Zoonotic pathogens of wild Asian primates in different habitats : A systematic review

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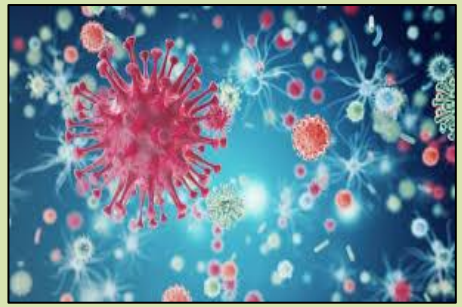
Context

Dynamic of interactions humans/non-human primates (NHPs) **have been modified**

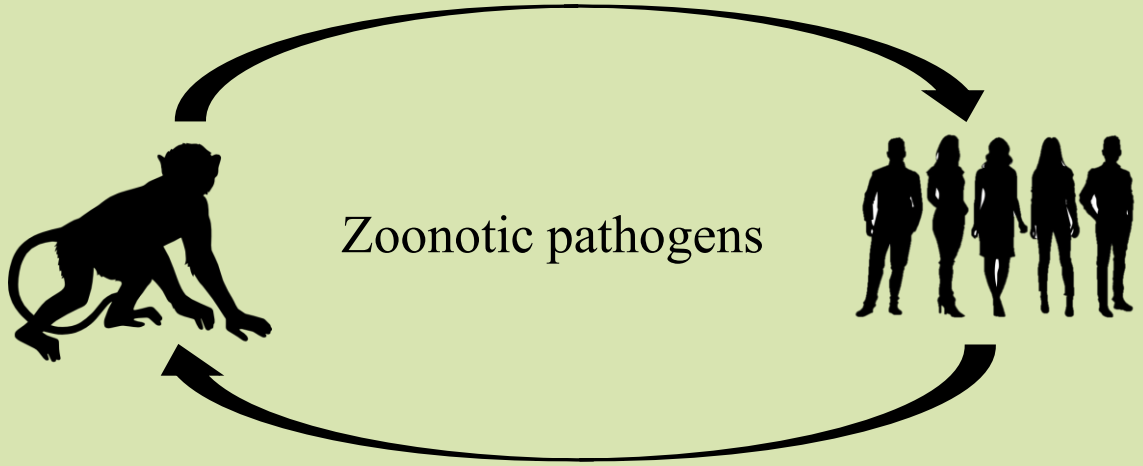
Habitats **overlap** → **increase conflicts** and **contacts** (direct or indirect)

Contacts →



Zoonotic pathogens

Context



- Zoonotic pathogens spread by **international travel and commerce** → new **naïve hosts**
- Alteration of **pathogens distribution patterns** + ↑ **geographical proximity**
  → **emergence** of new infectious zoonotic diseases

Context

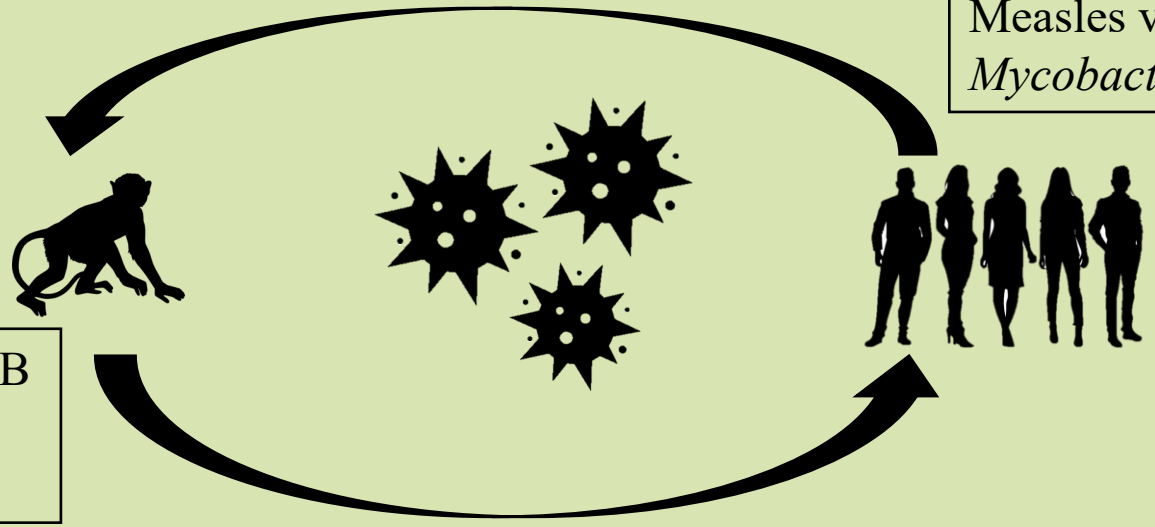
Emerging infectious disease (EIDs) = **75%** animal origin

