Country Profile: NIGERIA

Scientific basis for zoonosis education program

(as of February 2023)

In situ project partner: PANDRILLUS – Drill Ranch

Location: Calabar, Cross River ☑ **urban** ☑ **rural**

Outreach to (area):

The project has a centre in the municipality (Calabar) and a field site in a rural location (Afi). Educational activities take place at both sites. Other states in the country will be reached via media and the ambassador system that will be managed by Pandrillus.

Structure

1. National characteristics

- English as the official language; Hausa, Yoruba, Igbo (Ibo), Fulani, and **over 500 additional indigenous languages**; Pidgin is commonly used in several areas.
- **Africa's most populous country**; significant population clusters are scattered throughout the country, with the highest density areas being in the south and southwest (World Factbook 2022); level of urbanization 53%.
- Position 107 (out of 113 countries) in the Global Food Security Index 2022 (The Economist 2022) and Position 103 (out of 121 countries) in the Global Hunger Index (Welthungerhilfe & Concern Worldwide 2022)

1.1. National legislation

Nigeria has strong federal legislation protecting wildlife. However, enforcement is poor or non-existent in most contexts. Many states have additional laws. Some laws/acts include:

- Endangered Species (Control of International Trade and Traffic) Act, 1985[1], amended 2016[2] (WildAid 2021):
    - First Schedule prohibits hunting or capture or trade
    - Second Schedule prohibits hunting or trade in wild animals unless a license has been issued under this Act
- National Environmental (Protection of Endangered Species in International Trade) Regulations, 2011[3]: prohibition of import, export, and re-export of animal species and specimens indicated in CITES Appendices I, II and III.
- National Environmental Standards and Regulations Enforcement Agency (establishment) Act, 2007[4]
- National Park Service Act[5]
- According to WHO (2017), Nigeria has no formal policy, strategy or plan for responding to zoonotic outbreaks.
- According to the GHS Index (2021), Nigeria has no national legislation, plans or equivalent strategy documents which include measures for risk identification and reduction for zoonotic disease spillover events from animals to humans.

1.2. Human population

225,082,083 Mio people (2022 est.; World Factbook 2022)

Population growth rate: 2.53% (2022 est.; World Factbook 2022)

Religion (2018 est.; World Factbook 2022):

- Islam: 53.5 %
- Christianity: 45.9% (subgroups: Roman Catholics 10.6%; Other Christian 35.3%)
- other groups: 0.6%

[1] https://www.animallaw.info/sites/default/files/stngendangeredspeciesact.pdf
[2] https://placbillstrack.org/8th/upload/Endangered-Species-Control-of-International-Trade-and-Traffic-Amendment-Act-2016.pdf
[3] https://gazettes.africa/archive/ng/2011/ng-government-gazette-dated-2011-05-09-no-43.pdf
[4] https://www.placng.org/lawsofnigeria/laws/nesrea.pdf
[5] https://placng.org/lawsofnigeria/laws/N65.pdf

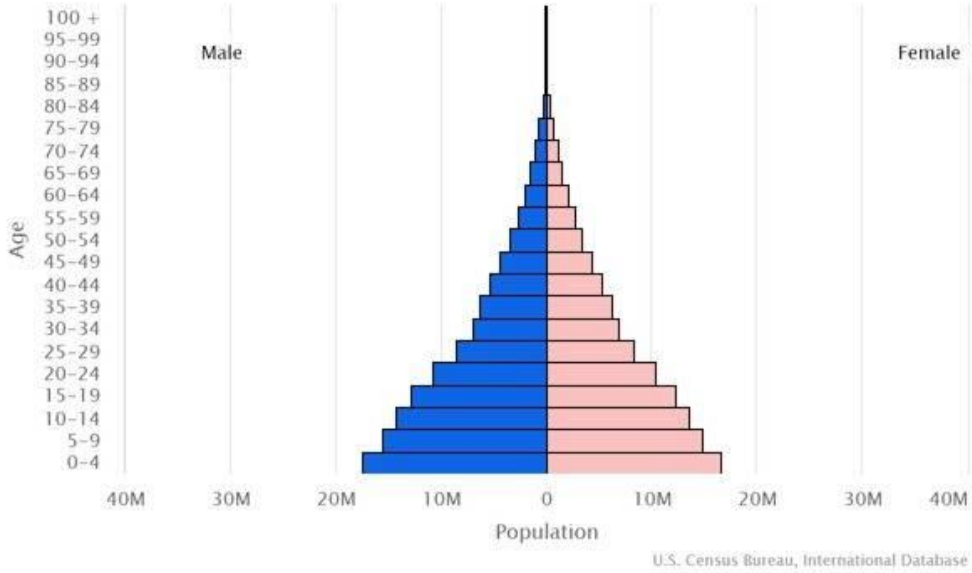
Ethnic groups:

The population of is composed of more than 250 ethnic groups (World Factbook 2022). Percentage estimation of the main tribes by 2018:

Hausa 30%, Yoruba 15.5%, Igbo (Ibo) 15.2%, Fulani 6%, Tiv 2.4%, Kanuri/Beriberi 2.4%, Ibibio 1.8%, Ijaw/Izon 1.8%, other 24.9%

Age structure (2020 est.; World Factbook 2022):

- 0-14 years: 41.7% (male 45,571,738/female 43,674,769)
- 15-24 years: 20.27% (male 22,022,660/female 21,358,753)
- 25-54 years: 30.6% (male 32,808,913/female 32,686,474)
- 55-64 years: 4.13% (male 4,327,847/female 4,514,264)
- 65 years and over: 3.3% (male 3,329,083/female 3,733,801)



2. Relevant zoonotic diseases

2.1. Key points on zoonotic diseases

Some zoonotic diseases (such as yellow-fever and trypanosomiasis) are transferred to humans by insect bites. Those "vector-borne" diseases are not covered by this country profile, as this project aims raising awareness for consumption-linked spillover risks (e.g. via bushmeat, keeping of wildlife as pets).

