disease? Reply

WOOD,[1,2,7] KEVIN D. LAFFERTY,[3]
ILLARY S. YOUNG,[5] PETER J. HUDSON[6]
D ARMAND M. KURIS[5]

ect is the sort of idea that everyone
If nature protects humans against
imagine the implications: nature's
allied in terms of *human suffering*
es a potent argument for conserva-
ven to those who would otherwise
upport conservation initiatives. The
tion effect has been recognized by
to make the case for conservation
aims regarding the benefits of nature
human health" (Bauch et al. 2015).
obson (2012) were among the first

Does the dilution effect generally occur in animal diseases?

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(*Received 1 October 2016; accepted 5 December 2016; first published online 11 January 2017*)

SUMMARY

The dilution effect (DE) has been reported in many diseases, but its generality is still highly disputed. Most current criticisms of DE are related to animal diseases. Particularly, some critical studies argued that DE is less likely to occur in complex environments. Here our meta-analyses demonstrated that the magnitude of DE did not differ between animal *vs* plant diseases. Moreover, DE generally occurs in all three subgroups of animal diseases, namely direct-transmitted diseases, vector-borne diseases and diseases caused by parasites with free-living stages. Our findings serve as an important contribution to understanding the generality of DE.

Key words: Diversity–disease relationship, host species diversity, vector-borne disease, direct-transmitted disease, parasite with free-living stage.

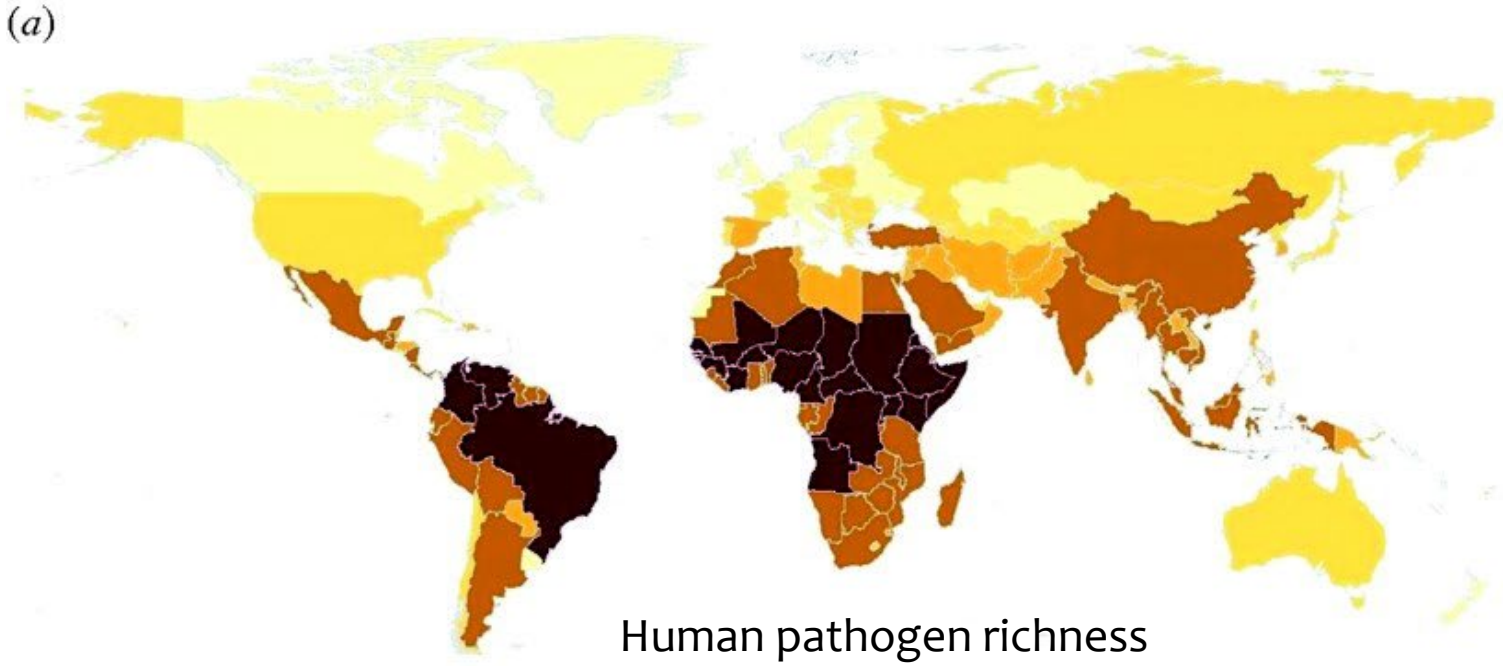
INTRODUCTION

Host diversity has been postulated to influence transmission risk of infectious diseases (Johnson & Thieltges, 2010; Keesing *et al*. 2010, 2006). In theory, increase in host diversity in communities can either amplify or reduce pathogen transmission through mechanisms such as regulating the abun-

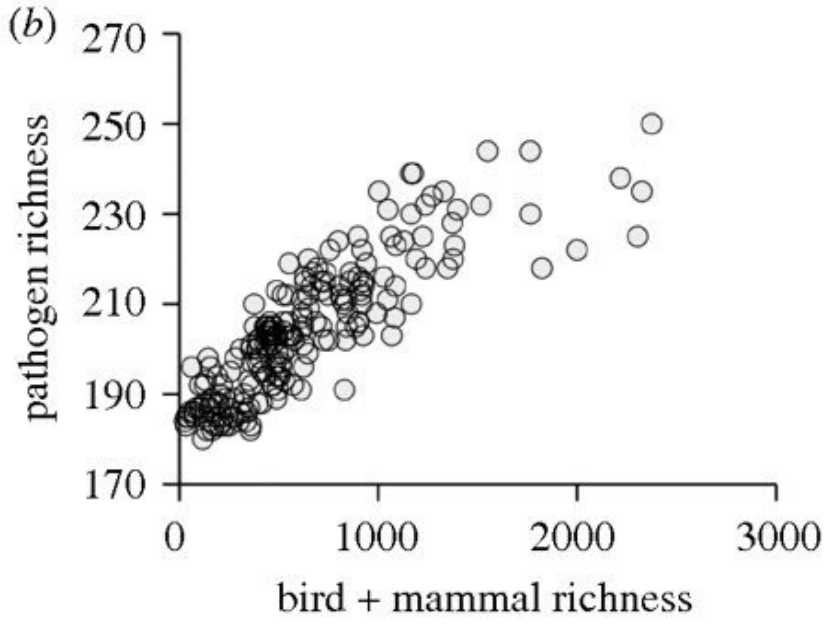
condition of ongoing biodiversity decline (Keesing *et al*. 2006; Ostfeld & Keesing, 2012).

When retrospecting the recent critical studies (Cardinale *et al*. 2012; Randolph & Dobson, 2012; Salkeld *et al*. 2013; Wood & Lafferty, 2013; Young *et al*. 2013; Wood *et al*. 2014), we found an interesting phenomenon that almost all current criticisms of

High host diversity = high pathogen diversity

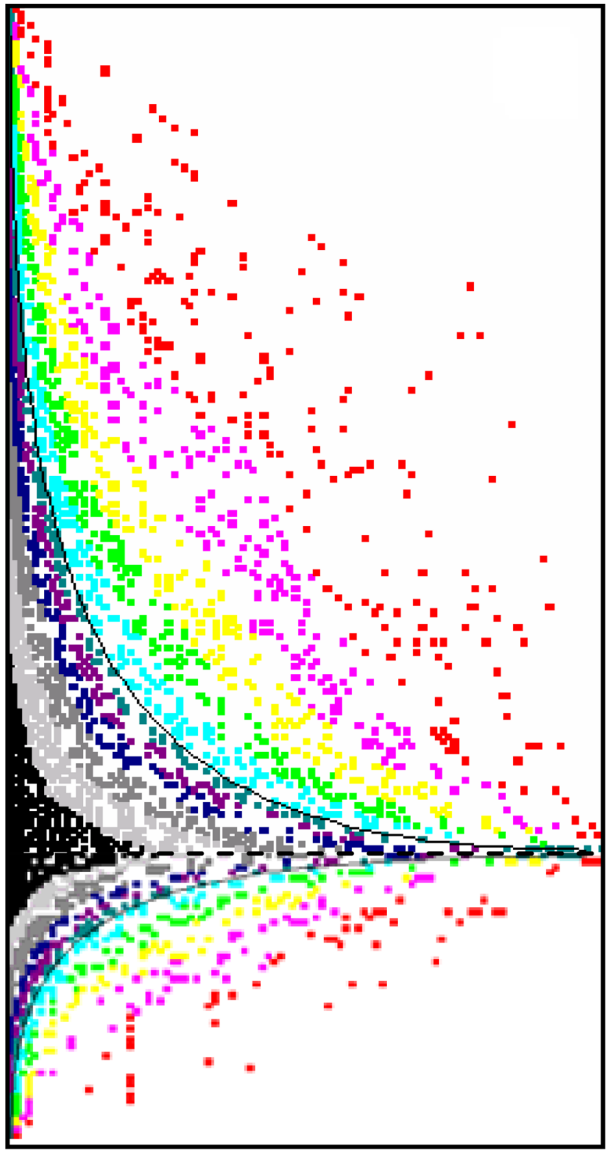


Human pathogen richness

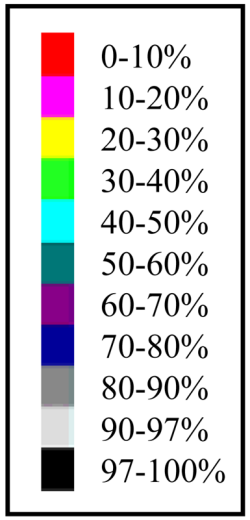


Dunn et al. (2010) Proc. Royal Soc. B

"Diversity begets diversity"



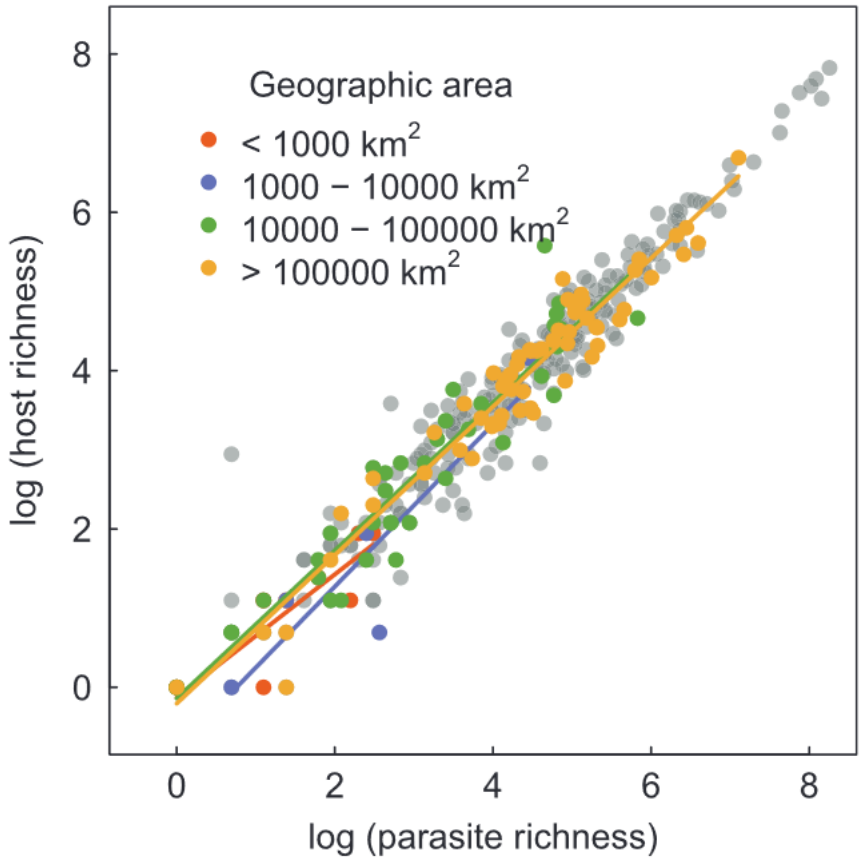
PID species composition



Northern Hemisphere
(172 countries)