Recent epidemics/pandemics
e.g. : **SARS-CoV-2**, Severe acute respiratory syndrome (**SARS**)

Necessity to **understand, prevent** and **control**
the emergence of zoonotic diseases

Context

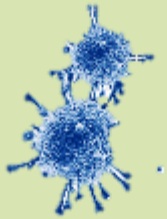
NHPs → Genetic proximity to humans, **sensitive** to identical pathogens



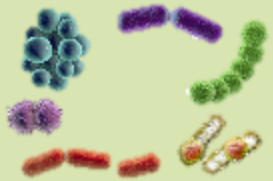
Herpesvirus B
HIV-1
Ebola virus

Measles virus
Mycobacterium tuberculosis

Shared zoonotic pathogens **(27.5%)**

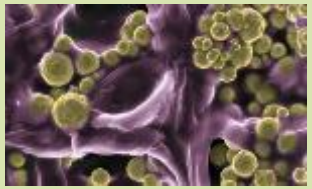


Viruses



Bacteria

Parasites



Fungi

Different routes of transmission:

- Respiratory
- Body fluid contact
- Faecal/oral
- Vector borne

Context

Human/ NHPs interfaces ➔ **different degrees** of landscape **anthropisation**

Forested

Rural

Urban

Multiple social and environmental factors
→ **likelihood** of interspecies transmission of zoonotic pathogens

Context

Asia

High human population density + Large NHPs community + Frequent human/ NHPs contacts = **Hotspot for emerging zoonotic diseases**

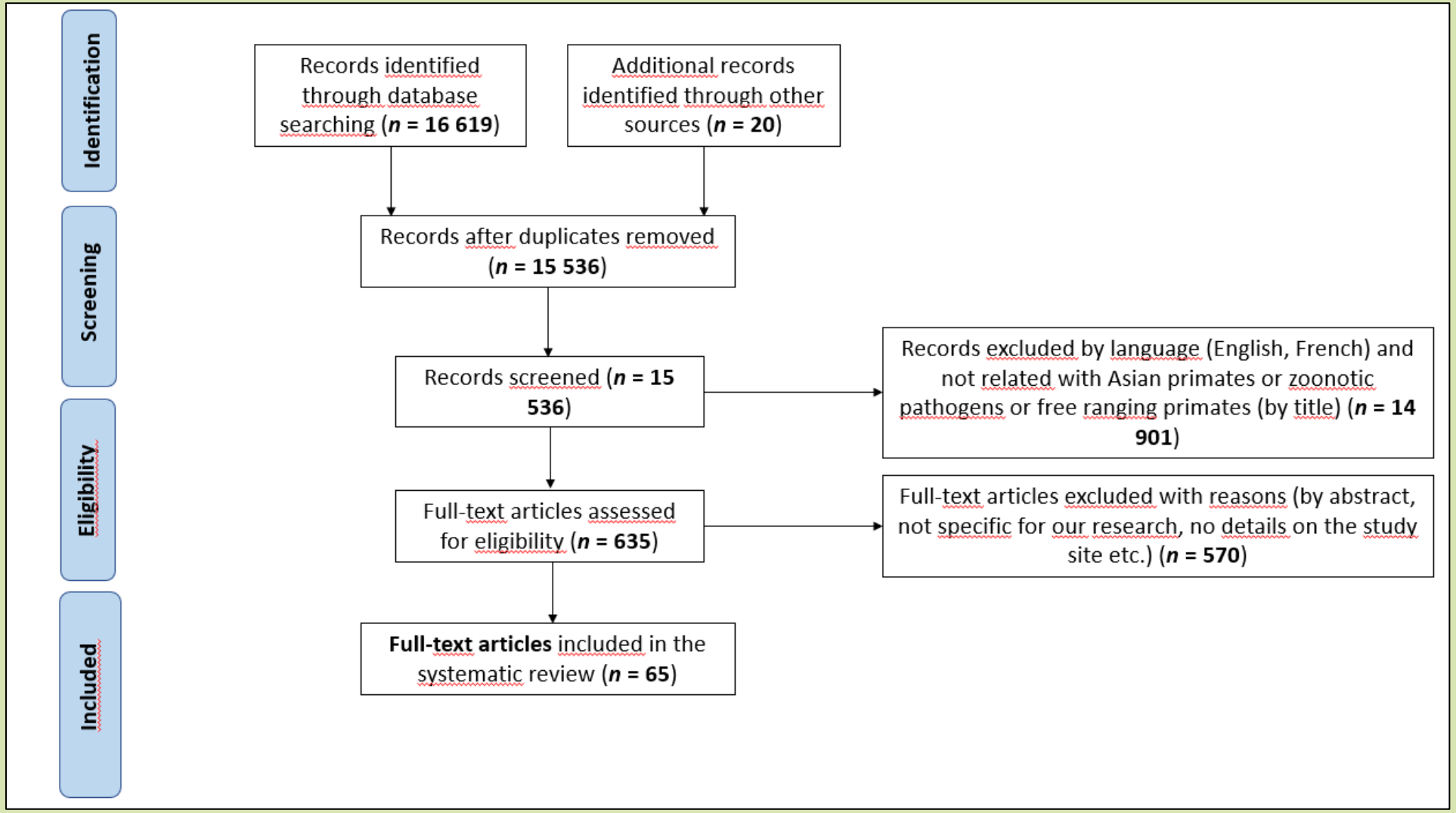
Current gaps in knowledge :

