Preventing the next pandemic

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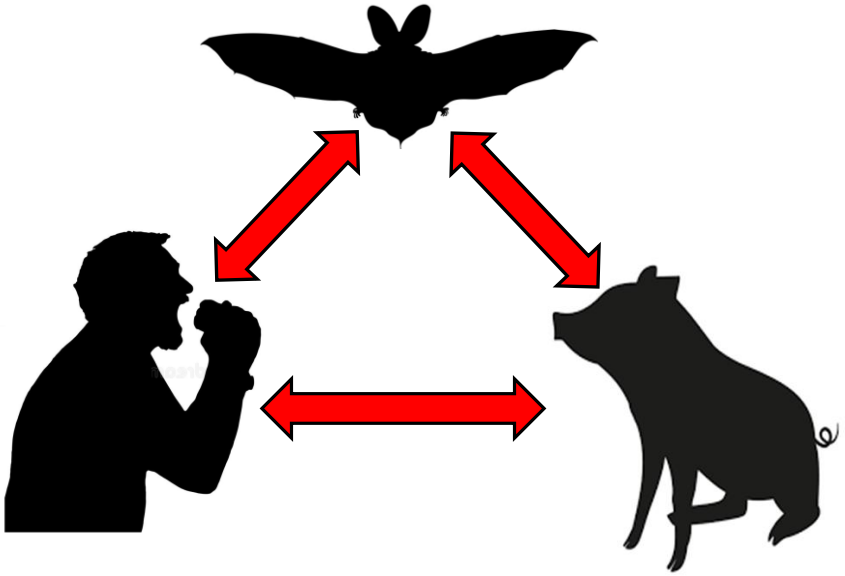
Zoonoses and risks

- 111 recent epidemic disease outbreaks have zoonotic origins (i.e. HIV-AIDS, Ebola, MERS and SARS)
- 60% of human emerging disease events are caused by zoonotic pathogens, with most (72%) originating in wildlife.
- Most human pathogens are zoonotic (80% of viruses)
- (50% of bacteria, 40% of fungi, 70% of protozoa and 95% of helminths)

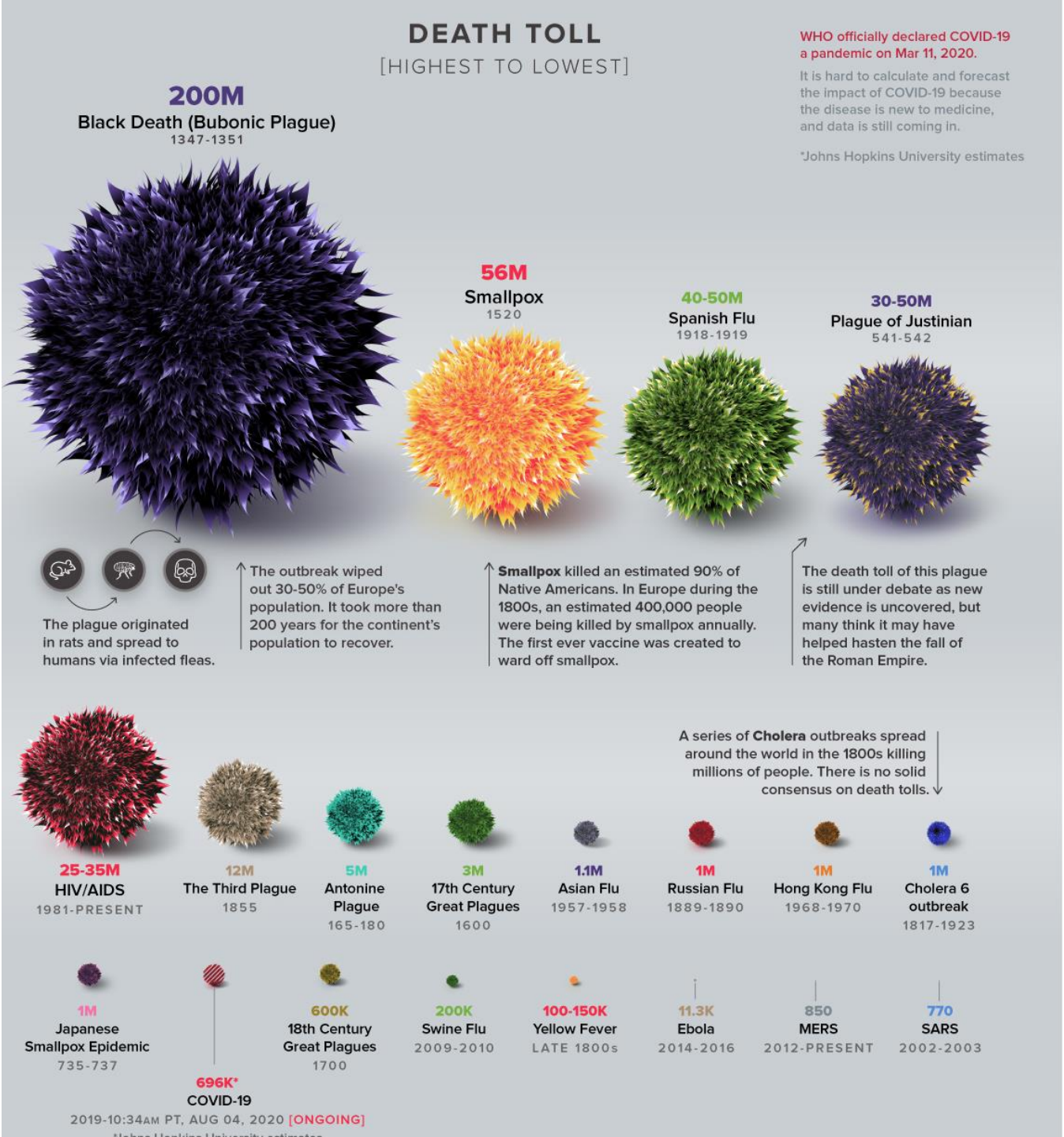
Route of spillover

1. **Direct**: Bites, scratches, fluids (i.e. Rabies)
2. **Indirect**: Contamination (i.e. Marburg)
3. **Vector-borne**: Bites (i.e. Lyme, Plague)
4. **Foodborne/Waterborne**: Contamination (i.e. Hendra, Ebola)



A brief history of Pandemics

- Though by no means the largest pandemic COVID has already caused major global fatalities



Zoonoses and fatality

- Seven coronaviruses (CoVs) are currently known to infect humans (Andersen et al 2020), four of which are regularly found in populations in which they cause only mild symptoms (Corman et al 2018)
- However, the betacoronaviruses, SARS-CoV-1, MERS and SARS-CoV-2 are more often fatal
- Over 200 novel coronaviruses have been identified in bats and approximately 35% of the bat virome sequenced is composed of coronaviruses (Banerjee et al. 2019)

Interface between humans and exposure

- Not all wildlife! –much comes from livestock
- Understanding the possibilities for spillover and drivers behind spillover risk are essential
- Here we will discuss why some species are better reservoirs, the interfaces that cause risk, and how landscape governance impacts on probable risks

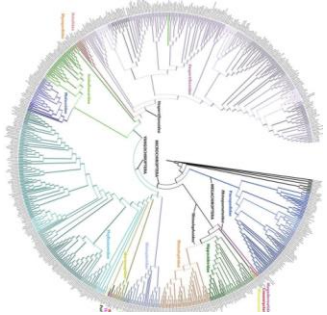
Wildlife reservoirs

- Some species can act as reservoir hosts of viruses, whilst many species have the capacity to act as reservoirs this is more common in some taxa than others
- Broadly we can think of such hosts in three main categories

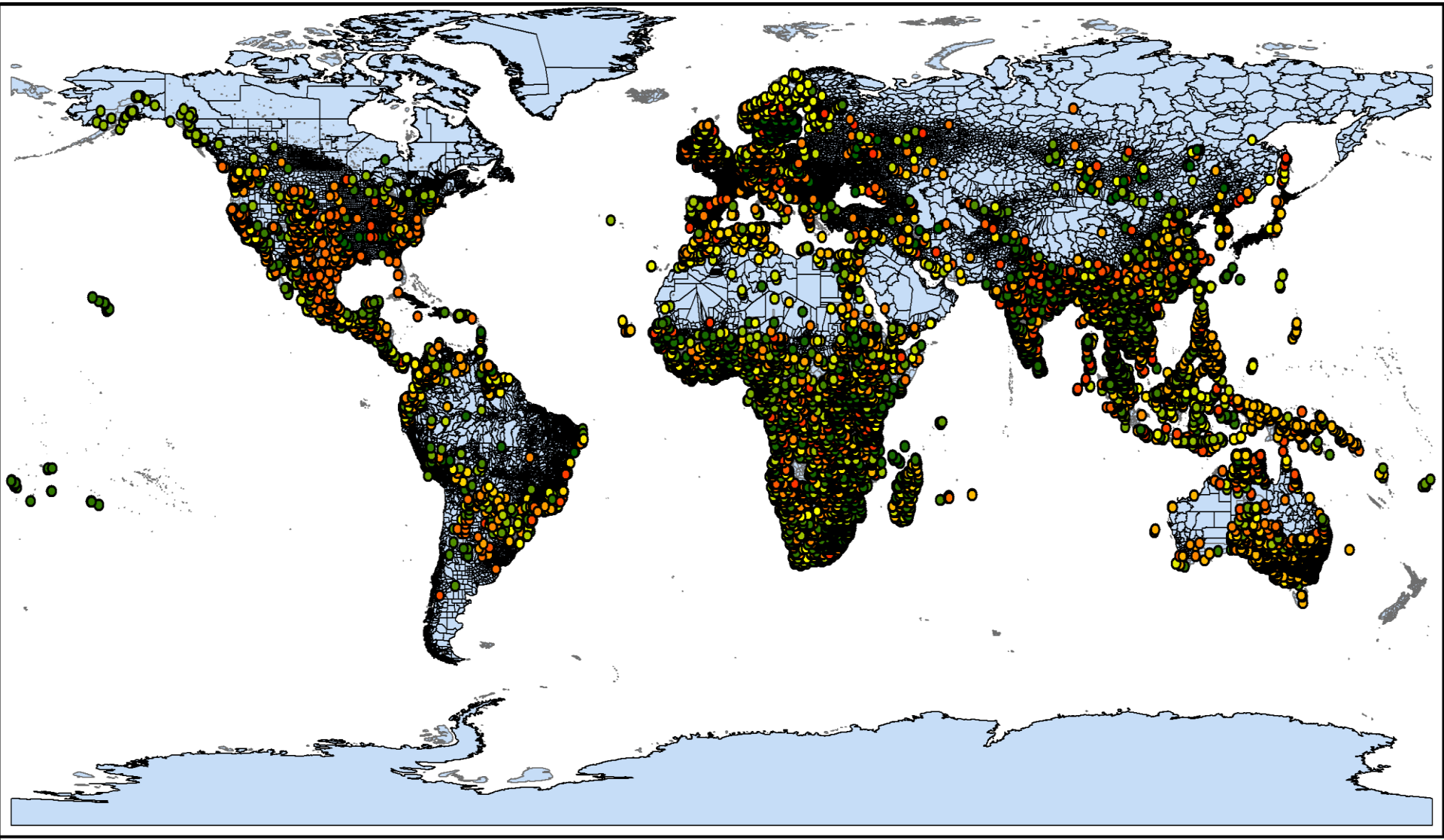
1. Species which are in close contact with humans and can spread pathogens (i.e. pets)
2. Species which are good at spreading between individuals (rodents, civets)
3. Species with immune systems adapted to act as reservoirs