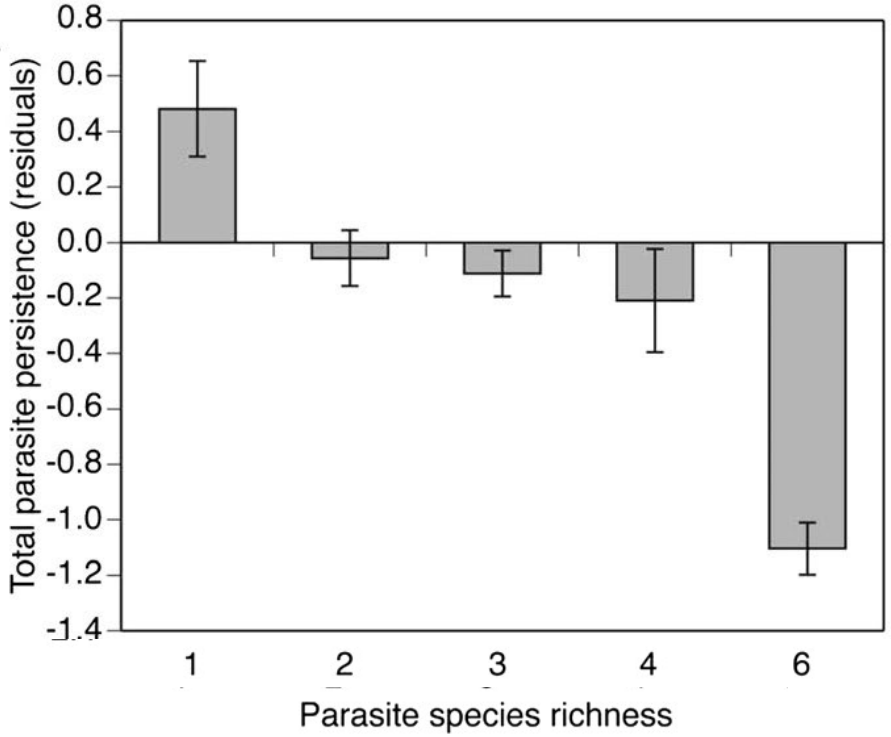
Equator

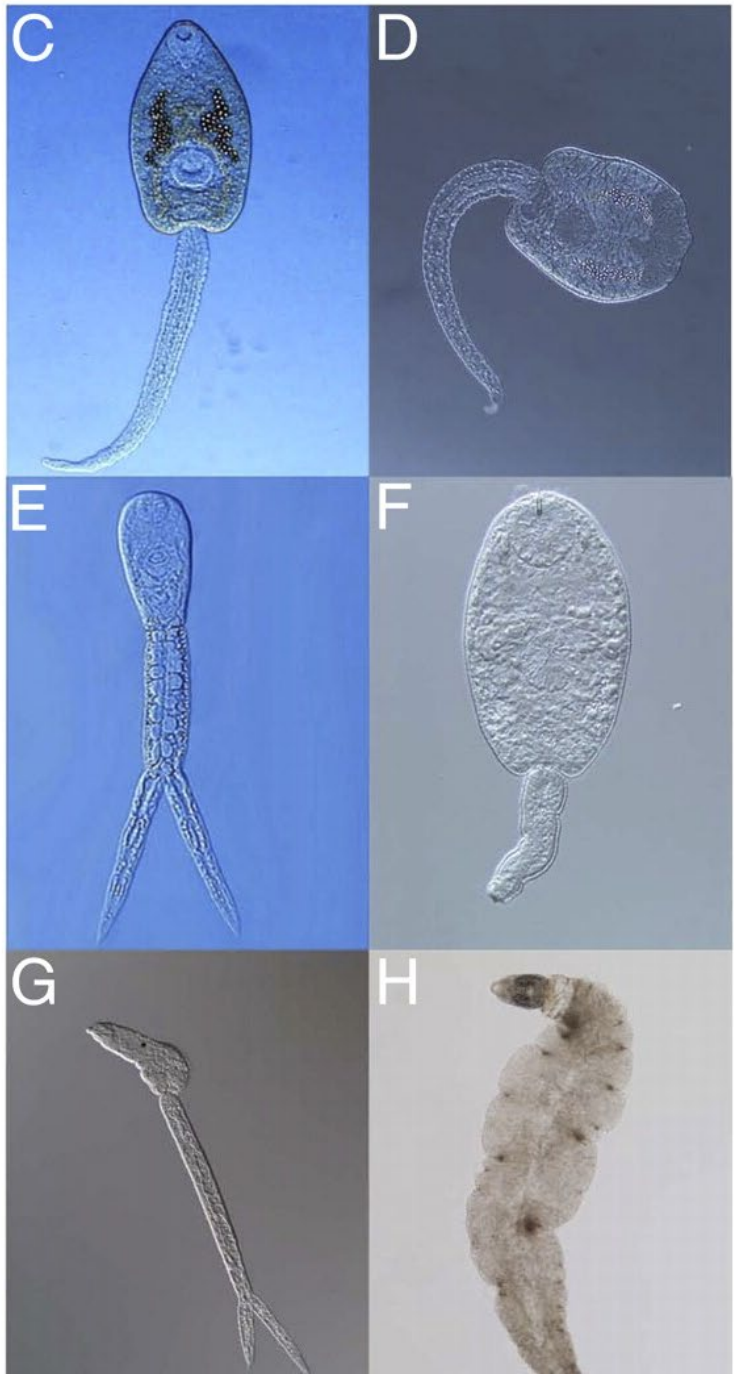
Southern Hemisphere
(52 countries)



Guernier et al. (2004) Plos Biology

Dallas et al. (2017) Glob. Ecol. Biogeogr.



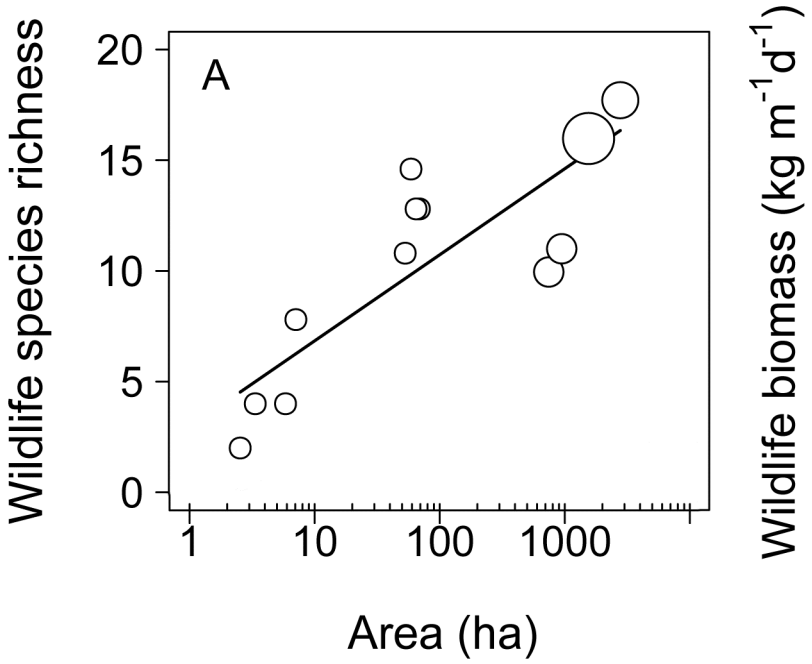


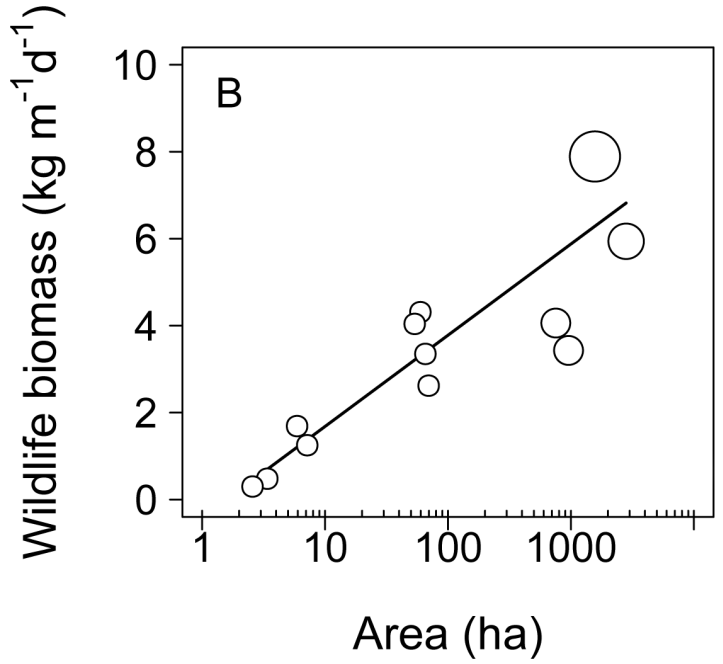
Parasite richness reduced overall infection success of trematodes in Pacific tree frogs

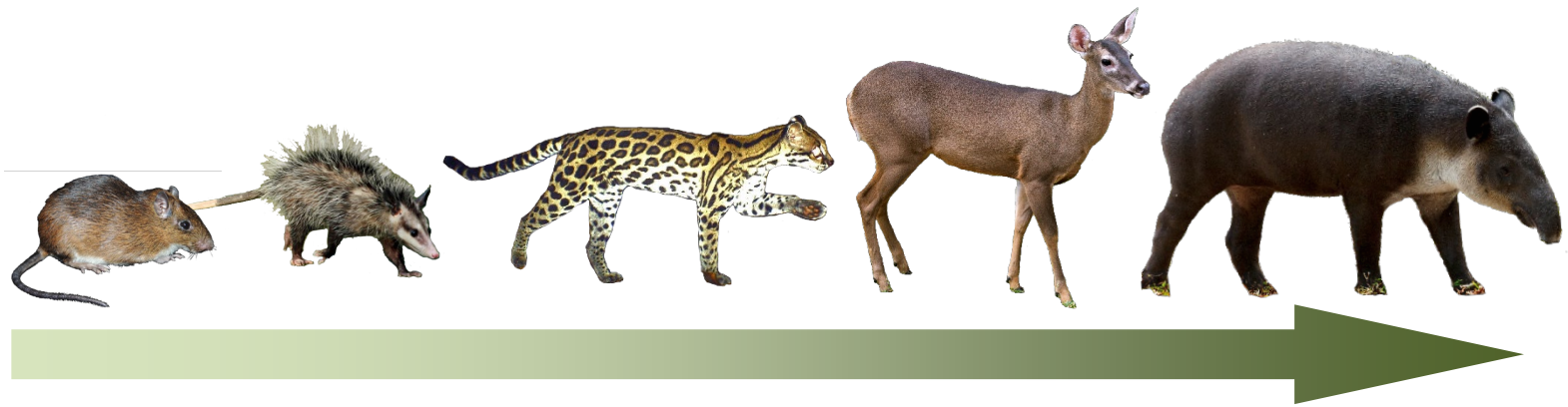
Mechanism: Co-infecting parasites interfere with each other