- **Limited zoonotic pathogens inventory** in NHPs living in Asia
- **Zoonotic infection risks** influenced by the **type of habitat ?**

Objective

- **Inventory of zoonotic pathogens** and their transmission routes in **wild Asian NHPs**
- Assessing the zoonotic pathogens **frequency** in **different types of habitats**

Data compilation



PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method

Data compilation

Informations collected from each study:

- Host primate species
- Zoonotic pathogen species
- Pathogen transmission route
- Country of the study
- Type of habitat
- Diagnostic method

- **5 groups of zoonotic pathogens**

Viruses

Bacteria

Protozoa

Fungi

Gastrointestinal parasite

- **Classification:**

Forested

Rural

Urban

Low **High**

Anthropisation

Data analysis

Zoonotic pathogens diversity **between habitat types :**

- **Control of potential biases due to effort sampling**
  → weighted % of species occurrence

- **Method of extrapolation and accumulation curves of species richness***

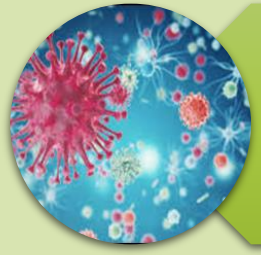
*Gotelli and Colwell (2001)

Results

65 articles selected from 1965 to 2021
(35 urban, 18 rural, 48 forested)