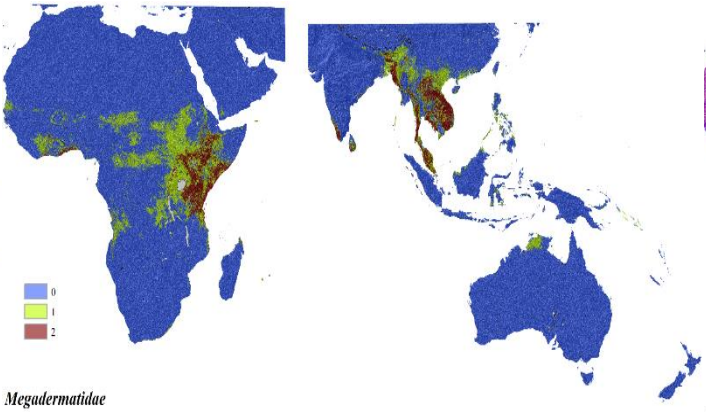
Immune based adaptations

- Special immune adaptations; bats
- Though bats are largely grouped due powered flight they are deeply divergent
- The costs associated with flight have driven selection on almost every process in bats from the cellular level up
- As a consequence bats live upto 10x longer than expected and provide ideal models to understand the causes of aging in inferior mammals
- Much more work is needed on almost every aspect of bat ecology, as they remain understudied and highly cryptic

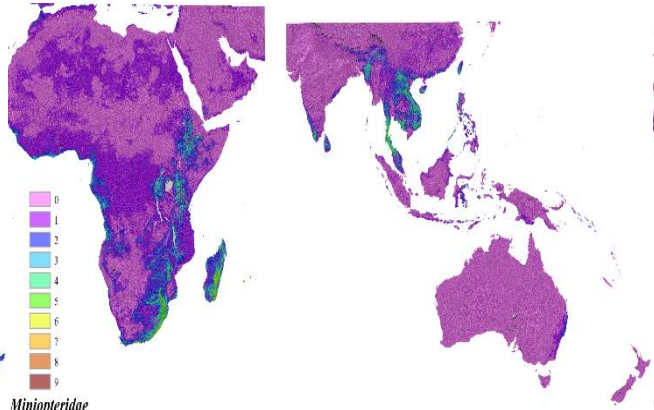


Where in the world are bats?