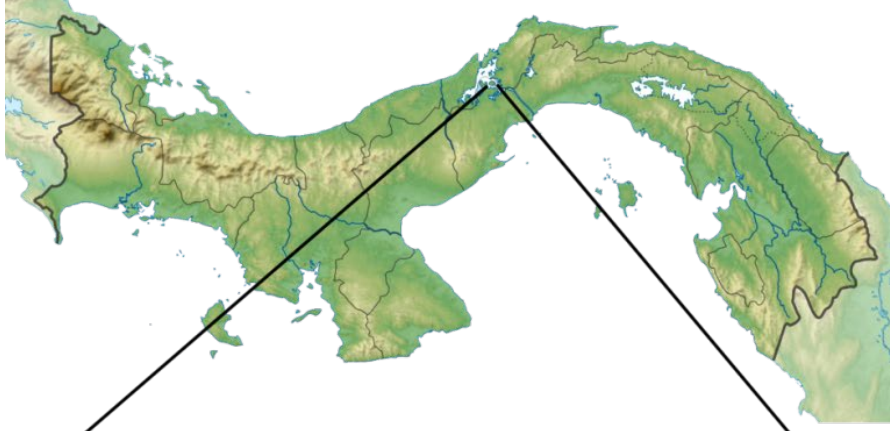
Johnson & Hoverman (2012) PNAS

Larger forests support larger animals and more diverse wildlife communities

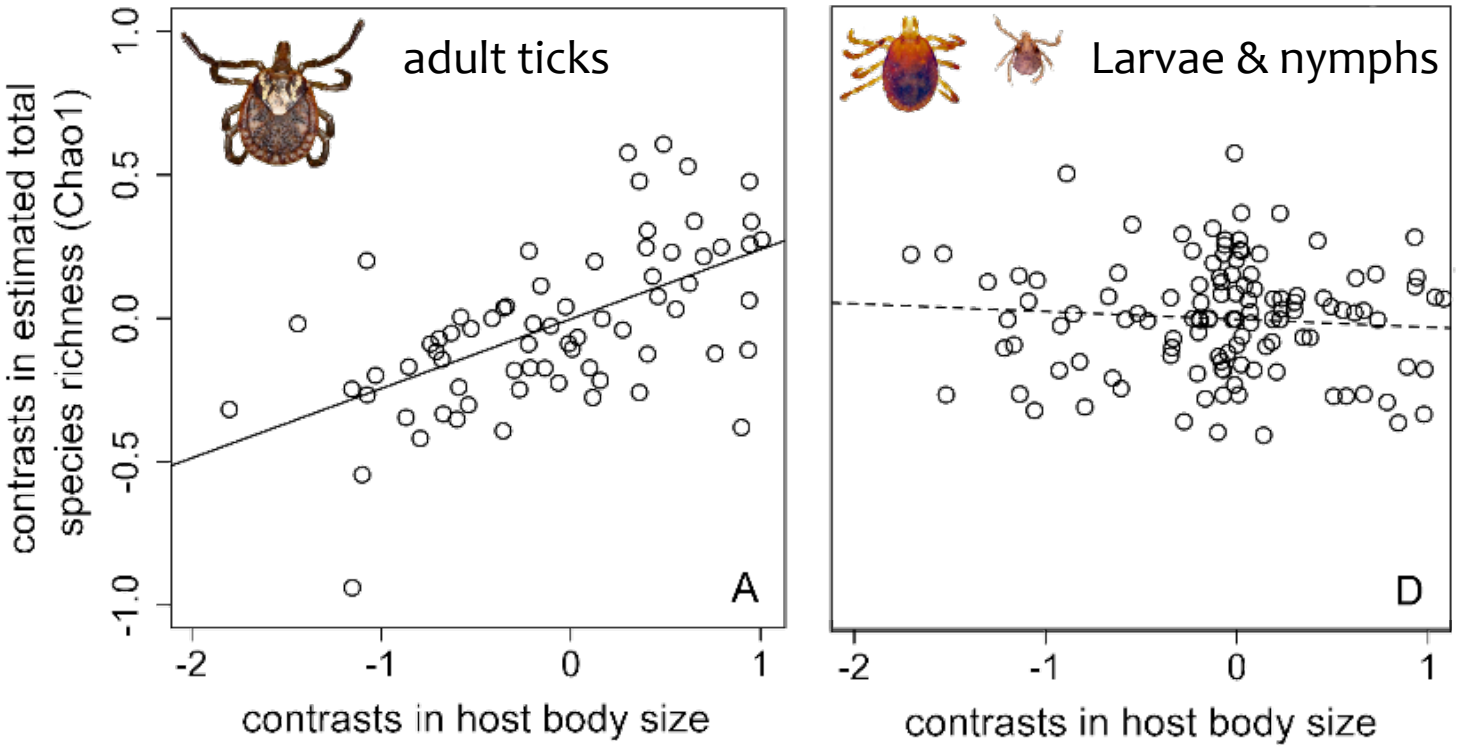


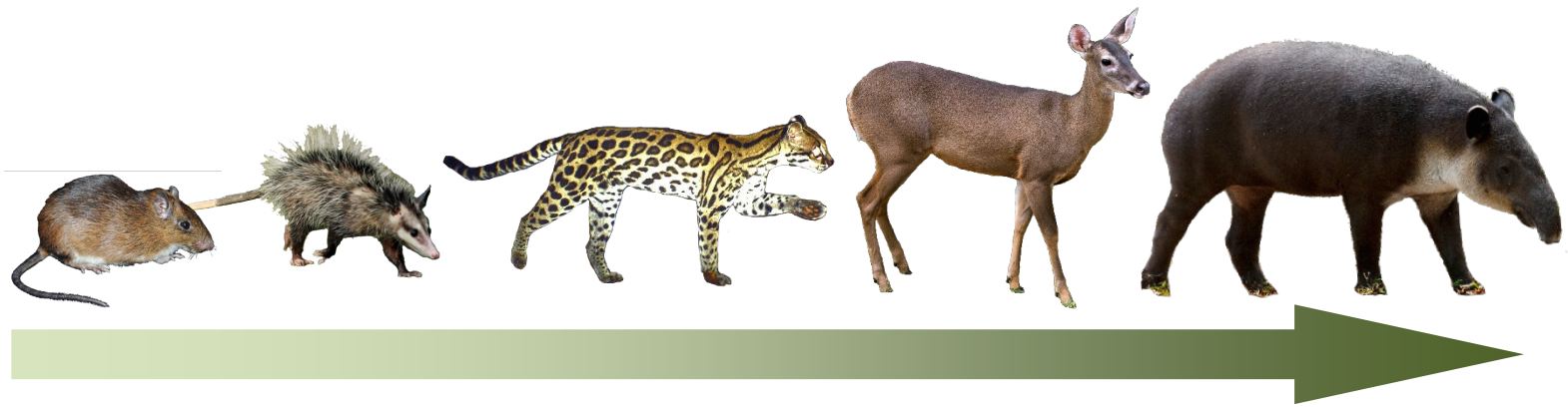


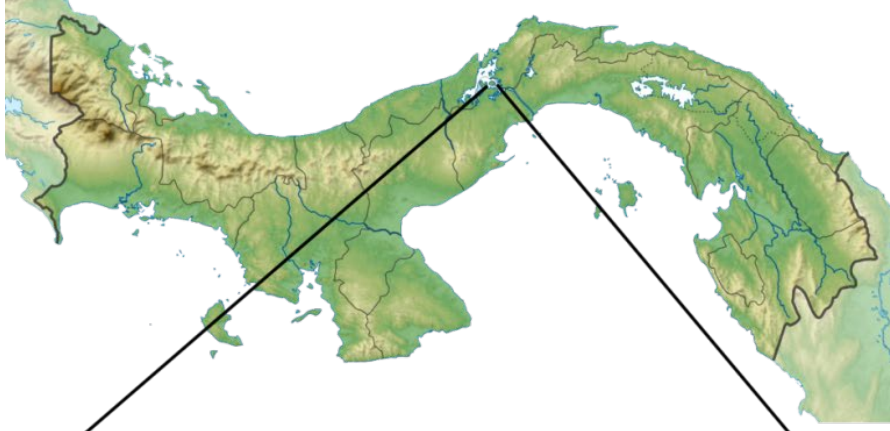


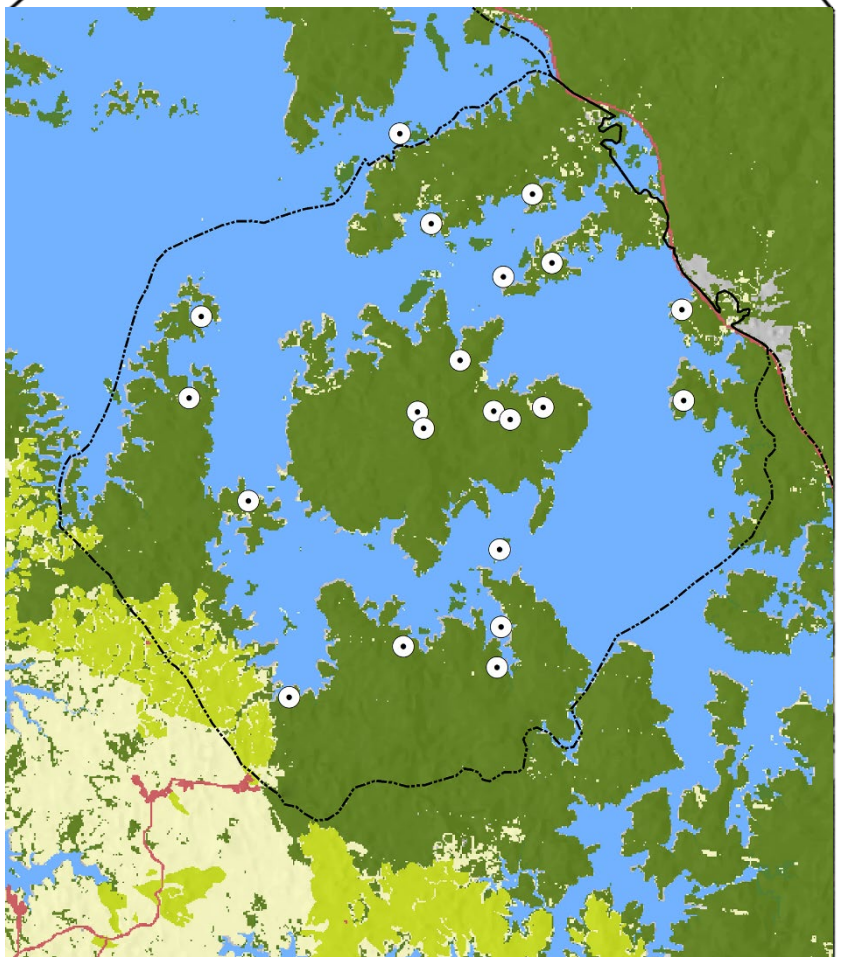