12 Asian countries

9 genus asian primate host
25 asian primate host **species**



131 zoonotic pathogen species identified

Inventory

	Urban habitat	Rural habitat	Forested habitat	Transmission route	References
Adult T-cell Leukaemia			*Macaca fascicularis*	**Body Fluid Contact**	Hayami and al, 1983
Cercopithecine herpesvirus 1	*Macaca mulatta/Macaca thibetana*				Jones-Engel and al, 2006/Yong and al, 2013
Epsteinbarr			*Pongo sp*		Kilbourn and al, 2003
Foamy Virus			*Pongo sp*		Kilbourn and al, 2003
Mumps			*Pongo sp*		Kilbourn and al, 2003
Rhesus cytomegalovirus	*Macaca mulatta*				Jones-Engel and al, 2006
Simian Foamy Virus	*Macaca fascicularis/Macaca mulatta/Macaca thibetana*		*Macaca mulatta*		Jones-Engel and al, 2005/Jones-Engel and al, 2006/Feeroz and al, 2013/Yong and al, 2013
Simian Pox Virus	*Macaca thibetana*				Yong and al, 2013
Simian Retrovirus	*Macaca thibetana*				Yong and al, 2013
Simian type D retrovirus	*Macaca mulatta*				Jones-Engel and al, 2006
Simian virus 40	*Macaca mulatta*				Jones-Engel and al, 2006
Simian T-cell Lymphotropic Virus	*Macaca mulatta/Macaca thibetana*				Jones-Engel and al, 2006/Yong and al, 2013
Adenovirus			*Pongo sp*	**Respiratory**	Kilbourn and al, 2003
Influenza A	*Macaca tonkeana*				Jones-Engel and al, 2001
Measles Morbilivirus	*Macaca tonkeana*				Jones-Engel and al, 2001
Parainfluenza 1	*Macaca tonkeana*				Jones-Engel and al, 2001
Parainfluenza 2	*Macaca tonkeana*				Jones-Engel and al, 2001
Parainfluenza 3	*Macaca tonkeana*				Jones-Engel and al, 2001
Respiratory syncytial			*Pongo sp*		Kilbourn and al, 2003
Coxackie B-4			*Pongo sp*	**Fecal/Oral**	Kilbourn and al, 2003
Enterovirus	*Macaca mulatta/Semnopithecus entellus/Trachypithecus pileatus*		*Macaca mulatta/Semnopithecus entellus/Trachypithecus pileatus*		Oberste and al, 2012
Hepatitis A	*Macaca thibetana*		*Macaca fascicularis*		Yong and al, 2013/ Burke and al, 1984
Parechovirus	*Macaca mulatta/Semnopithecus entellus/Trachypithecus pileatus*		*Macaca mulatta/Semnopithecus entellus/Trachypithecus pileatus*		Oberste and al, 2012
Rotavirus SA11			*Pongo sp*		Kilbourn and al, 2003
Chikungunya virus			*Macaca fascicularis/Macaca leonina/Macaca arctoides*	**Vector Borne**	Tongthainan and al, 2020
Dengue virus		*Pongo sp*	*Macaca fascicularis/Macaca leonina/Macaca arctoides/Macaca sinica/Pongo sp*		Tongthainan and al, 2020/De Silva and al, 1999/Kilbourn and al, 2003/Wolfe and al, 2001
Japanese encephalitis		*Pongo sp*	*Pongo sp*		Kilbourn and al, 2003/Wolfe and al, 2001
Kyasanur Forest Disease			*Macaca radiata/Semnopithecus entellus/Trachypithecus pileatus*		Pavri and al, 1989/Mouryat and al, 2013/
Sindbis		*Pongo sp*	*Pongo sp*		Kilbourn and al, 2003/Wolfe and al, 2001
Tembusu		*Pongo sp*	*Pongo sp*		Kilbourn and al, 2003/Wolfe and al, 2001
West Nile virus			*Macaca fascicularis*		Ain-Najwa and al, 2020
Zika virus		*Pongo sp*	*Macaca fascicularis/Macaca leonina/Macaca arctoides/Pongo sp*		Tongthainan and al, 2020/Kilbourn and al, 2003/Wolfe and al, 2001

Viruses :

Respiratory route and contact with body fluids
→ mainly **urban habitat**

Vector-borne transmission
→ mostly **rural** and **forested habitats**

Other types of pathogens
→ **no qualitative differences** between habitats

Zoonotic pathogens occurrence comparison between habitats

Bacteria

Interface	Number of studies	% of species founded	% of species founded corrected
Urban	7	49	38
Rural	2	9	25
Forested	6	42	38
Total	15	100	100

Gastrointestinal Parasite

Interface	Number of studies	% of species founded	% of species founded corrected
Urban	16	26	31
Rural	14	26	35
Forested	26	47	34
Total	56	100	100

Protozoa

Interface	Number of studies	% of species founded	% of species founded corrected
Urban	17	32	30
Rural	8	19	38
Forested	25	49	31
Total	50	100	100