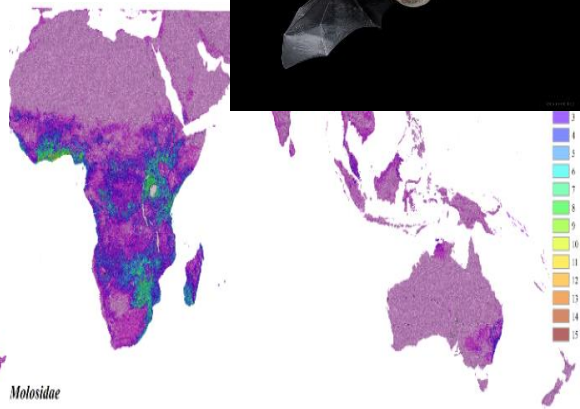




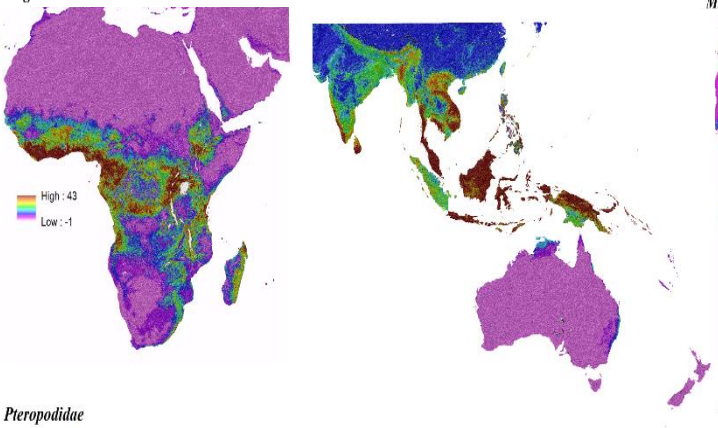
Megadermatidae



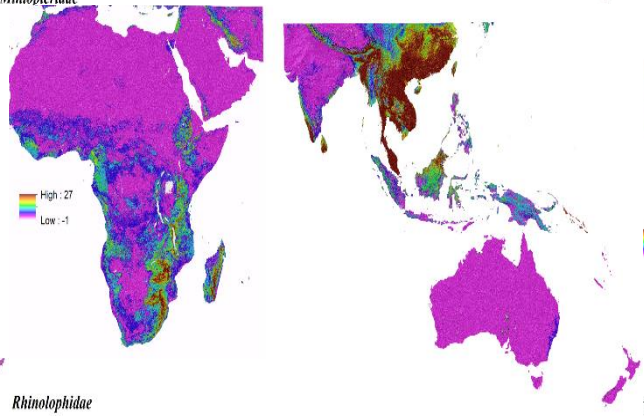
Miniopteridae



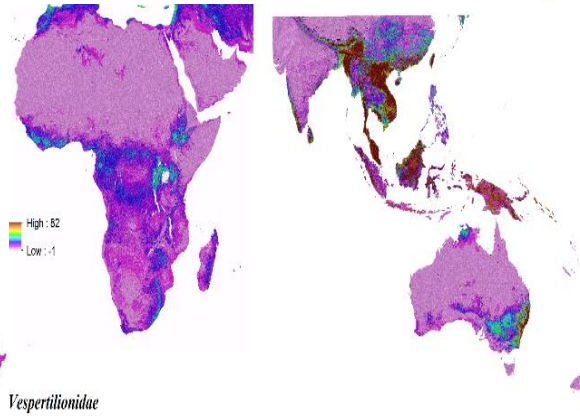
Molosidae



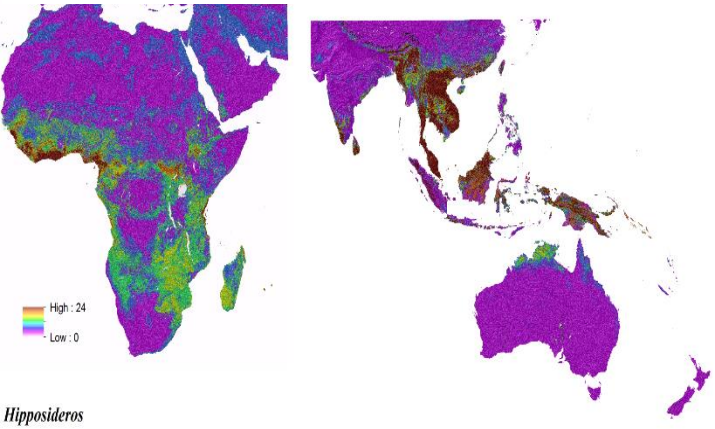
Pteropodidae



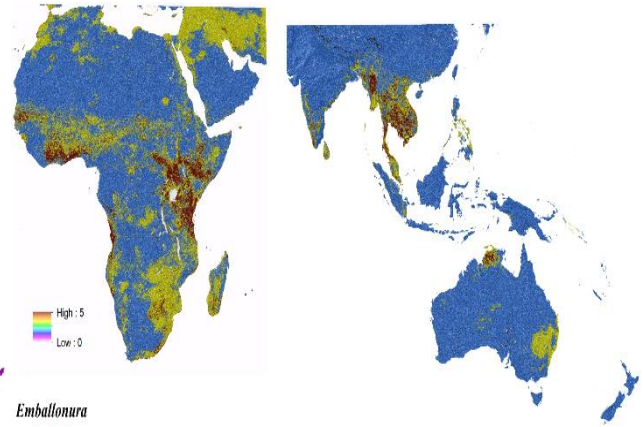
Rhinolophidae



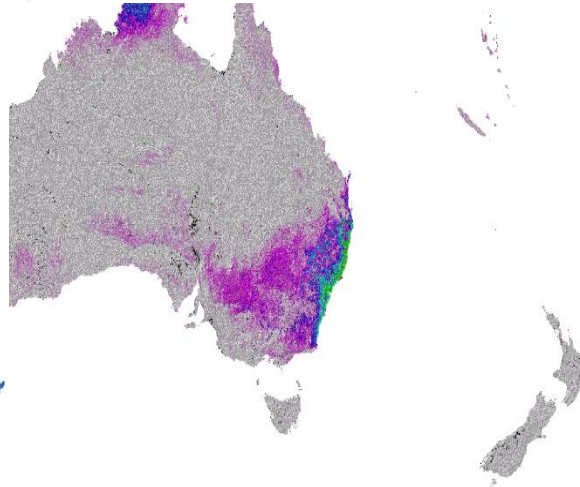
Vespertilionidae



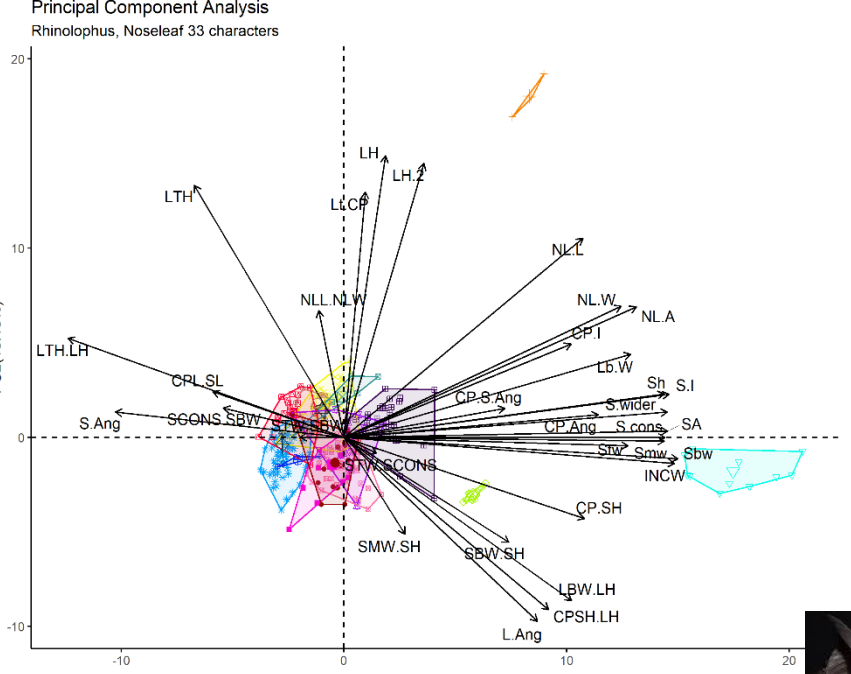
Hipposideros

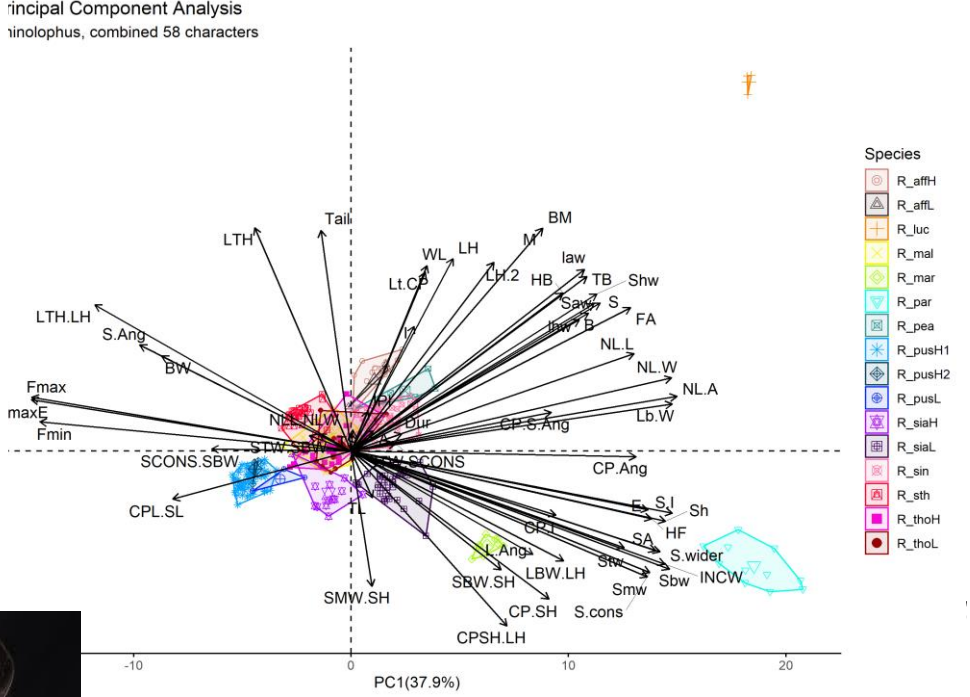


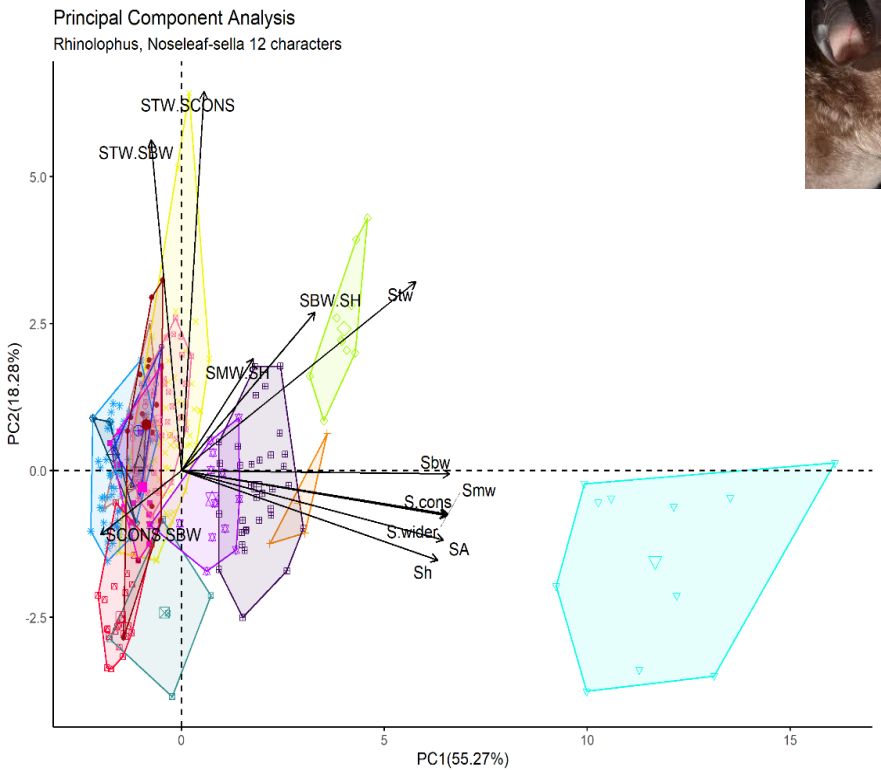
Emballonura

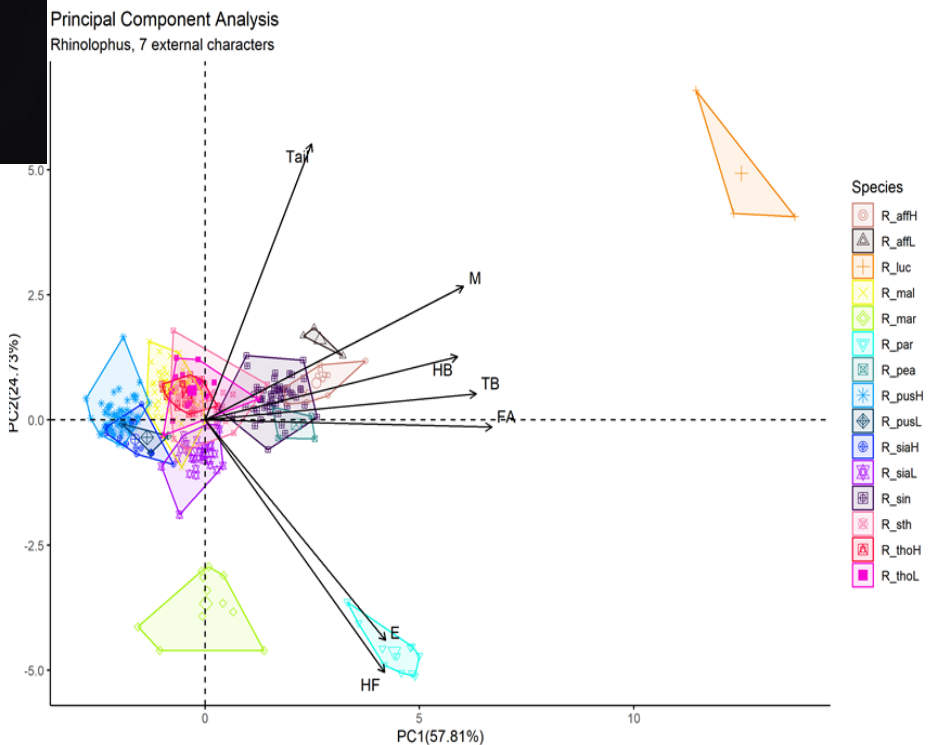


Cryptic dive


Principal Component Analysis
Rhinolophus, Noseleaf 33 characters
LH
LH.2
LTH
Lt.CB
NL.L
NLL.NL.W
NL.W
NL.A
CP.I
LTH.LH
Lb.W
CPL.SL
Sh
S.I
CP.S.Ang
S.wider
S.Ang
SCONS.SBW
STW.SBW
CP.Ang
S.cons
SA
Stw
Smw
Sbw
STW.SCONS
INCW
CP.SH
SMW.SH
SBW.SH
LBW.LH
CPSH.LH
L.Ang
Species
R_affH
R_affL
R_luc
R_mal
R_mar
R_par
R_pea
R_pusH1
R_pusH2
R_pusL
R_siaH
R_siaL
R_sin
R_sth
R_thoH
R_thoL


rincipal Component Analysis
inolophus, combined 58 characters
LTH
Tail
BM
M
WL
LH
law
Lt.CB
LH.2
HB
TB
Shw
Saw
S
FA
LTH.LH
S.Ang
BW
B
NL.L
NL.W
NL.A
Fmax
maxF
Fmin
NLL.NL.W
Lb.W
CP.S.Ang
SCONS.SBW
STW.SBW
STW.SCONS
CP.Ang
CPL.SL
TL
F
S.I
Sh
CP.I
HF
SA
L.Ang
S.wider
Stw
LBW.LH
SBW.SH
Sbw
INCW
Smw
SMW.SH
CP.SH
S.cons
CPSH.LH
PC1(37.9%)
Species
R_affH
R_affL
R_luc
R_mal
R_mar
R_par
R_pea
R_pusH1
R_pusH2
R_pusL
R_siaH
R_siaL
R_sin
R_sth
R_thoH
R_thoL