Larger hosts carry more tick species

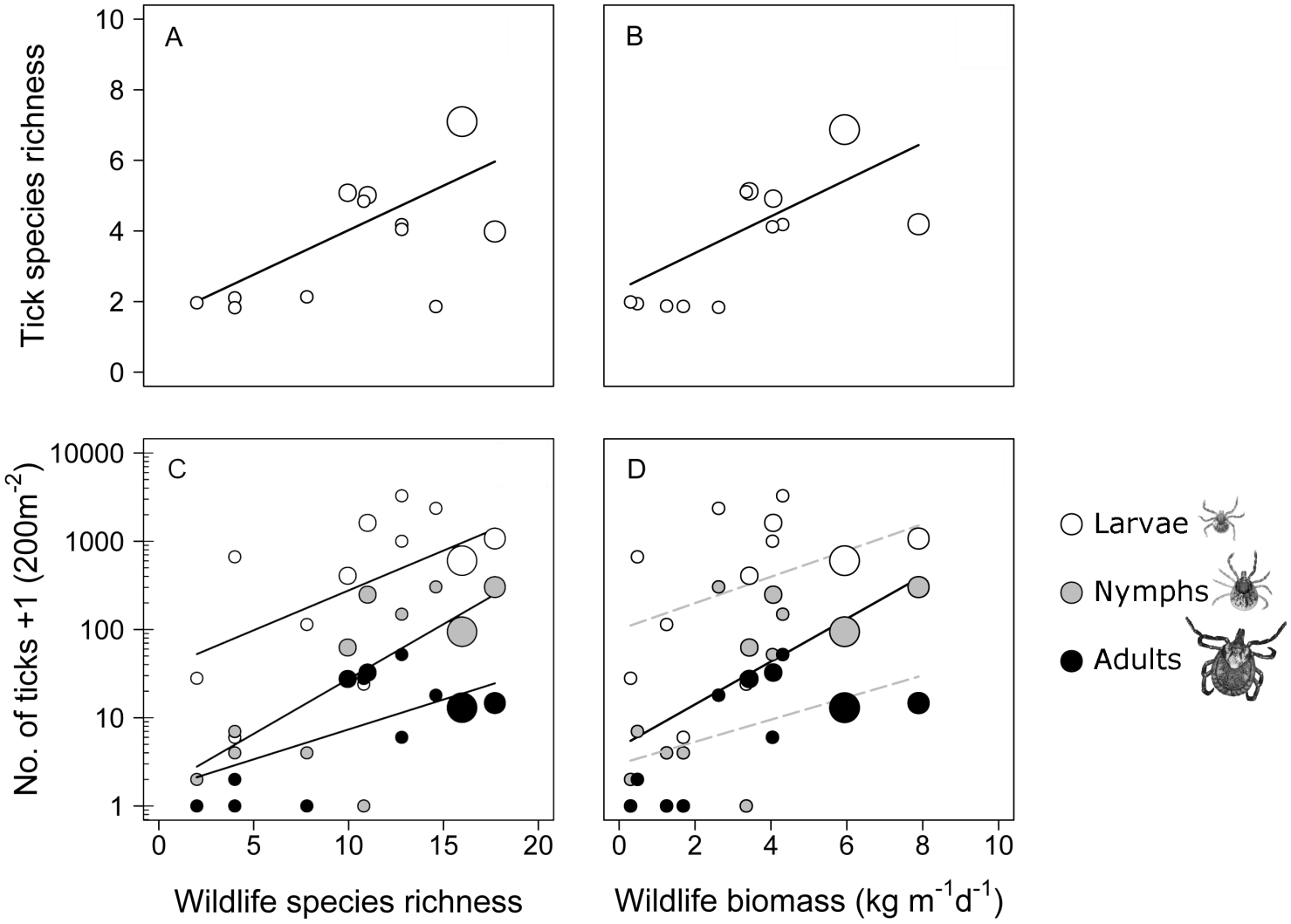


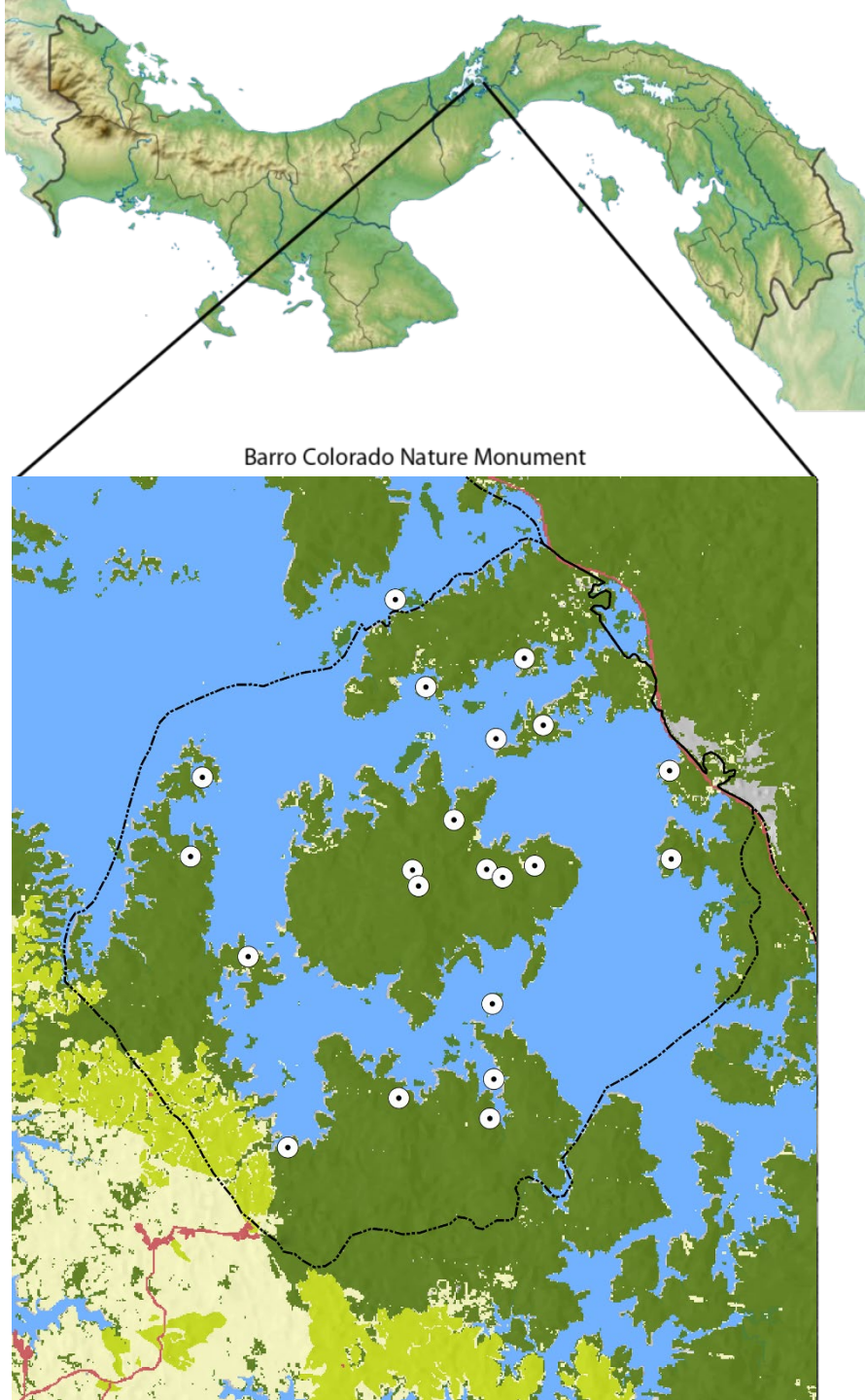




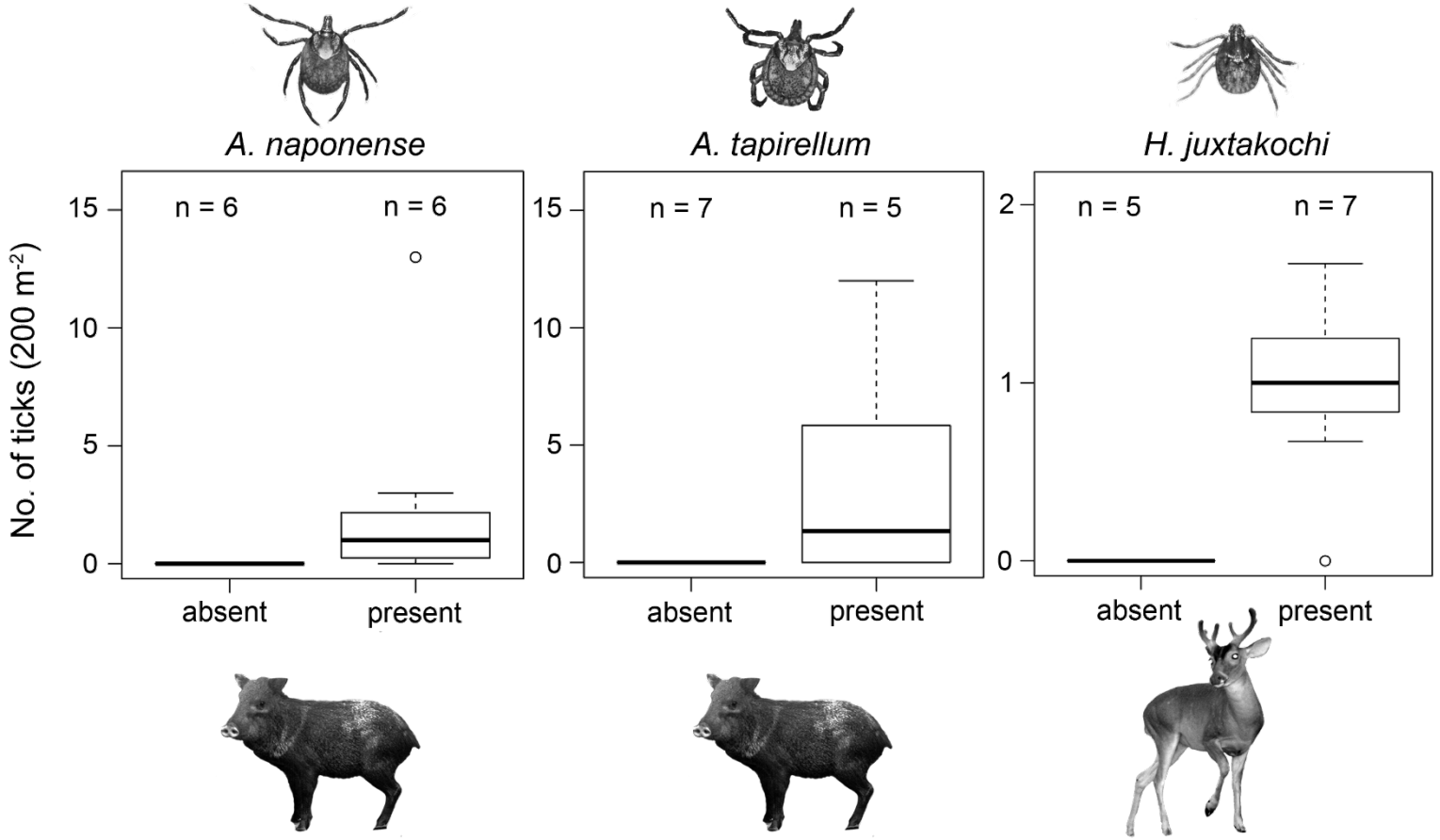


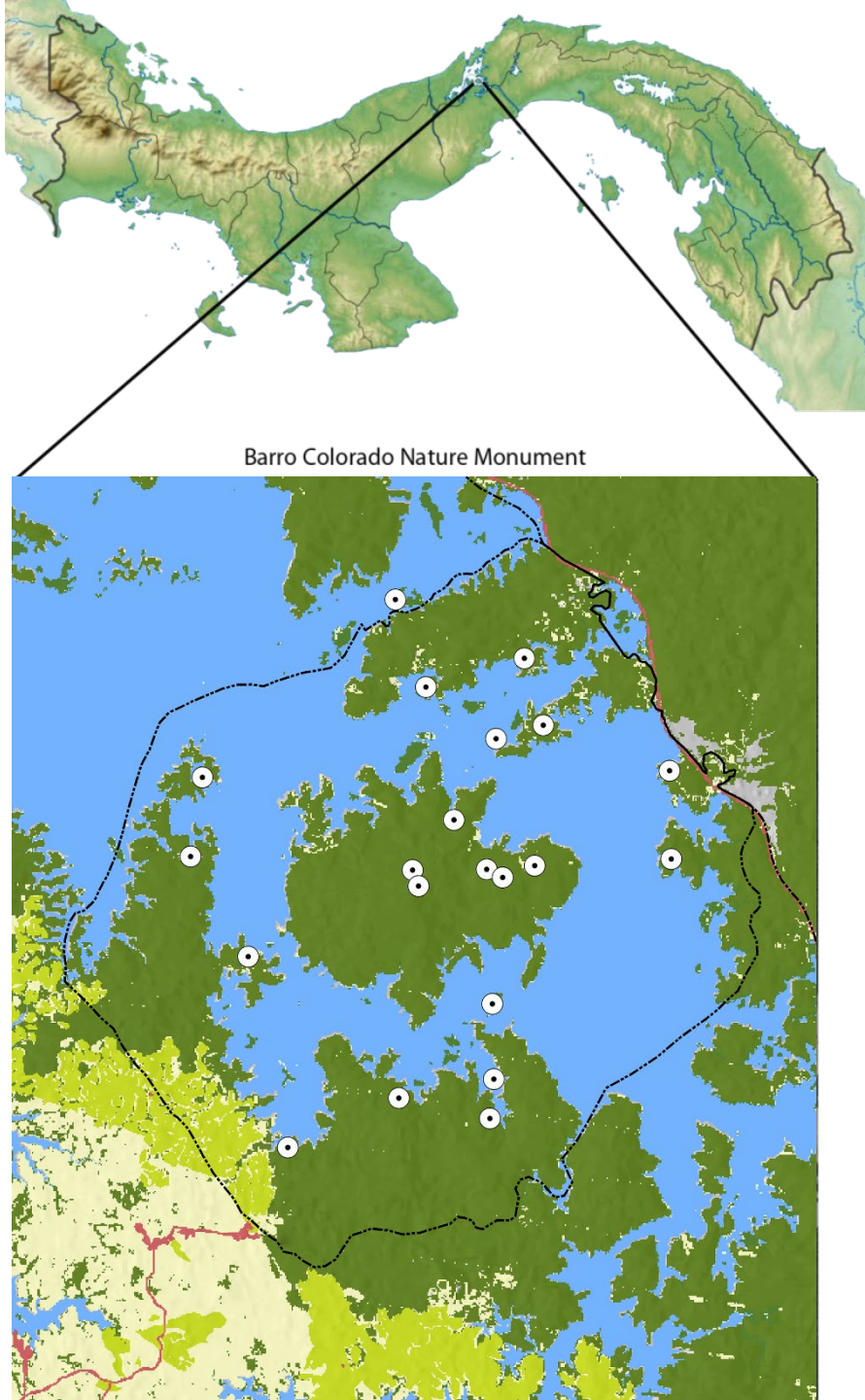
Tick species richness & density increased with wildlife species richness & biomass