Virus

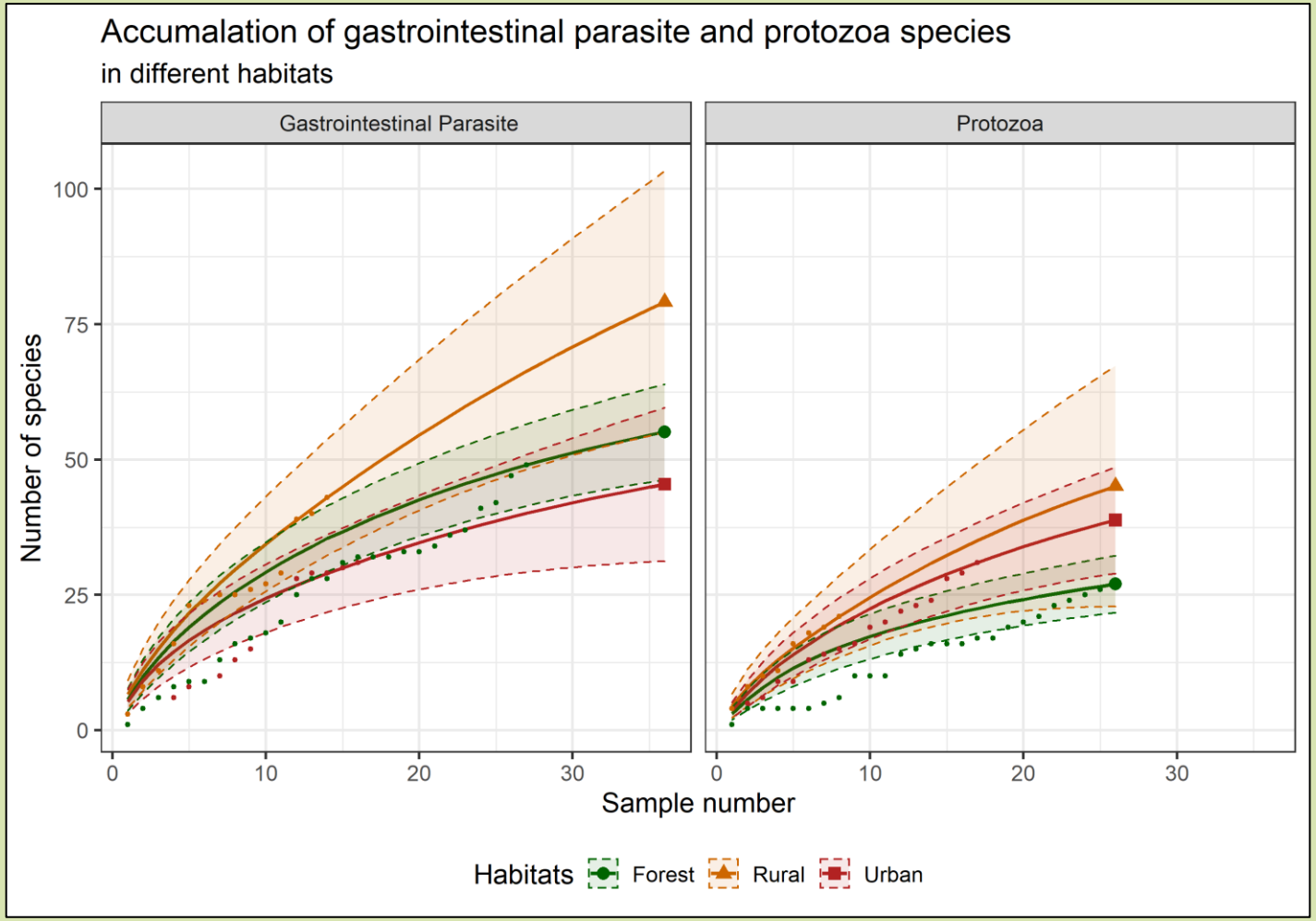
Interface	Number of studies	% of species founded	% of species founded corrected
Urban	6	35	29
Rural	1	9	46
Forested	11	56	26
Total	18	100	100

Weighted % of **species occurrence:**

Bacteria → urban and forest habitats
Viruses → rural habitats

Gastrointestinal parasites and **protozoa**
→ **similar** in the 3 types of habitats