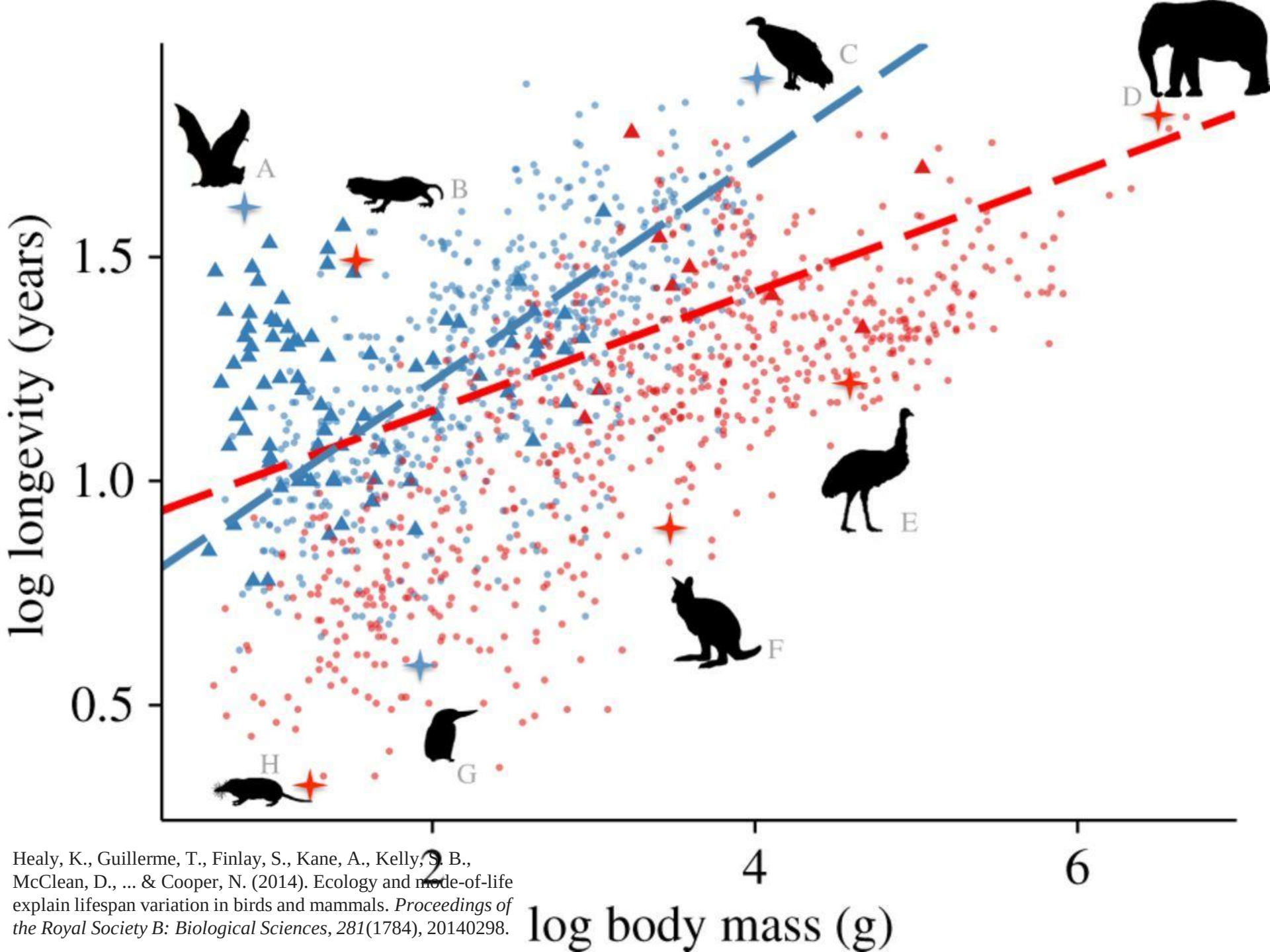

Principal Component Analysis
Rhinolophus, Noseleaf-sella 12 characters
STW.SCONS
STW.SBW
SBW.SH
Stw
SMW.SH
Sbw
Smw
S.cons
S.wider
SA
Sh
SCONS.SBW
PC2(18.28%)
PC1(55.27%)
Species
R_affH
R_affL
R_luc
R_mal
R_mar
R_par
R_pea
R_pusH1
R_pusH2
R_pusL
R_siaH
R_siaL
R_sin
R_sth
R_thoH
R_thoL


Principal Component Analysis
Rhinolophus, 7 external characters
Tail
M
HB
TB
FA
E
HF
PC2(24.73%)
PC1(57.81%)
Species
R_affH
R_affL
R_luc
R_mal
R_mar
R_par
R_pea
R_pusH
R_pusL
R_siaH
R_siaL
R_sin
R_sth
R_thoH
R_thoL

Bat immunity & Longevity

- Being a bat is stressful!
- Babies born at 25% of mothers weight
- Longest gestation for their bodysize
- Metabolism which can accelerate to 16x
- Long migrations in some species
- Many species hibernate

Distance travelled	Species
100-275	4
275-500	9



Healy, K., Guillerme, T., Finlay, S., Kane, A., Kelly, S. B., McClean, D., ... & Cooper, N. (2014). Ecology and mode-of-life explain lifespan variation in birds and mammals. *Proceedings of the Royal Society B: Biological Sciences*, *281*(1784), 20140298.

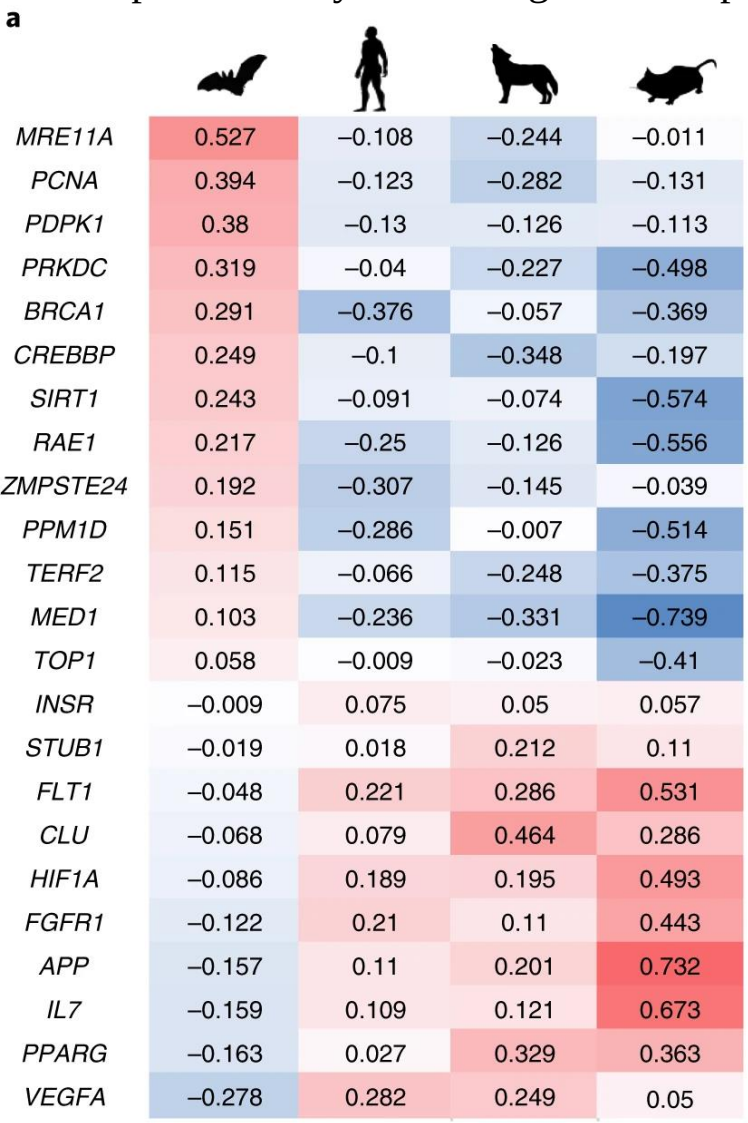
Getting old….

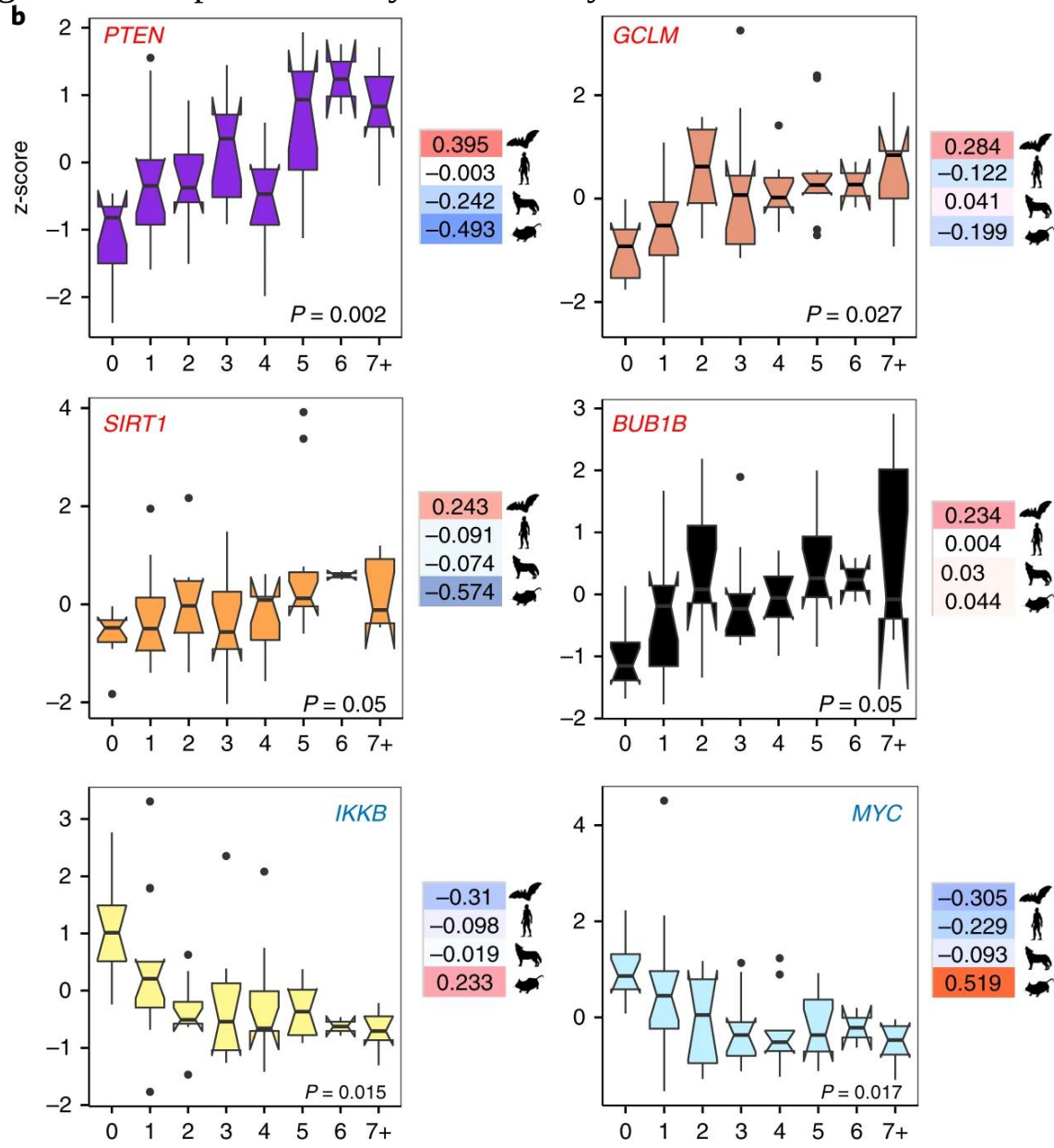
- 2 old mammals…….

- Crumbling bones
- Loss of sight
- Loss of hearing
- Sensitive to illness

…..bats can’t afford to get old

Transcriptomic analysis shows genes are upregulated to repair, and may additionally decrease senescence





Huang, Z., Whelan, C. V., Foley, N. M., Jebb, D., Touzalin, F., Petit, E. J., ... & Teeling, E. C. (2019). Longitudinal comparative transcriptomics reveals unique mechanisms underlying extended healthspan in bats. *Nature ecology & evolution*, *3*(7), 1110-1120.