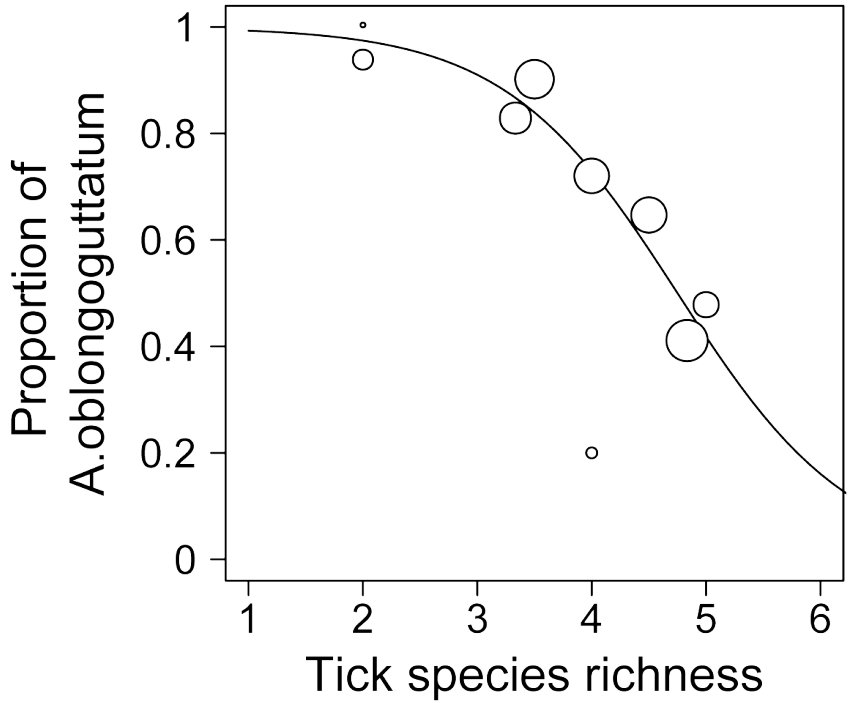


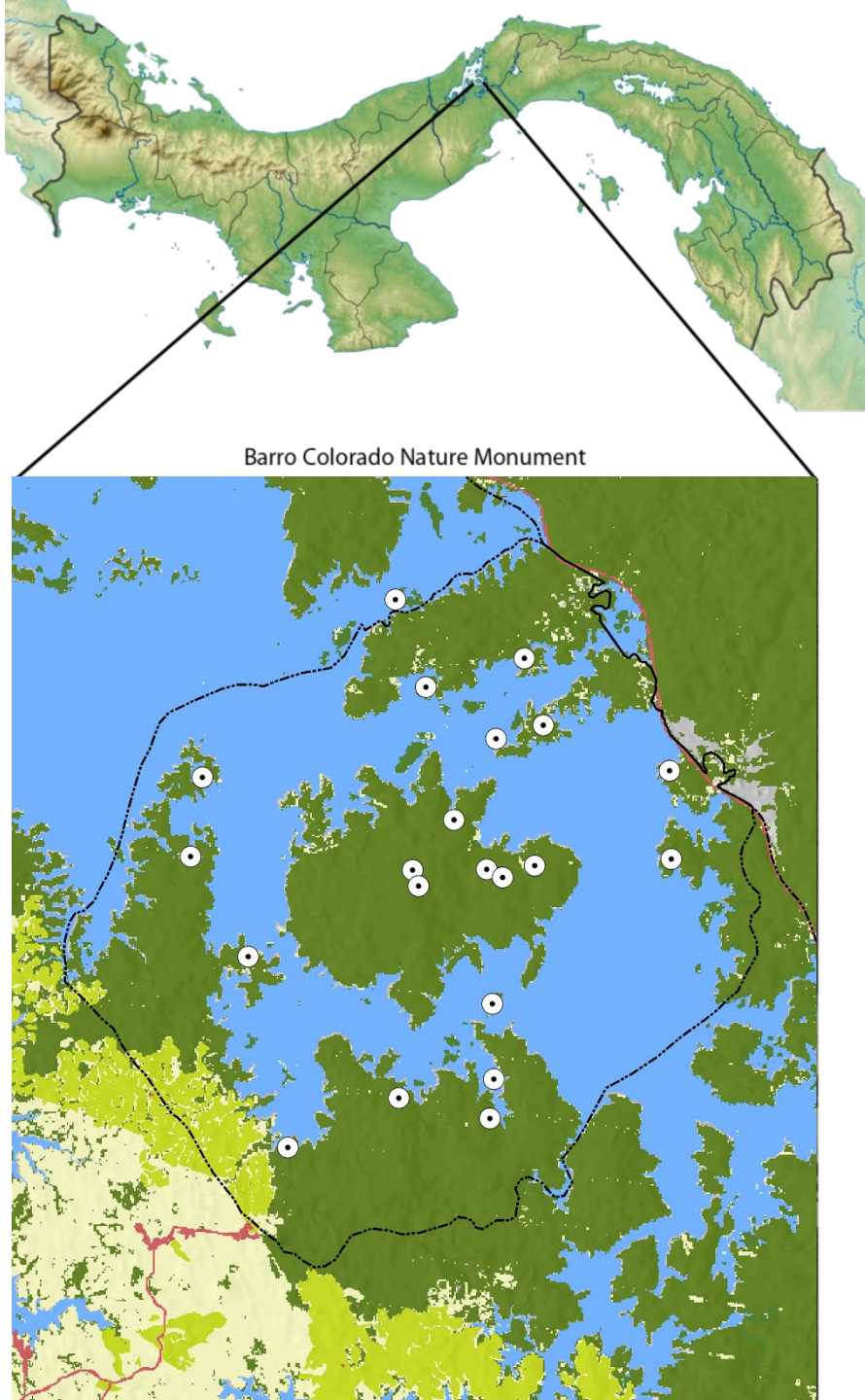
Specialist tick species were only present when their preferred host species was present





In the end, only one generalist tick species remained

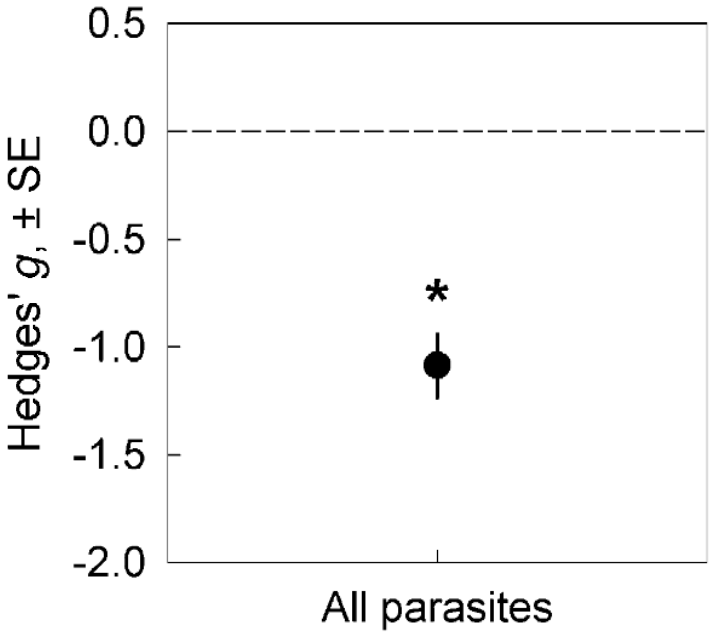




... generalist vectors responsible for most transmission of infectious diseases!

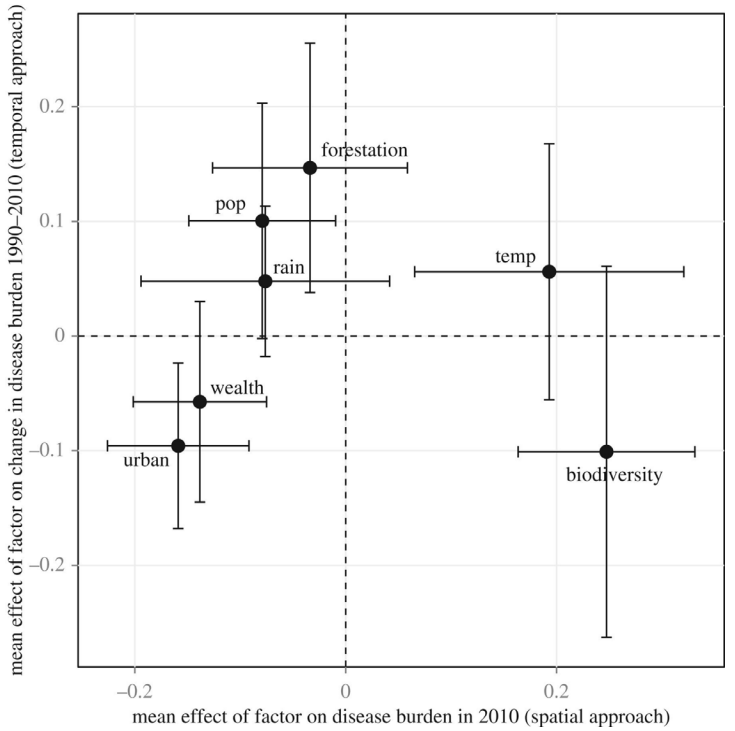
Meta-analyses

Civitello et al. (2015) PNAS
Magnussen et al. (2020) Ecology



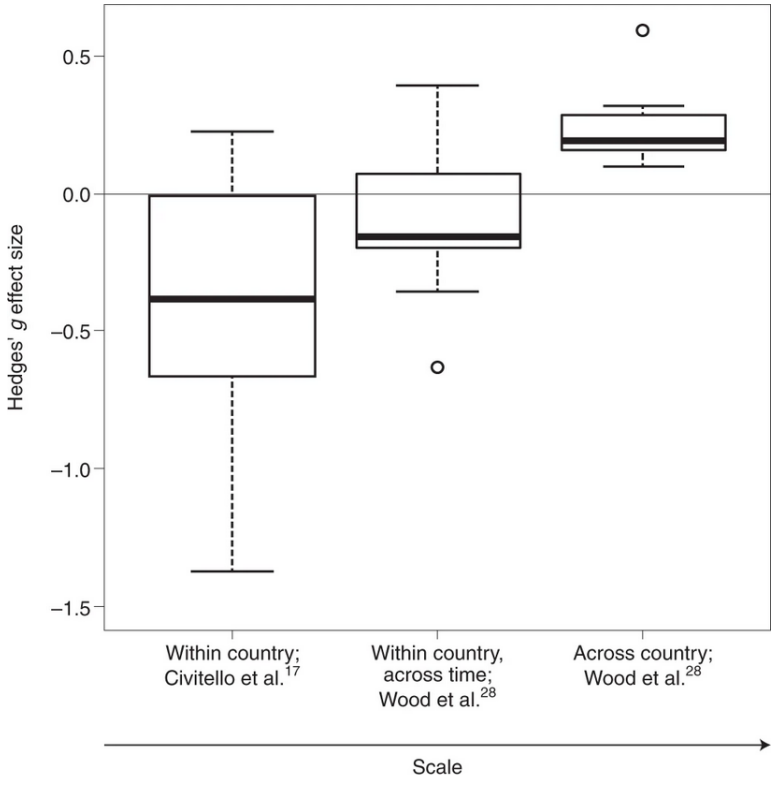
"broad evidence for the dilution effect"

Wood et al. (2015) Philos. Trans. R. Soc.



"no general, large-scale dilution effect"

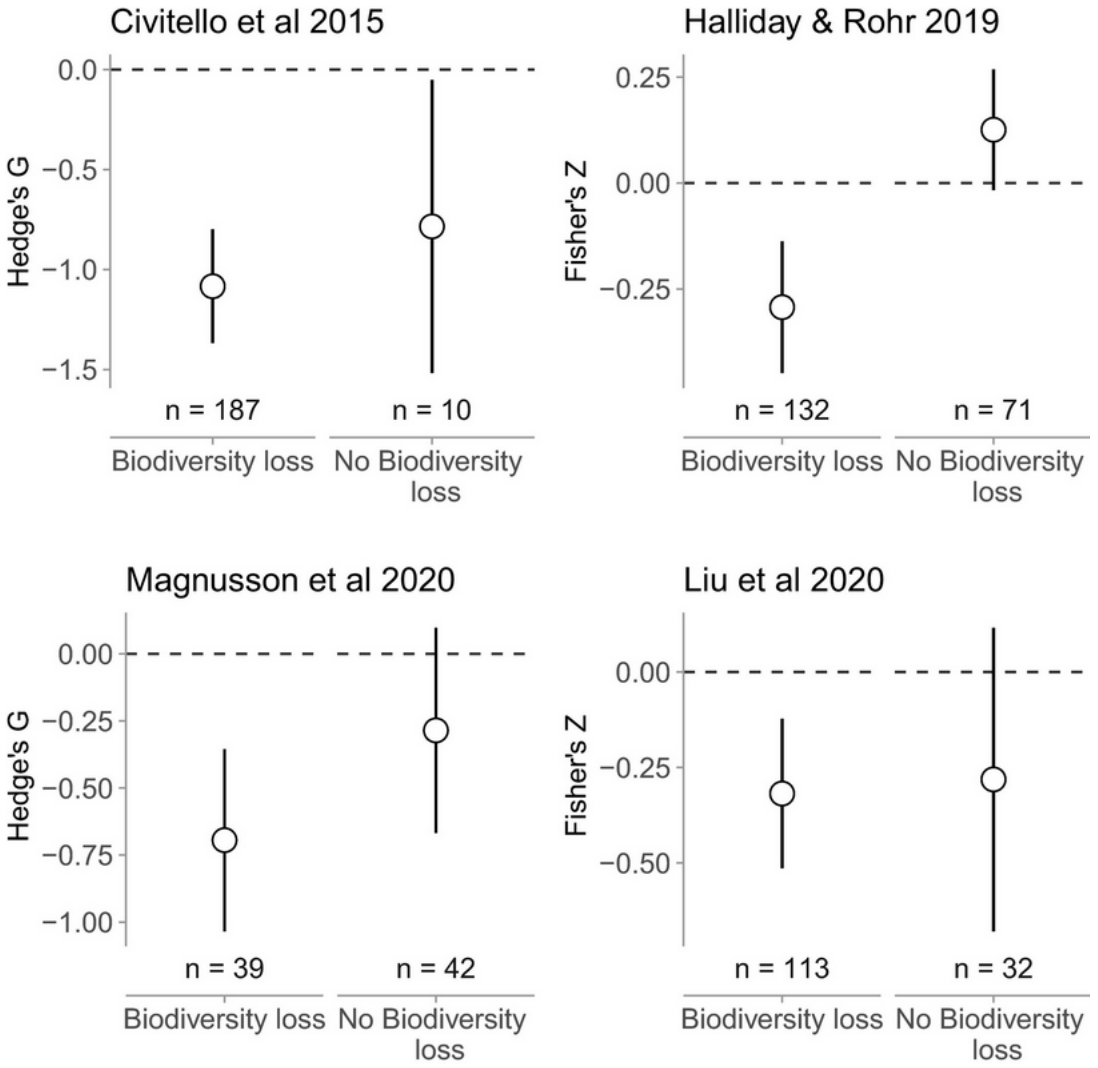
Halliday & Rohr (2019) Nat. Commun.
Rohr et al. (2020) Nat. Ecol. Evol.