Zoonotic pathogens occurrence comparaison between habitats



Dotted line: accumulation curve
Solid line: rarefaction curve

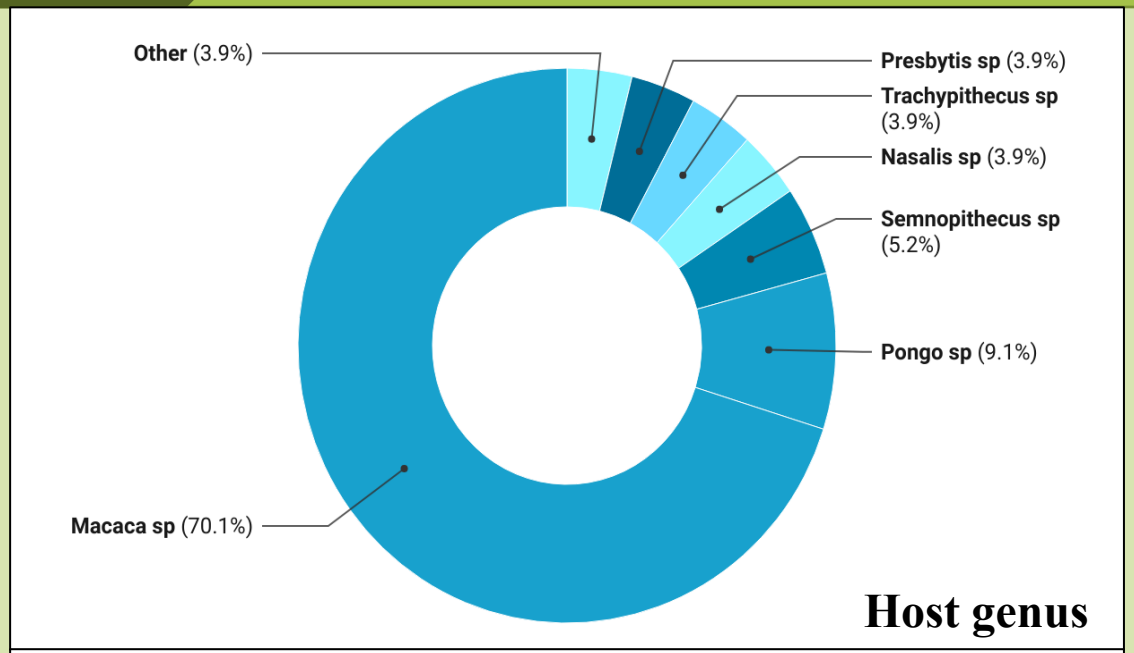
Extrapolation and accumulation curves of species richness

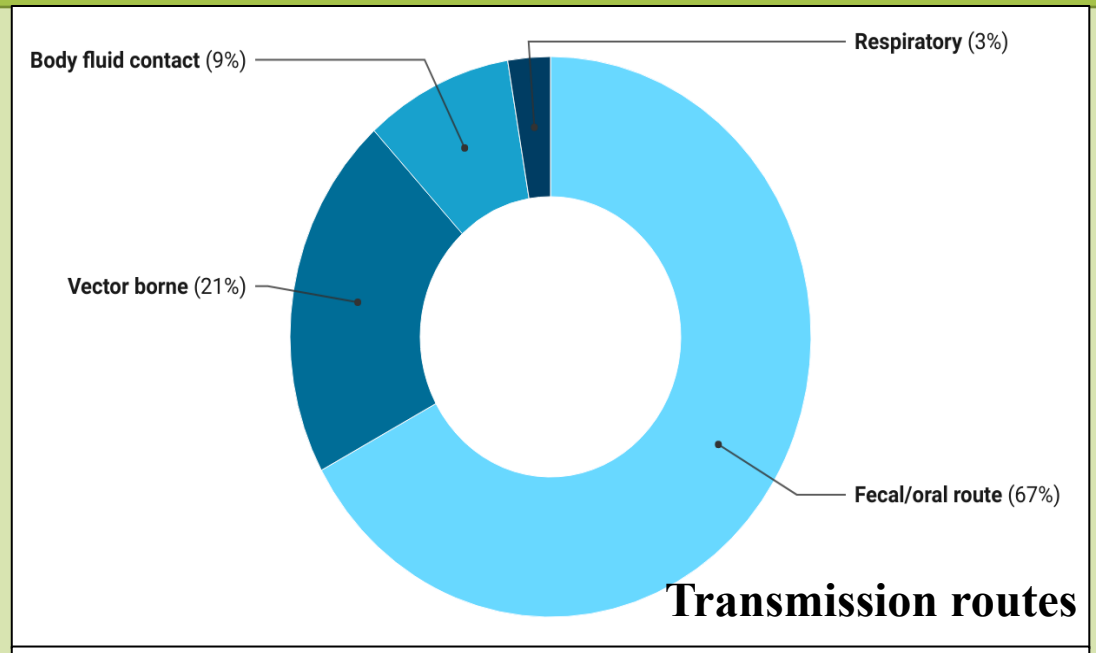
Comparison of habitats
→ **Overlap** of confidence intervals
→ **No difference between habitats**