Bats as reservoirs

- Bats adaptations high stress life confers both longevity and viral resistance
- However the end of the evolutionary arms race is a “cold-war” or co-existence meaning that bats can largely host viruses without showing symptoms and the virus will largely be dormant within bat cells
- Understanding drivers of increased spillover will be essential to attempting to reducing the risk of spillover into other groups

Other credible reservoirs

- Pangolins-Little known, seems capable of hosting, but little strong or conclusive evidence, so likely to exist at low levels in population
- Carnivores; civets, raccoon-dogs etc, capacity for hosting similar viruses. Such viruses may accumulate in liver (and elsewhere) and spread very well in unhygienic conditions; generally viverrids and mustelids would be good reservoirs
- These species act as good intermediaries because they are often housed in poor conditions, can be laundered, and co-occupy spaces with bats as well as humans

Consuming wildlife-and the risks

- Wildlife consumption in Asia has transitioned from subsistence to luxury-this is not the case in parts of the world (i.e. Africa) where wildmeat may still be a fundamental part of the diet
- Wildlife is easy to buy across much of Asia, from luxury high value items to novel but lower price items (i.e squirrels)
- Hunting is still very common across rural areas across Asia, including bats and other high risk wildlife
- In terms of species extinction it is still the major threat for island bat species, and many species used in medicine

Other regional zoonotic outbreaks

- Hendra
- Nipah
- Plague
- ……All of these have caused fatalities in Asia (or Australasia)

- These generally occur though the routes detailed below

Captive wildlife

- Fur farms
- Pets
- Medicine
- Ornamental
- Fashion industry
- Food
- Many species are actually harvested from the wild commercially and for personal use; the use of wildlife is worth billions annually; but captive wildlife and ranching has particularly high zoonotic risk

Fur-farms

- Every year, around 100 million animals are raised and killed for their fur
- Minks -72 million in 2015
- China (2014 stats): 60 million mink, 13 million foxes, 14 million raccoon dogs bred and killed on fur farms
- European Union: 42.6 million mink, 2.7 million foxes; 155,000 raccoon dogs; 206,000 chinchilla killed for fur in the EU
- Rabbits are also killed for fur (and, in some cases, their meat) in large but unknown numbers (likely hundreds of millions) in Europe and China
- In 2015, more than 4 million animals were killed for their pelts in North America

Biosafety

- Rural poverty alleviation schemes in some countries have focused on breeding these species for meat and fur
- As a consequence many wild animals can be mixed in with captive wildlife, both through wild capture or open conditions
- In rural areas there is also potential for feed contamination
- Unhygienic conditions means urin
  between cages; providing ideal co
  spread
- Transport also provides ideal cond

Additional issues with farmed wildlife

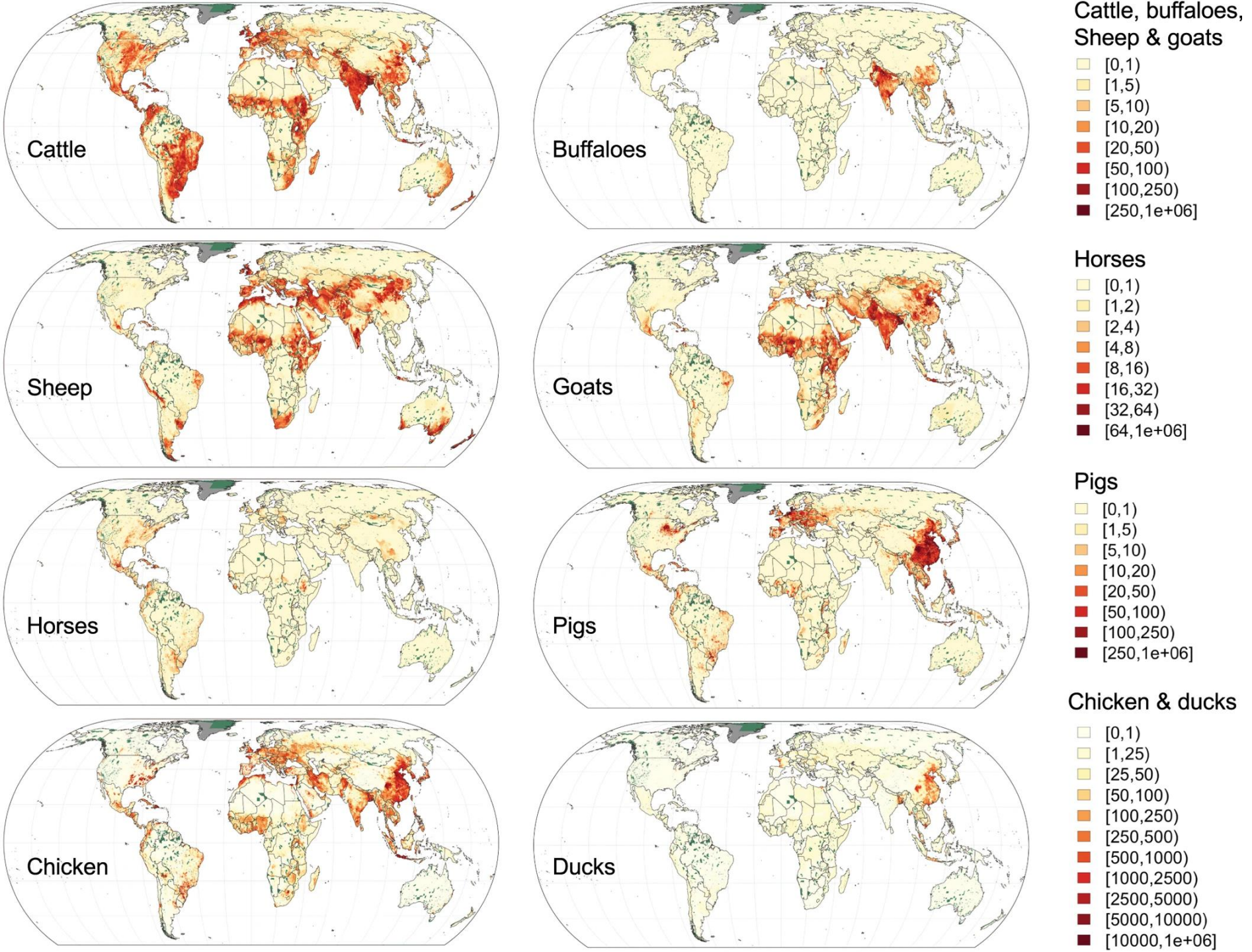
- Weak legislation and poor health
- Wild caught individuals bring in parasites which can spread and spread diseases
- Bigger interface for wildlife to be exposed to other wildlife (sharing caves/roostsites, eating or hunting other wildlife, exposure to urine etc)
- Poorer regulations with how animals are kept, or veterinary procedures
- Issues like otterfarms
- According to data released by the Chinese Academy of Engineering, the wildlife trade in China is valued at $74 billion, employing more than 14 million people, with the fur industry accounting for 74%

Livestock

- Whilst often neglected livestock is a major route-cause of many zoonosis
- This varies from large industrial scale farms (which in Asia typically have poorer biosafety, welfare and fewer healthchecks than in the West) to very small scale operations
- Growth hormones and steroids often used to increase growth rates can weaken immune systems and may increase viral risk

Livestock

- Major outbreaks of Avian flu and Swine flu have occurred even this year
- Swine flu “with pandemic potential” has been increasing over the last decade in Asia, especially China, including new and more virulent strains
- Increasing amounts of livestock (especially Chickens and pigs) are being bred in Asia, with over ½ the worlds pigs in China


Cattle
Buffaloes
Sheep
Goats
Horses
Pigs
Chicken
Ducks
Cattle, buffaloes, Sheep & goats
[0,1)
[1,5)
[5,10)
[10,20)
[20,50)
[50,100)
[100,250)
[250,1e+06]
Horses
[0,1)
[1,2)
[2,4)
[4,8)
[8,16)
[16,32)
[32,64)
[64,1e+06]
Pigs
[0,1)
[1,5)
[5,10)
[10,20)
[20,50)
[50,100)
[100,250)
[250,1e+06]
Chicken & ducks
[0,1)
[1,25)
[25,50)
[50,100)
[100,250)
[250,500)
[500,1000)
[1000,2500)
[2500,5000)
[5000,10000)
[10000,1e+06]

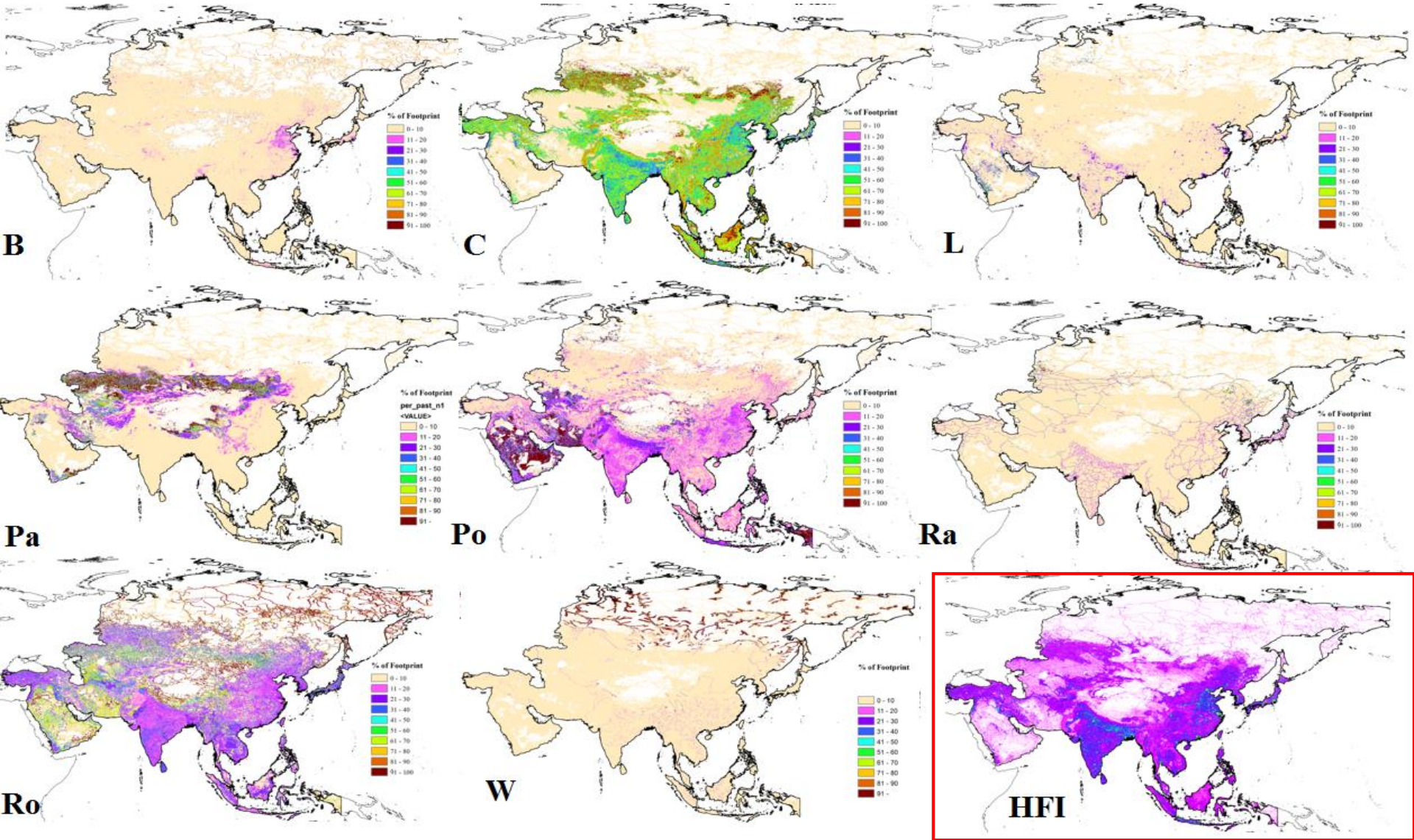
Livestock

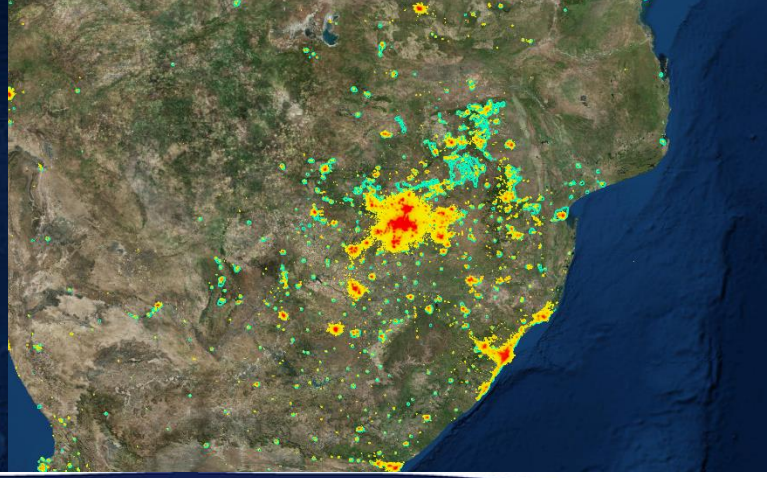
- Multiple routes of transmission
- Workers in pig farms often carry swine flu and have suffered (sometimes fatally)
- Smaller operations (i.e those seen in more mountainous areas) may bring people into very close contact with livestock-driving huge spillover risk
- Where wildlife and domestic animals share spaces it enhances spillover risk