"dilution effect is scale-dependent"

Meta-analysis[2]

- dilution effects inconsistent for natural biodiversity gradients,
- but common for gradients of biodiversity loss caused by disturbances



Halliday et al. (2020) Ecol. Lett.

Common ground (1)

Biodiversity should have a greater effect on parasites and pathogens that:

- have complex life cycles
- use multiple (wildlife) hosts
- are vector-borne
- are zoonotic

and not so much on parasites and pathogens that are:

- directly transmitted
- host-specialists

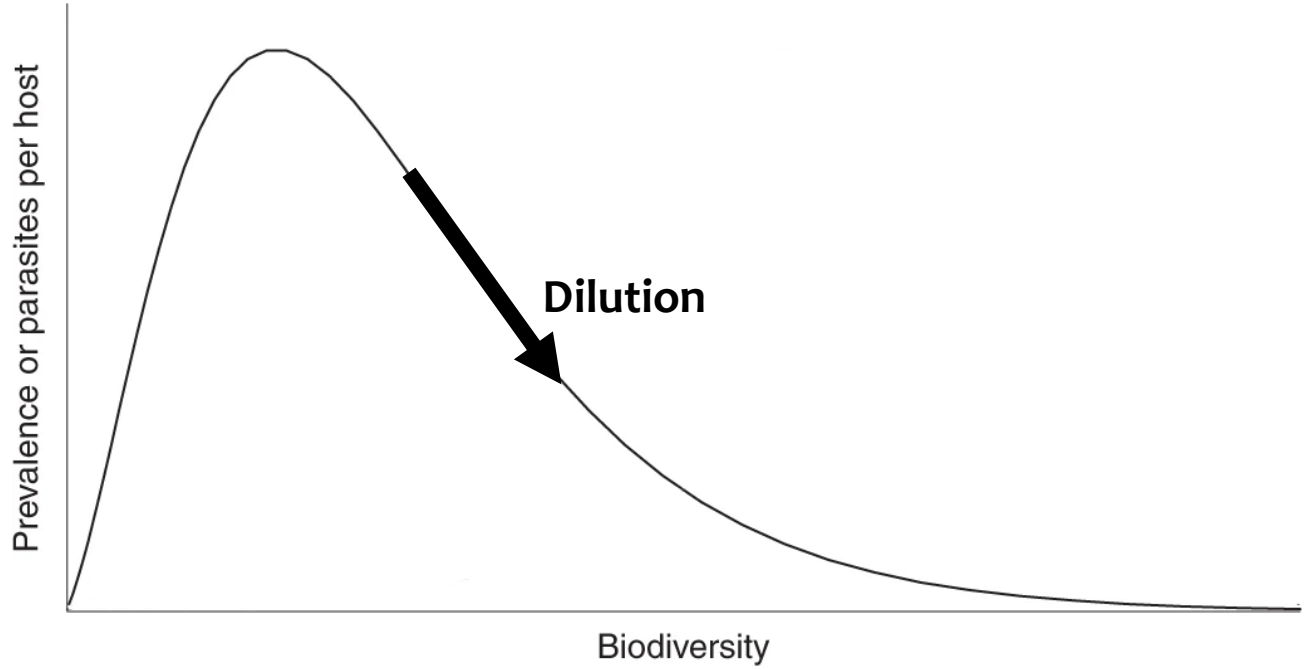
Common ground (2)

The biodiversity-disease relationship can be non-linear

- right-skewed

Fig. 3: Hypothetical relationships between biodiversity and disease risk.

From: Towards common ground in the biodiversity–disease debate



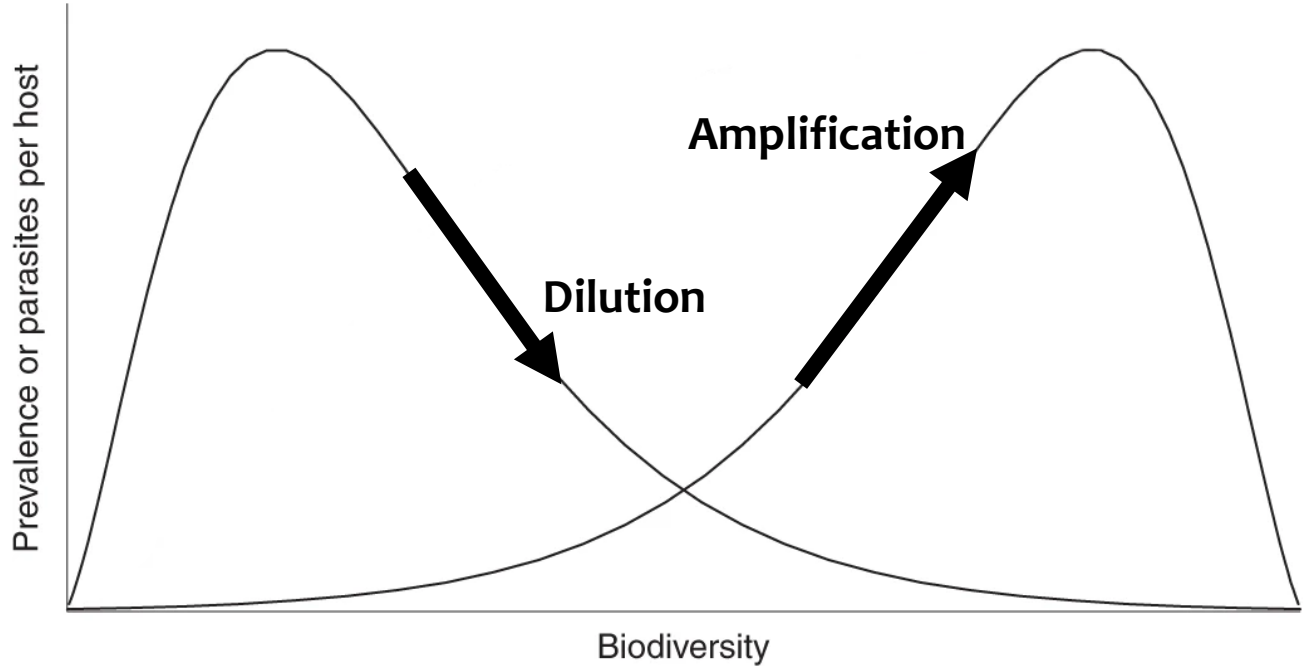
Common ground (2)

The biodiversity-disease relationship can be non-linear

- right-skewed
- left-skewed

Fig. 3: Hypothetical relationships between biodiversity and disease risk.

From: Towards common ground in the biodiversity–disease debate



Common ground (2)

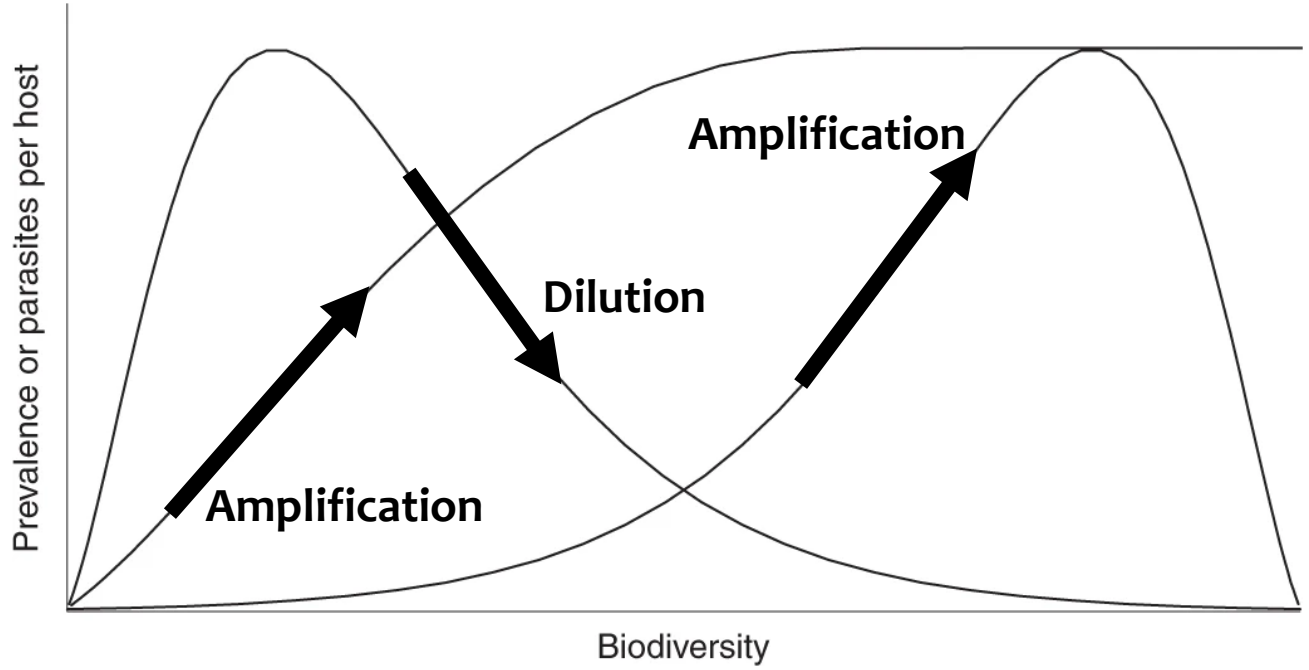
The biodiversity-disease relationship can be non-linear

- right-skewed
- left-skewed
- asymptotic

...and is dependent on the disease system

Fig. 3: Hypothetical relationships between biodiversity and disease risk.

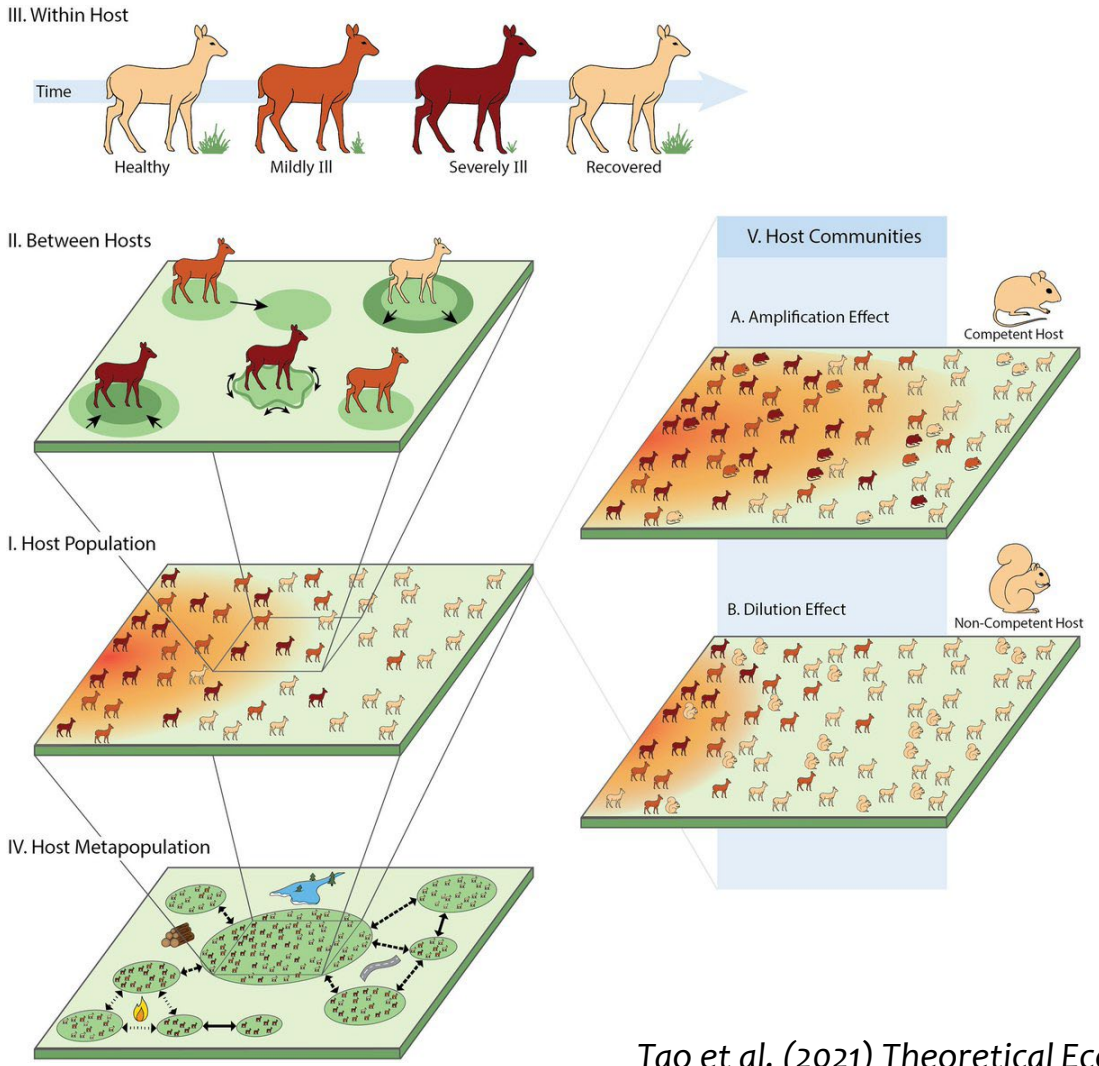
From: Towards common ground in the biodiversity–disease debate