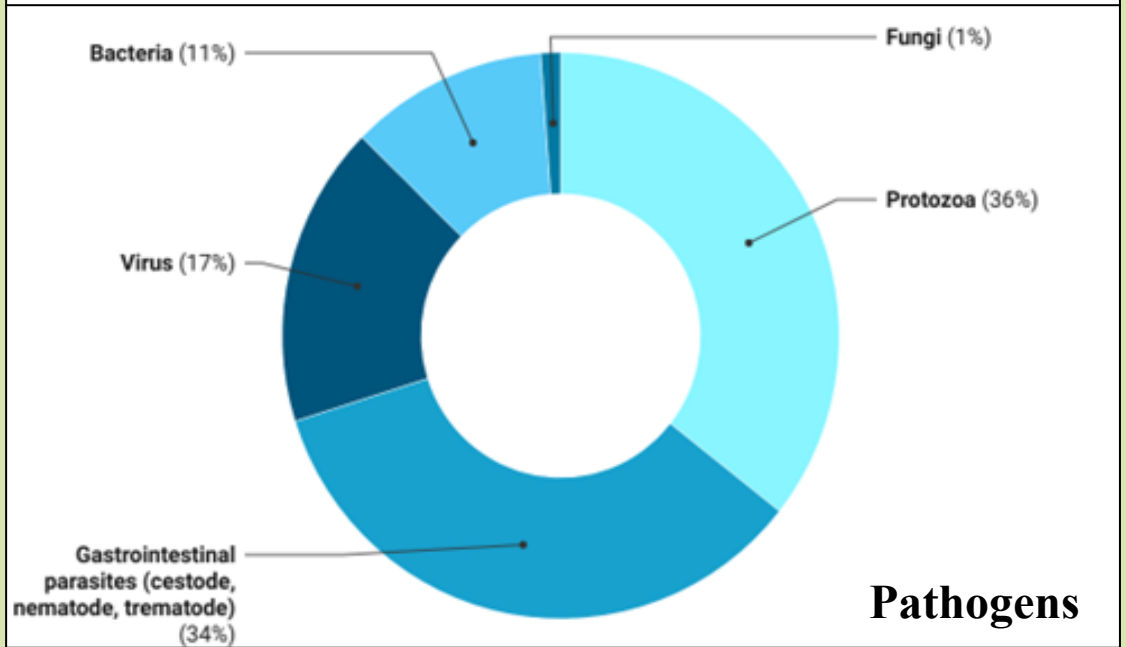
Impossible to conclude
→ Threshold not reached
→ **Need to continue sampling**