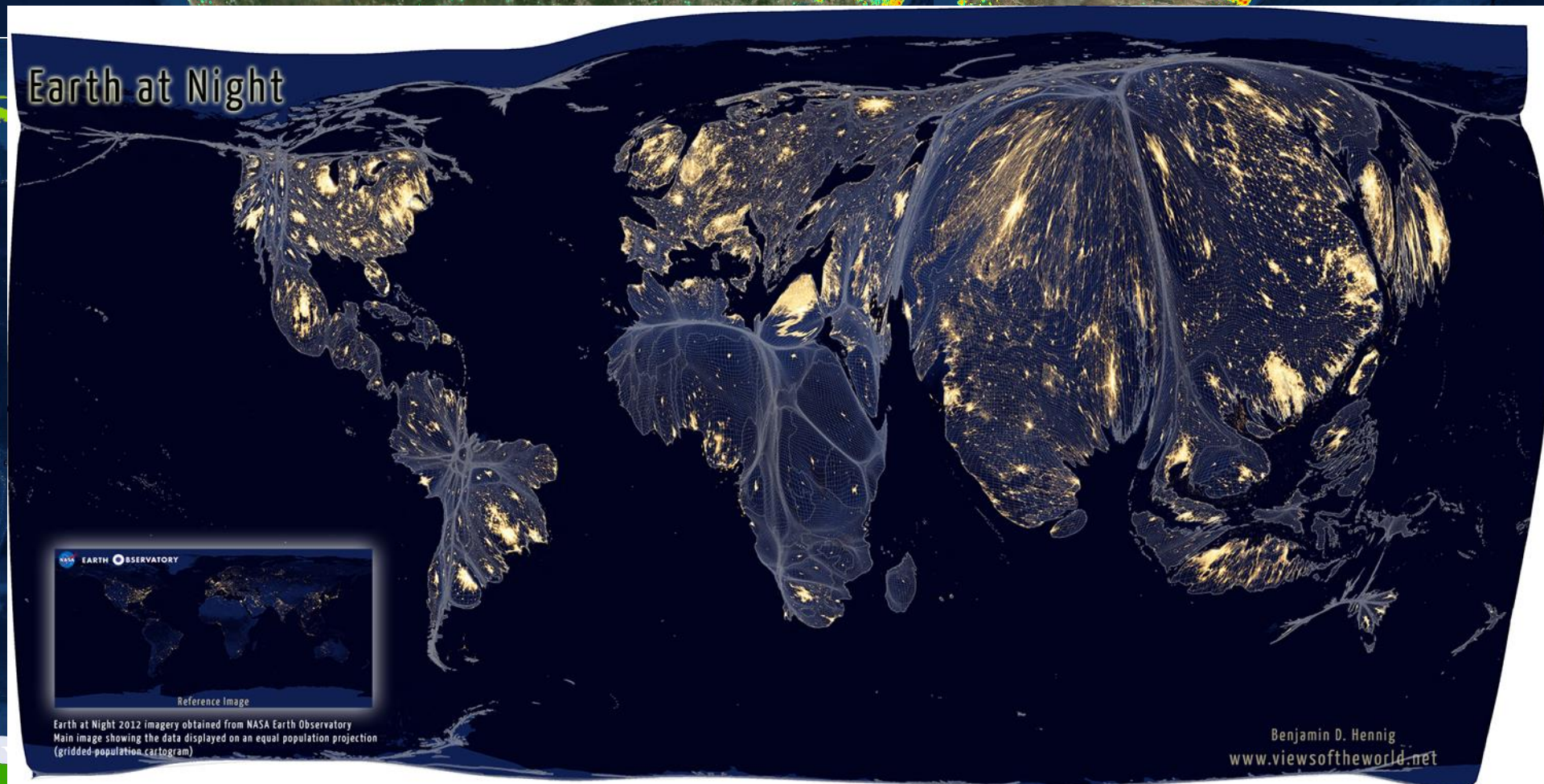
Is Asia at a higher risk?

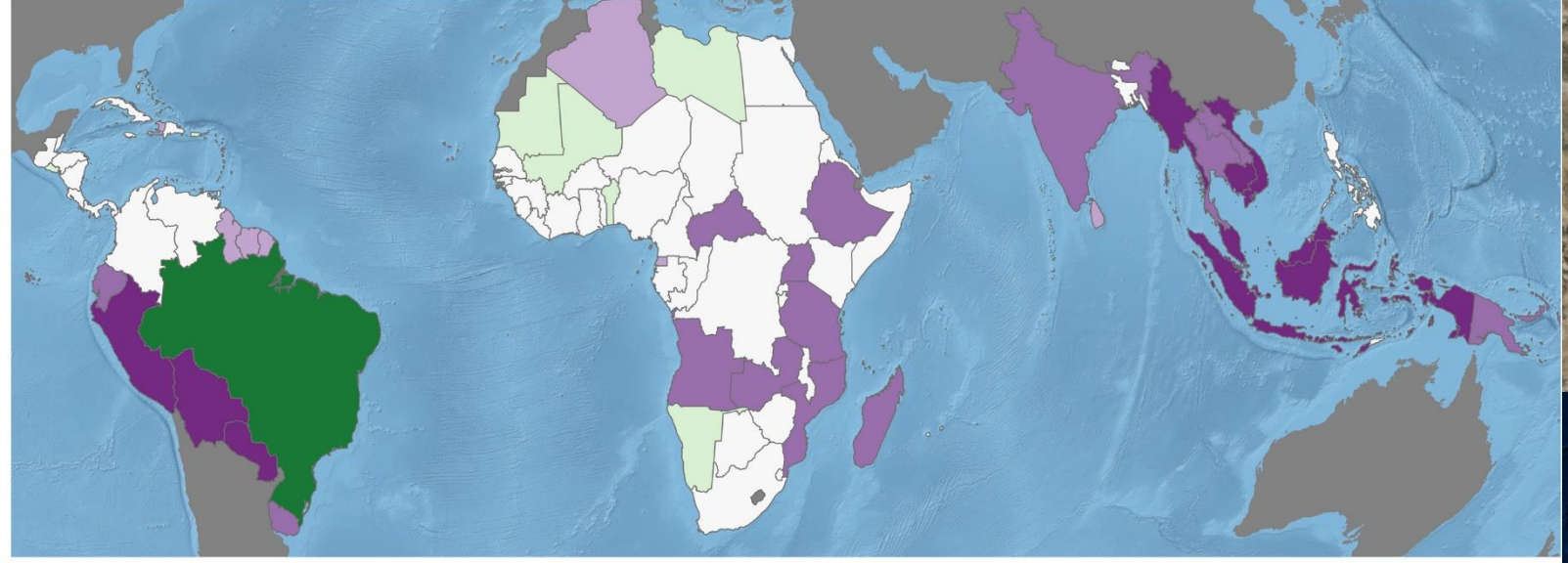
- Asia has well over half the worlds population
- With increasing population, industrialization and consumption of meat it is putting natural resources under increasing pressure
- The interface between livestock and wildlife is also considerable providing risks of spillover via direct contact, parasites or fluids
- However rate of change within Asia is also a major risk

Is Asia at a higher risk?






Earth at Night
EARTH OBSERVATORY
Reference Image
Earth at Night 2012 imagery obtained from NASA Earth Observatory
Main image showing the data displayed on an equal population projection
(gridded population cartogram)
Benjamin D. Hennig
www.viewsoftheworld.net



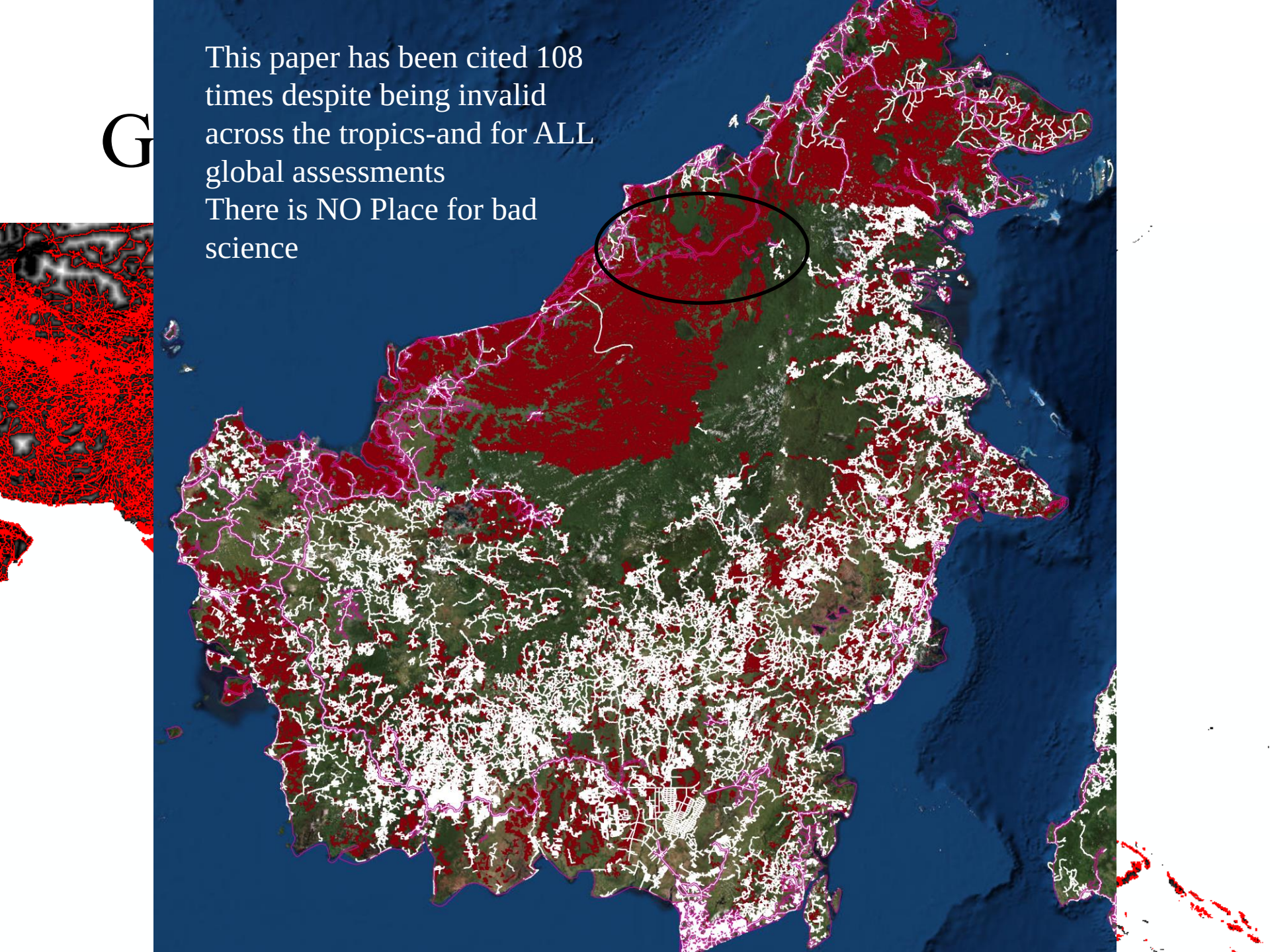
(a) Change in the rate of deforrestation (kha / yr)