Common ground (3)

Biodiversity-disease relationships are scale-dependent

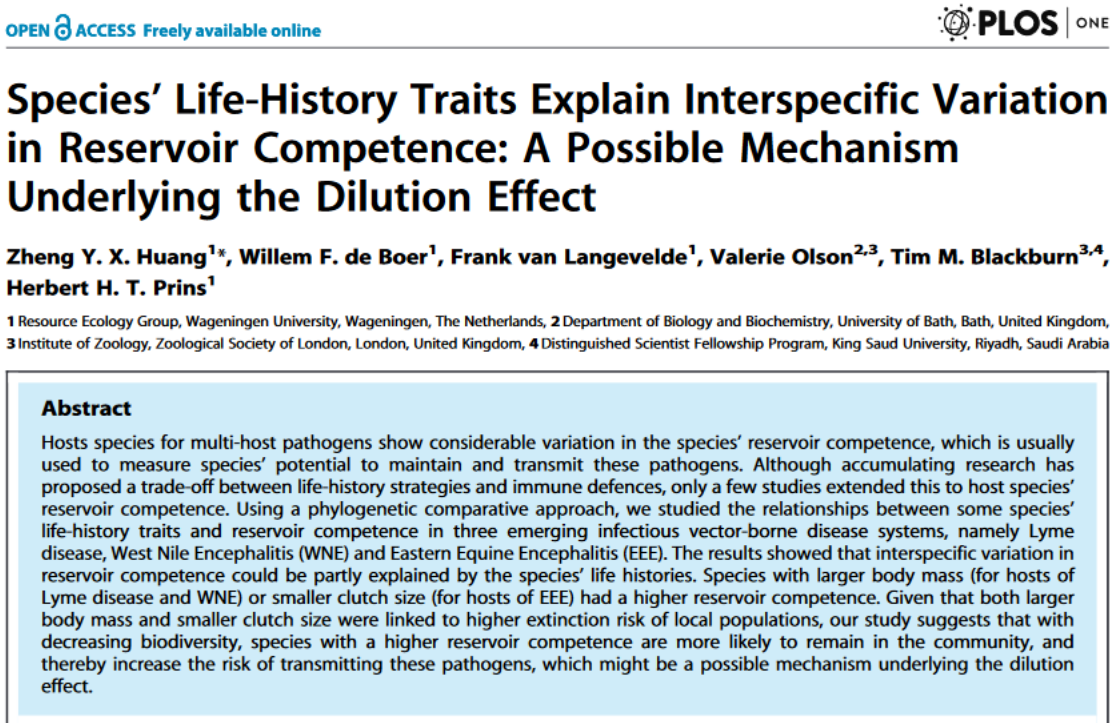
Dilution effect more likely to operate at small spatial scales



Tao et al. (2021) Theoretical Ecology

What are the underlying mechanisms?

- Competent hosts are more resilient to human disturbance



OPEN ACCESS Freely available online

PLOS ONE

Species' Life-History Traits Explain Interspecific Variation in Reservoir Competence: A Possible Mechanism Underlying the Dilution Effect

Zheng Y. X. Huang[1]*, Willem F. de Boer[1], Frank van Langevelde[1], Valerie Olson[2,3], Tim M. Blackburn[3,4], Herbert H. T. Prins[1]

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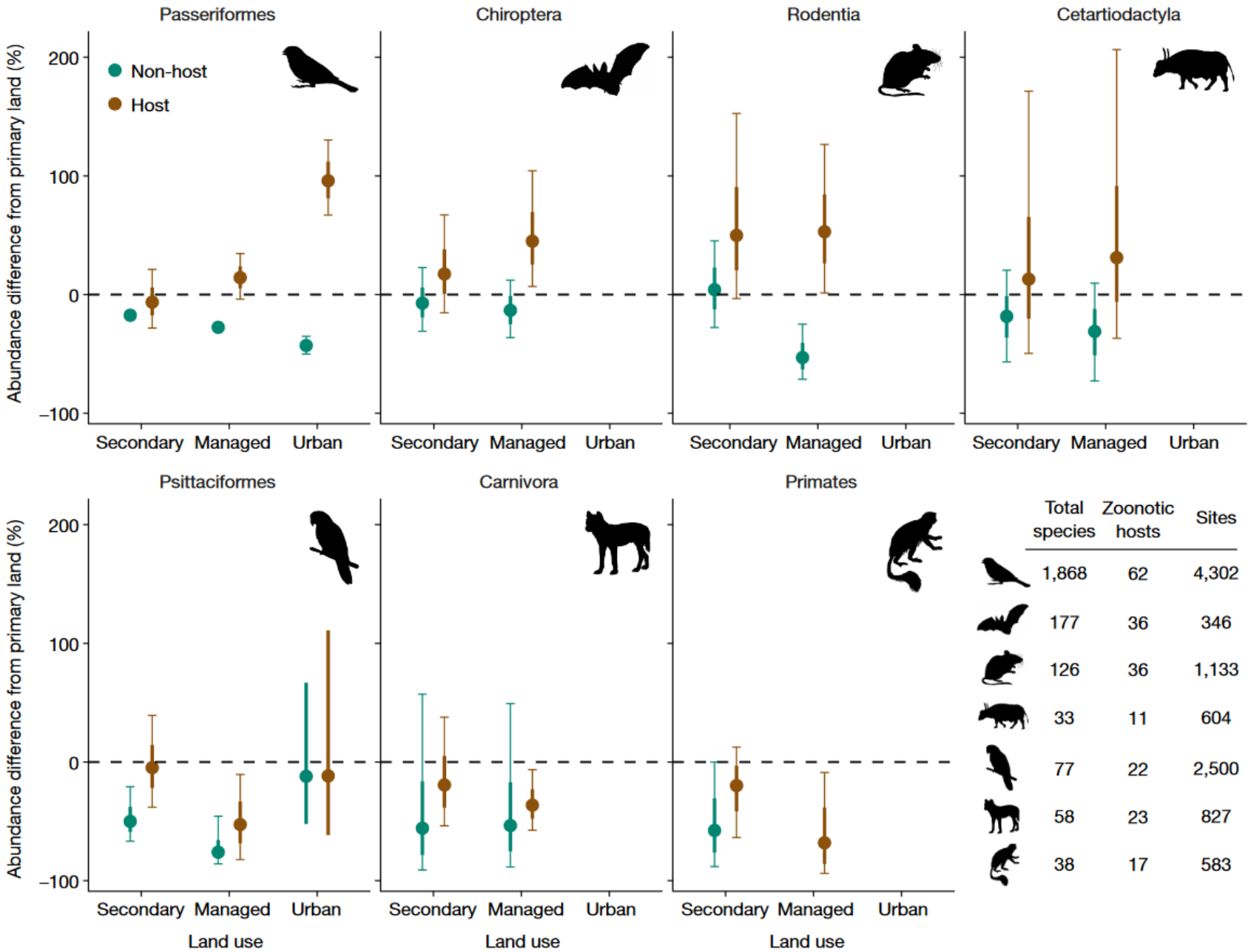
Abstract

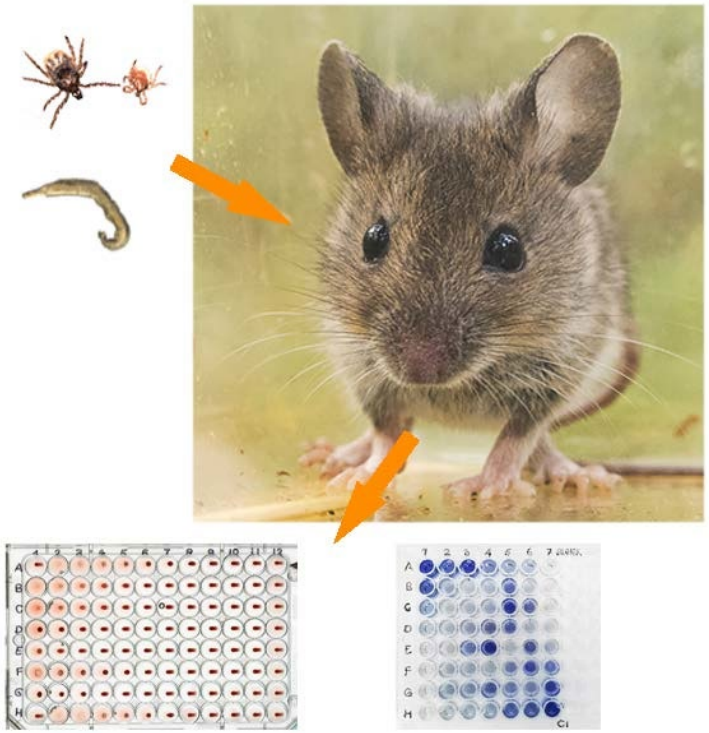
Hosts species for multi-host pathogens show considerable variation in the species' reservoir competence, which is usually used to measure species' potential to maintain and transmit these pathogens. Although accumulating research has proposed a trade-off between life-history strategies and immune defences, only a few studies extended this to host species' reservoir competence. Using a phylogenetic comparative approach, we studied the relationships between some species' life-history traits and reservoir competence in three emerging infectious vector-borne disease systems, namely Lyme disease, West Nile Encephalitis (WNE) and Eastern Equine Encephalitis (EEE). The results showed that interspecific variation in reservoir competence could be partly explained by the species' life histories. Species with larger body mass (for hosts of Lyme disease and WNE) or smaller clutch size (for hosts of EEE) had a higher reservoir competence. Given that both larger body mass and smaller clutch size were linked to higher extinction risk of local populations, our study suggests that with decreasing biodiversity, species with a higher reservoir competence are more likely to remain in the community, and thereby increase the risk of transmitting these pathogens, which might be a possible mechanism underlying the dilution effect.



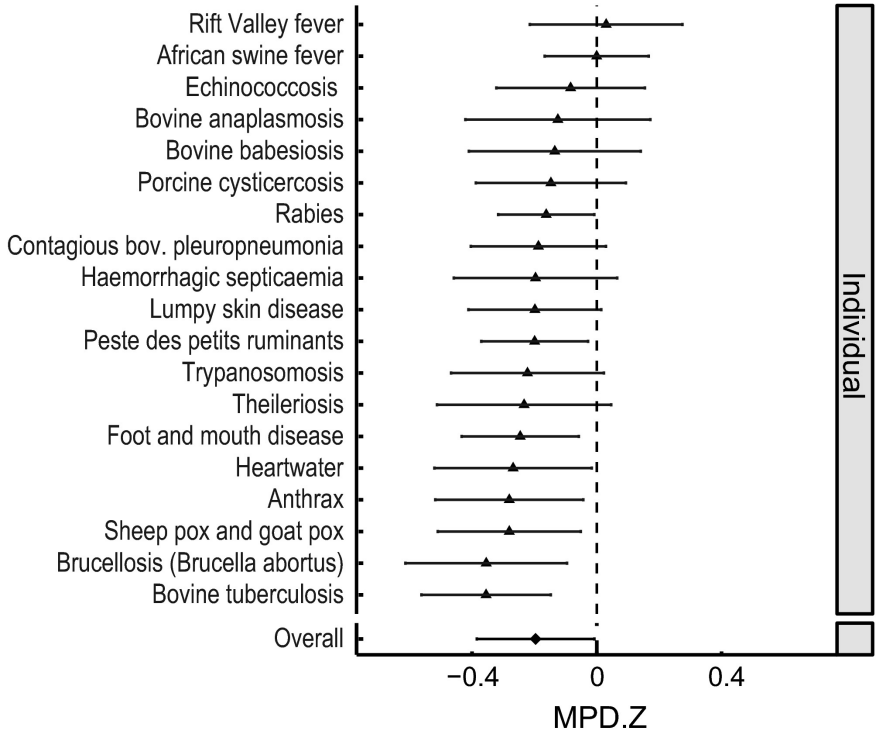
Gibb et al. (2020) Nature

What are the underlying mechanisms?