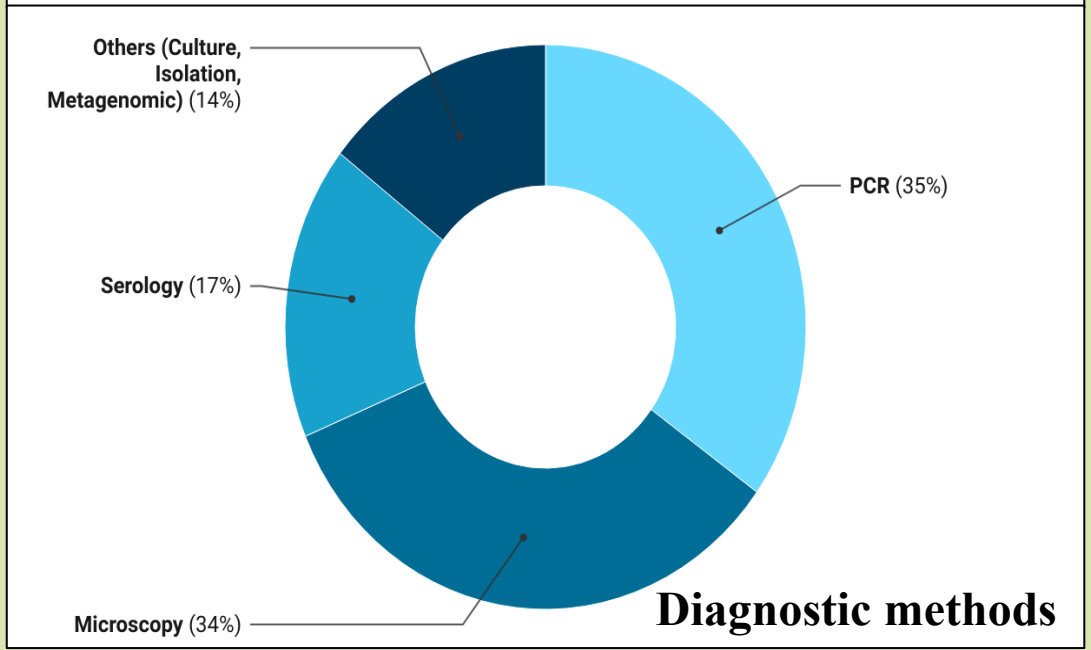
Gaps ?

Research gaps







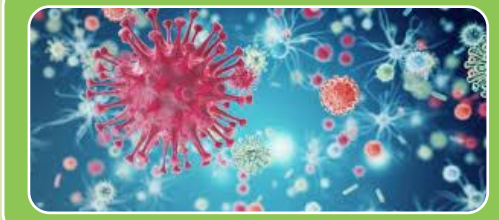


Discussion

Several **gaps identified & biases** in studies
→ **Inventory** of zoonotic pathogens and **diversity** representation in different habitats **influenced**

NHPs host

- Asian NHPs less study compare to African NHPs
- Geographic and distribution range



Zoonotic pathogens

- Types of samples
- Link with the transmission route

Diagnostic methods

- Specific vs Generic
- Generic = discovery zoonotic pathogens BUT expensive

Take home message:

- Zoonotic pathogens & transmission routes
  → **common** in some habitats BUT some are also **specific**

- BUT **gaps** in studies on zoonotic pathogens
  → need for **additional** studies

International and multidisciplinary **collaborations**
→ **preventives** or **reactionary** measures

Thank you for your attention !

Zoonotic pathogens diversity **comparison between habitats :**

- **Control potential biases due to effort sampling →** weighted % of **species occurence**

  Sampling effort on the **group of pathogens/transmission routes studied** :
  For each group of pathogens/transmission routes → **weighting factor** = (**total number of studies** carried out on **all the groups** of pathogens/**all transmission routes** / **total number of studies** carried out on **a specific** pathogen group/**a specific** transmission route)

  Sampling effort on the **habitat type** :
  For each group of pathogens → **weighting factor** = (**total number of studies** carried out on the group of pathogen **in all habitats** combined / **total number of studies** carried out on the pathogen group **in a specific habitat**)

- **Method of extrapolation and accumulation curves of species richness** (Gotelli and Colwell, 2001)

  Quantify and statistically measure the **differences in diversity** of zoonotic agent species **between habitat types**, EstimateS software

Zoonotic pathogens occurrence comparaison between habitats

Weighted % of **species occurrence:**

Pathogens	Number of studies	% of species found	% of species found corrected
Gastrointestinal parasite	56	54.3	36.1
Bacteria	15	7.0	17.3
Protozoa	50	29.7	22.2
Virus	18	8.9	18.4
Fungi	1	0.2	6.0
Total	140	100.0	100.0

Across all the studies, **gastrointestinal parasites** is the type of pathogen **the most detected** in studies

Transmission Route	Number of studies	% of species found	% of species found corrected
Fecal/oral	80	83.9	42.0
Respiratory	2	1.0	19.1
Vector borne	20	11.6	23.3
Body fluid	9	3.5	15.6
Total	111	100.0	100.0

Across all the studies, **Fecal/oral route** is the transmission route **the most detected** in studies