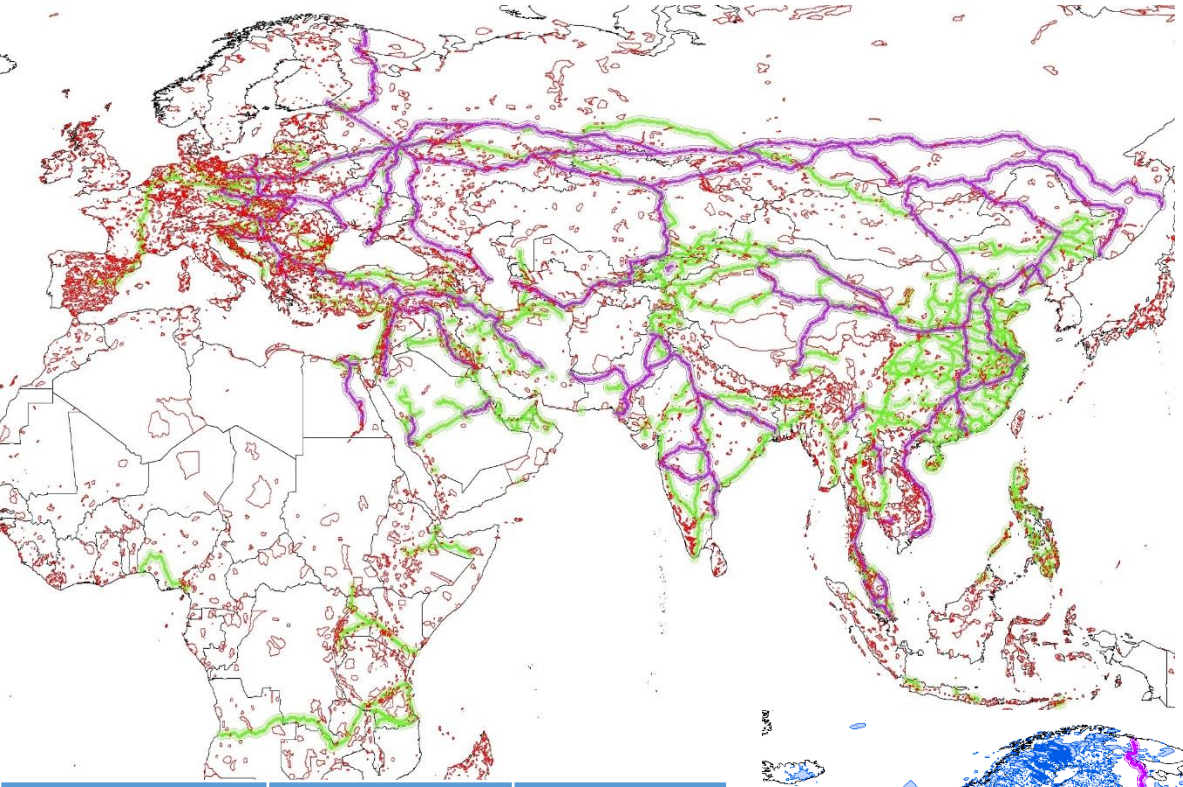
< -10 | -10 to -1 | -1 to 0 | NS | 0 to 1 | 1 to 10 | > 10

- Tropical deforestation resulted in a debt of more than 140 forest-specific vertebrates (*Rosa et al., 16)*
- The extinction debt would increase 20th-century extinctions in vertebrates by 120%
- Clearance for agriculture accounts for appx 80% deforestation from 1980-2000 *(Gibbs et al., 10)*
- Agriculture is the main driver in Asia, whereas political stability & GDP are correlates in SS Africa *(Lebois et al., 17)*

(b) Ch

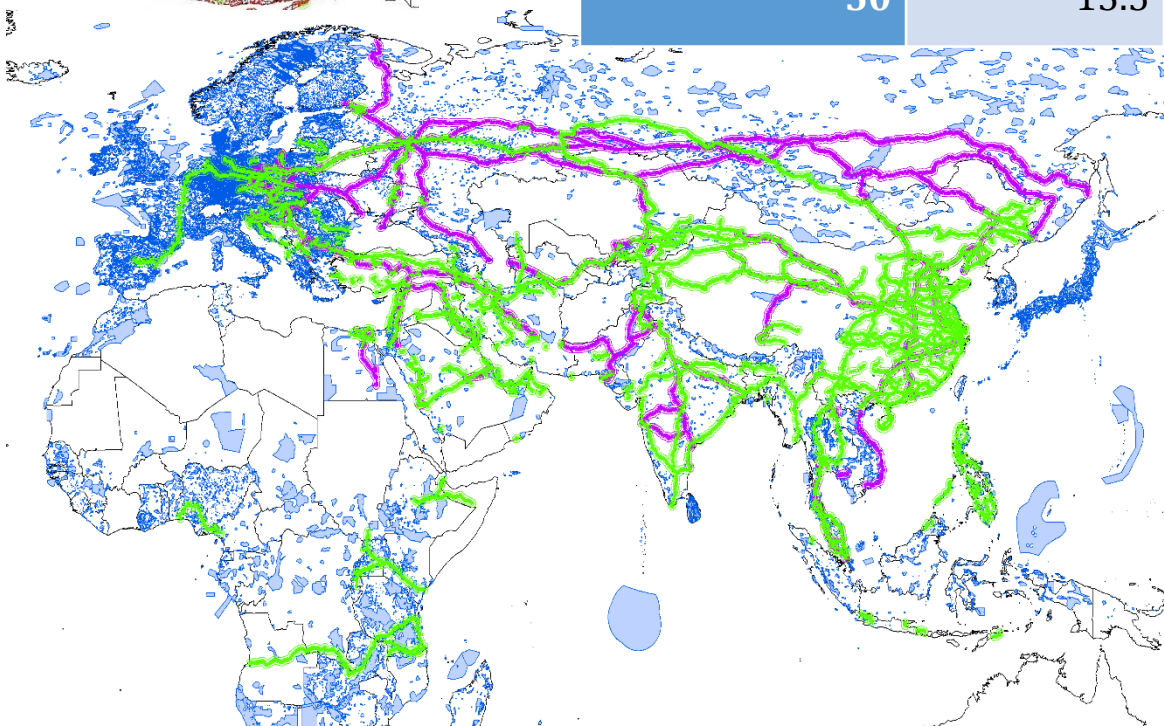
G

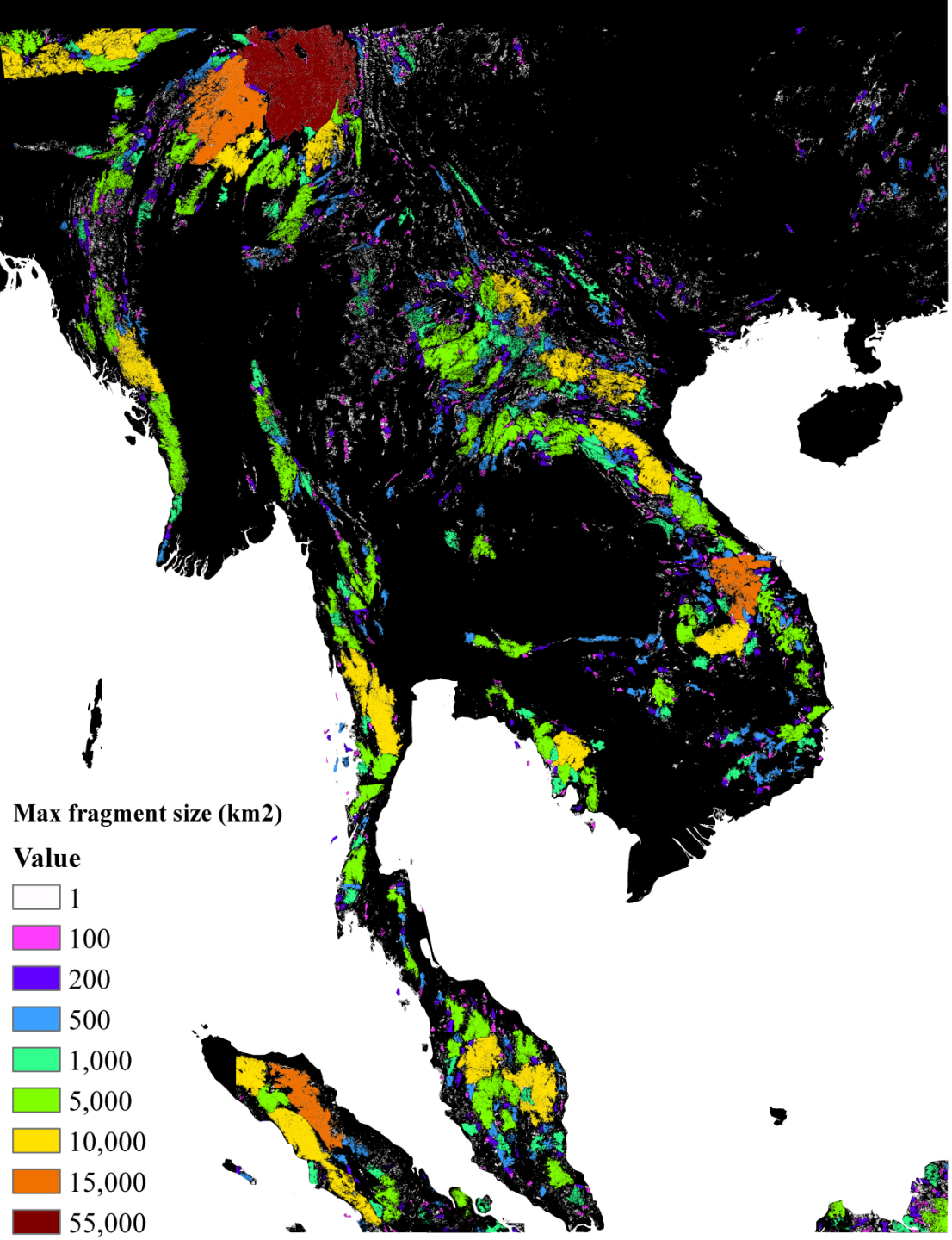

This paper has been cited 108 times despite being invalid across the tropics-and for ALL global assessments
There is NO Place for bad science