- Competent hosts are more resilient to human disturbance
  - Identify which host traits influence both host status and tolerance to human disturbance



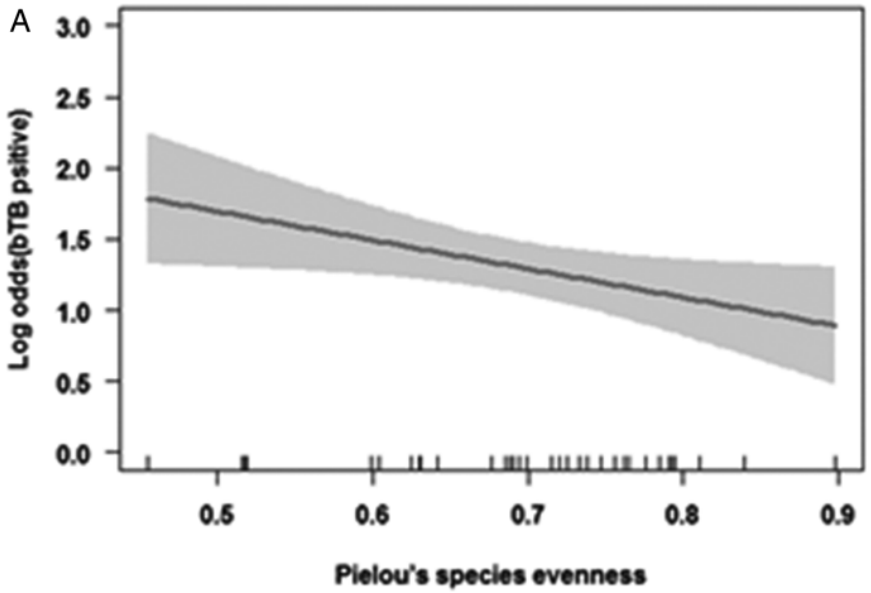
Hofmeester et al. (2019) Animals

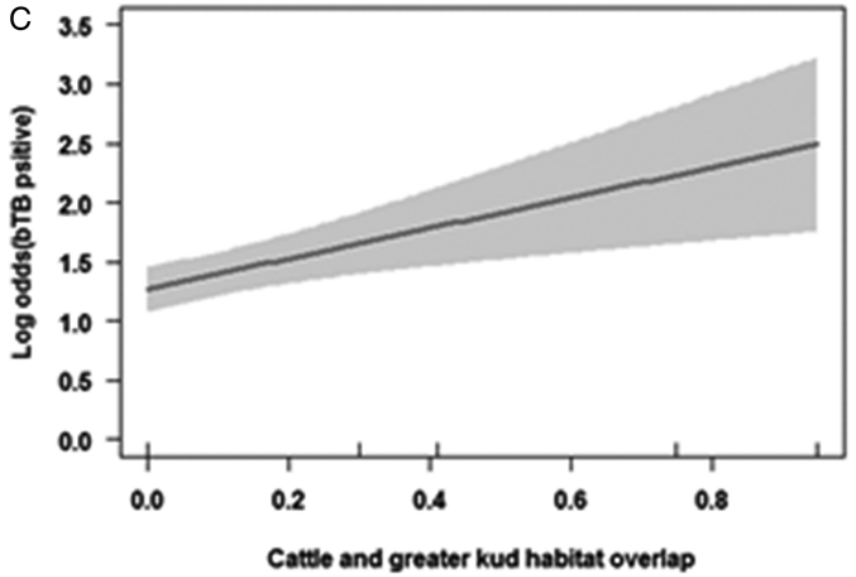


Wang et al. (2019) Functional Ecology

What are the underlying mechanisms?

- Competent hosts are more resilient to human disturbance
  - Identify which host traits influence both host status and tolerance to human disturbance
- Suppressed contact rates (encounter reduction)

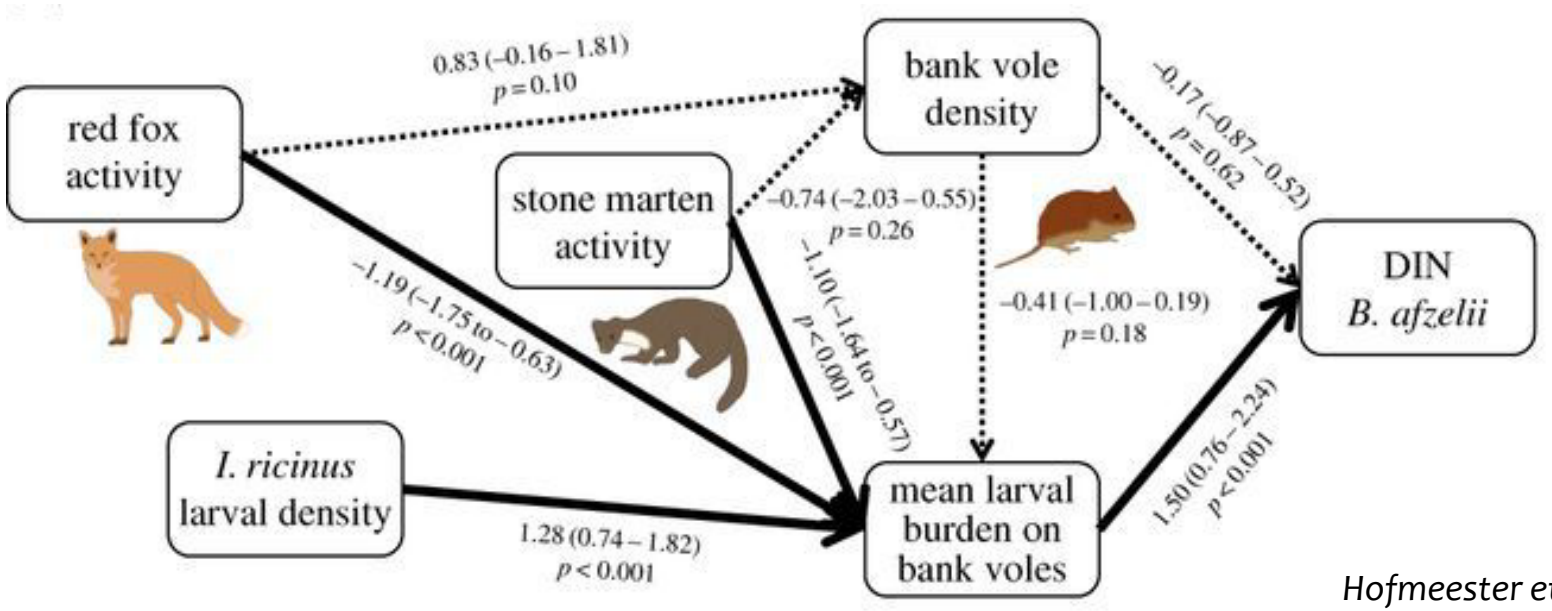




Sintayehu et al. (2017) Parasitology

What are the underlying mechanisms?

- Competent hosts are more resilient to human disturbance
  - Identify which host traits influence both host status and tolerance to human disturbance
- Suppressed contact rates (encounter reduction)
- Effects of predators
  - Effects on rodent behaviour?

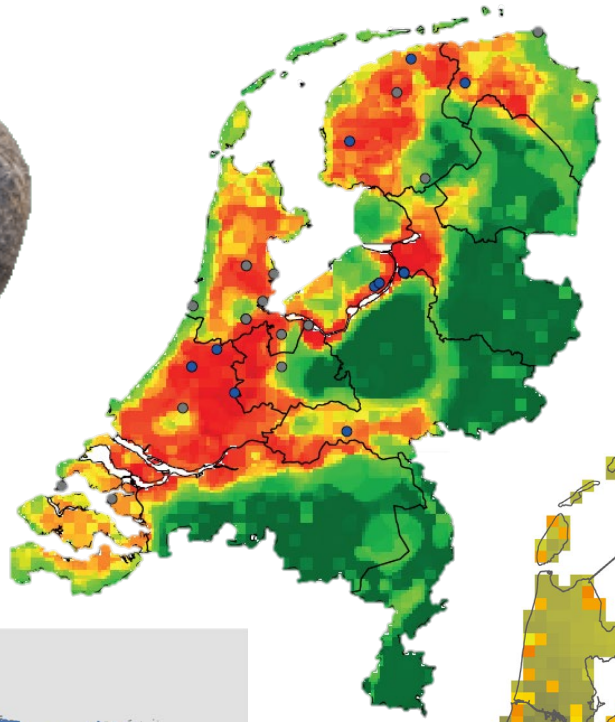


Hofmeester et al. (2017) Parasitology

Where are zoonotic EIDs most likely to emerge?

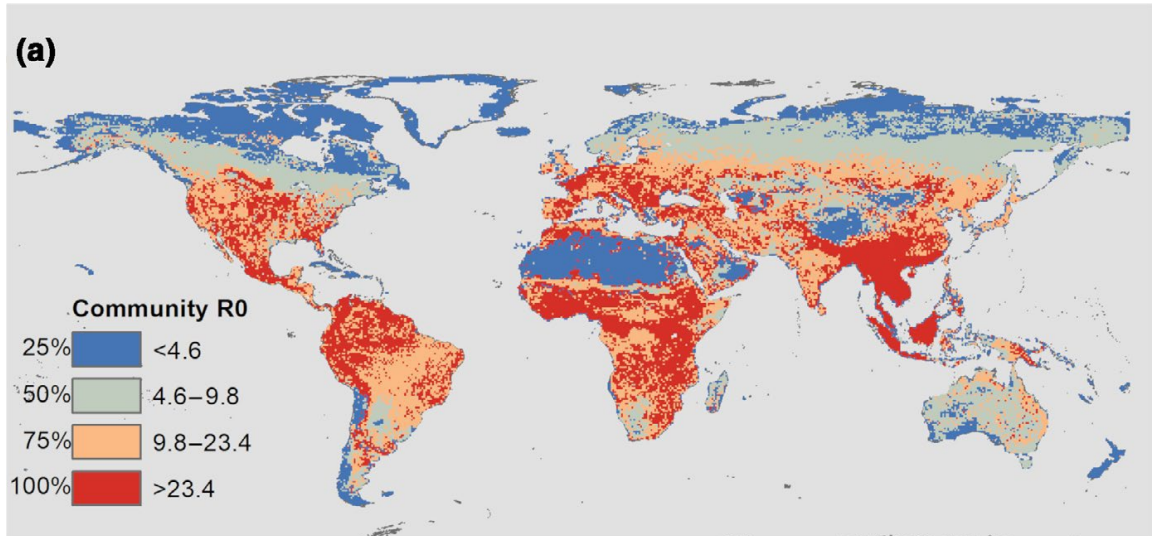
WNV

ASF

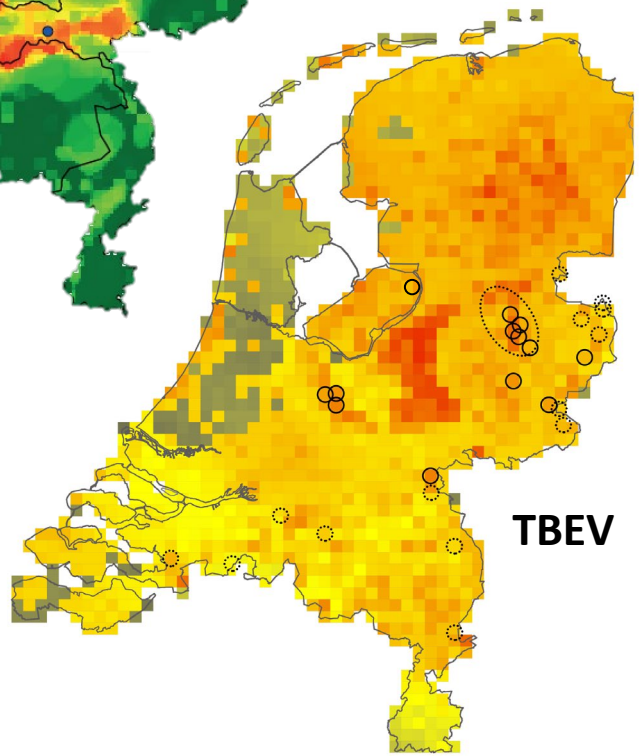


AIV

Schreuder et al. (2022) Pathogens



Wang et al. (2021) Global Change Biology



TBEV

Esser et al. (2020) Parasites & Vectors

Outstanding questions

- Can biodiversity recovery reverse the trend?
- Role of host density vs diversity?
- Biodiversity confounded with other factors (e.g. human population density, human behaviour, bushmeat) that affect contact rates
- Experimental studies needed (plants)
- How do other anthropogenic impacts (e.g. land use change) impact zoonotic hosts?