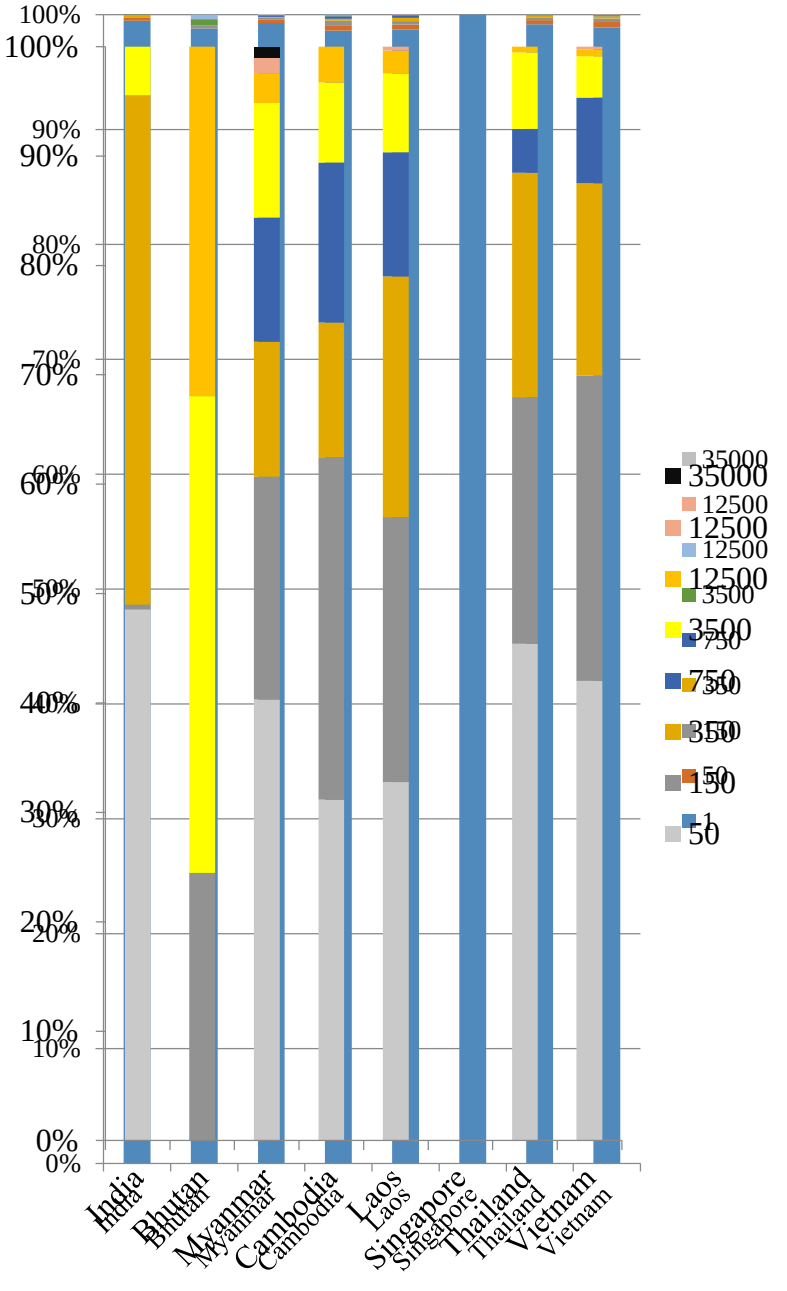
KM_Rail	No_KBAs	%_KBAs
1	440	14.9
7	477	19.9
14	580	27.5
30	830	40.2
50	1218	60.6
KM_Road	No_KBAs	%_KBAs
1	937	0.2
7	1164	1.9
14	1458	4.0
30	1957	8.6

Rail_km	%_Pas
1	0.1
7	0.6
14	1.3
30	3.0
50	6.8
Road_km	
1	0.0
7	1.1
14	3.0
30	6.7
50	13.5





Number of fragments in different size classes



Asia-under threat

- Rapid rates of development are quickly destroying native habitat, which has major implications for disease risk
- Loss of forests means species are forced to move into agricultural areas to obtain enough food
- This forces increased interactions between wildlife and domestic animals, and wildlife and humans
- Thus this increases the potential of encounters where spillover could occur

Asia-under threat

- Hunting, roost loss, habitat loss causes stress
- Stress leads to immunosuppression; so animals are more likely to encounter, suffer and pass on pathogens
- By modifying ecosystems we are exponentially increasing the risk of spillover
- By then bringing that wildlife into captivity and consumption we are further exacerbating the risk
- These will cause further pandemics-as we can see in cases like Ebola

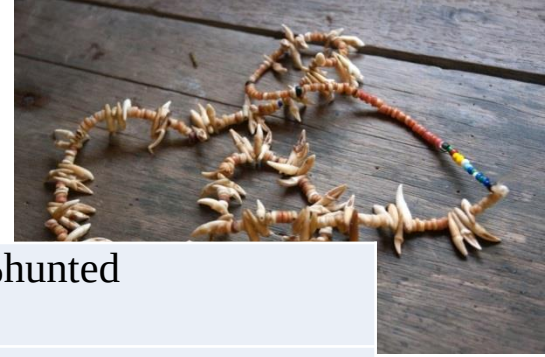
Bats as a casestudy

- Bats are frequently a scapegoat for issues with disease and fruit predation
- Mauritius culled over 20,000 *P. niger* (20% global population)
- Culls have also been used to combat crop damage elsewhere (*i.e. Australia)*
- Culling programs have failed to reduce rabies prevalence in vampire bats (Streicker et al. 2012); and failed attempt to cull *Rousettus aegyptiacus* in Uganda resulted in a rise in the prevalence of Marburg virus (Amman et al. 2014). Yet these happen globally

Threats

- Bat hunting for consumption as bushmeat and medicine affects at least 167 species of bats (13 % global bat species)
- Half (92/183) extant Pteropodidae species are hunted
- Pteropodids that are hunted are six times more likely to be Red Listed as threatened: 66 % species (CR, EN, VU, NT), compared to 11 % of species in the ‘Least Concern’ (LC) category

Threats



Region	Total#	On Red List	Not on list	Total hunted	%hunted
	1146	97	70	167	14.6
Caribbean islands	106	0	0	0	0
East Asia	130	3	4	7	5.4
Europe	42	0	0	0	0
Meso America	177	0	0	0	0
North Africa	41	3	1	4	9.8
North America	49	0	0	0	0
North Asia	43	0	0	0	0
Oceania	173	25	15	40	**23.1**
South America	249	0	8	8	3.2
South and Southeast Asia	365	43	20	63	*17.3*
SE	333	36	20	56	*16.8*
South	114	8	5	13	11.4
Sub-Saharan Africa	249	25	26	51	**20.5**
West and Central Asia	94	1	0	1	11

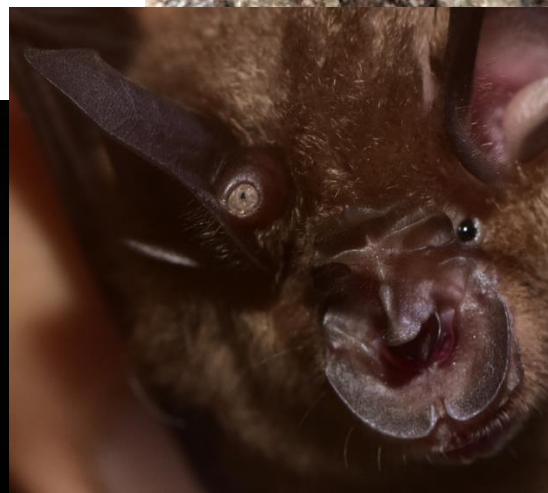
https://link.springer.com/chapter/10.1007/978-3-319-25220-9_12

Threats-*Mass mortality events*

How are these impacting on behavior, and risk (i.e. contaminants)?

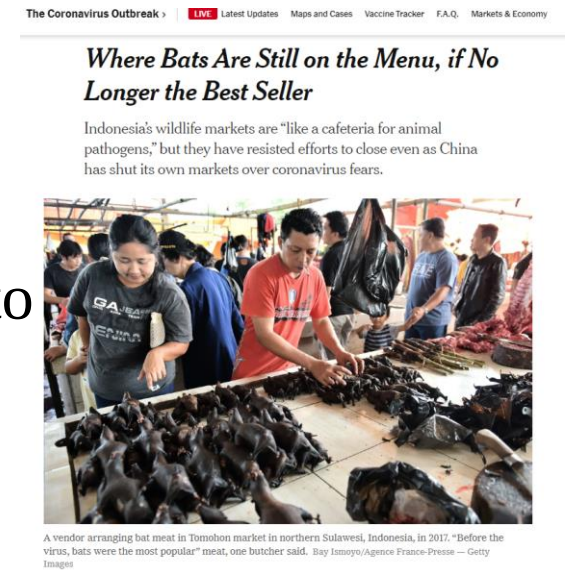
Using bats as indicators

- Parasite load and health-higher density, more transfer
- Greater incidence of fighting if overcrowded
- Multiple factors both influence health and potential risk
- Habitat loss increases novel communities, and shared parasites and pathogens



Our impacts-our outcomes

- Southeast Asia is a hotspot of biodiversity
- Yet it is a hotspot of threat-the highest rates of deforestation globally, highest rates of mining in the tropics, and a 5.7% annual loss of karst
- Destroying habitat increases interactions and spillover opportunity, and increased stress increases ability to contract and carry viruses
- Unless we protect habitat we will see increased and continued emergence of threats
- Consumption of wildlife and farming of wild species is inherently high risk
- Biosafety needs to be improved through all components of meat production and efforts made to prevent wildlife-livestock interactions



Our future-our choices

- Covid is a consequence of unsustainable resource use
- The difference between Covid and the 100s of other Novel Zoonoses is that it spreads well, can be spread asymptomatically-and we now move more
- The difference between now and the 2012 cases-connections
- This will not be the last pandemic unless we learn-maintain healthy habitats and populations, reduce interactions and spillover
- Sustainability and tracking systems to identify and stop spread, and reduce use of high risk species is key to reducing furture pandemics


Questions?