In a nutshell:

- **About 75% of all novel infectious diseases are zoonoses** (i.e. diseases transmitted from animals to humans).
- **More than 70% of zoonoses originate from wild animals.**
- Legal AND illegal wildlife trade promote spreading of pathogens and zoonotic spillover events.
- While zoonotic diseases have their origin in animals, human-to-human transmission may become the dominant pathway (e.g. COVID-19, AIDS). Nevertheless, the original source has been in animals (mostly wildlife) and **risks for new spillover events should be reduced to a minimum.**
- Viruses present the greatest zoonotic disease threat to humans because their fast rates of evolution will allow them to easily adapt to new hosts. However, other zoonotic diseases are caused by **bacteria or parasites**.
- According to WHO the number of zoonotic outbreaks in the African region increased by 63% in the decade from 2012-2022, compared to the decade before.
- During a workshop in December 2018, **ECOWAS agreed upon a list of seven priority zoonotic diseases for the region** – Anthrax, Rabies, Ebola and other viral haemorrhagic fevers (for example, Marburg fever, Lassa fever…), zoonotic influenzas, zoonotic tuberculosis, Trypanosomiasis* and Yellow fever*.
- Nigeria is among the top ten countries with the highest burden of infectious and zoonotic diseases globally.
- Many zoonotic infections are characterized to be endemic in Nigeria, including Lassa fever, tuberculosis, yellow fever, trypanosomiasis, rabies, toxoplasmosis, and taeniasis. Nigeria ranked rabies, avian influenza, Ebola Virus Disease, swine influenza and anthrax as zoonotic diseases of particular interest, among others.
- In early June 2022, the Nigerian Government has banned the sale of bushmeat as a precaution to stop the spread of Mpox.
- **Reptile-associated salmonellosis** globally increases in countries. In some of the most poverty-afflicted regions of Africa, the burden of this neglected disease may be alarming.

2.2. Table: Zoonotic health risks relevant for Nigeria

Zoonosis	**Type of pathogen**	**Symptoms**	**Means of transmission**	**Outbreaks** (when?)	**Extent** (how many felt ill / died)	**Measures by the Government** (e.g., hunting ban, closure of bushmeat markets, education campaigns)	**References**
Ebola	Virus (Filovirus)	**Incubation time**: 2-21 days **Symptoms**: e.g. life-threatening **haemorrhagic fever**, malaise, fatigue, aching limbs, pain in abdomen, nausea, diarrhoea, internal and external bleeding (haemorrhages), delirium, shortness of breath	**Spillover from wildlife to humans**: bushmeat and contact to bats (primary hosts) as well as primates, rodents & duikers (secondary hosts) **Human to human**: Direct contact, blood, body liquids, faeces, vomit	2014-2016	average case fatality rate is approximately 50% 20 cases; 8 deaths >> mortality 40% Rapid case management, isolation of infected persons Prevalence in humans in Nigeria: 2%	**Priority for Government in Nigeria** NCDC is always on high alert. 2017: Viral Haemorrhagic Fevers Preparedness and Response Plan published	CDC 2022a Ihekweazu et al. 2021 WHO 2021a Otu et al. 2018 Nigeria Centre for Disease Control 2017a Judson *et al.* 2016 Olugasa et al. 2015 CDC 2014
Lassa Fever	Virus (Arenavirus)	**Incubation period**: 6-21 days, highly virulent **Symptoms**: **haemorrhagic fever**, general weakness, and malaise. After a few days, headache, sore throat, muscle pain, chest pain, nausea, vomiting, diarrhoea, cough, abdominal pain. In severe cases facial swelling, general bleeding tendency (mucosal bleeding), pleural and pericardial effusions, neurological symptoms, slowed heartbeat, low blood pressure. Death approx. 12 days after onset of disease in irreversible	**Spillover from wildlife to humans**: Contamination with excrement/secretions of rodents; consumption of uncooked rodent meat **Human to human**: direct contact with blood, tissues, secretions and urine of infected	2019, 2018, 2017, 2016, 2015 First discovered in Nigeria in 1969. Endemic in Nigeria. Incidences in at least 17 states since 2016.	About 80% of people who become infected with Lassa virus have no symptoms 36% of Nigeria estimated as Lassa Fever risk area 21.3% of Nigerians have Lassa virus specific antibodies 2019: 213 cases; 42 deaths 2018: 2576 cases; 209 deaths	**Priority for Government in Nigeria** NCDC has activated the National Emergency Operations Centre alert mode for effective multi-sectoral, multi-disciplinary coordination of the response.	WHO undated a,b Izah et al. 2022 WHO 2022j WHO 2021c Muhammad 2020 Nigeria Centre for Disease Control and Prevention 2019a WHO 2019b Nigeria Centre for Disease Control 2018 Tambo et al. 2018

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		shock with organ failure, hypovolaemia and anuria.	persons, sexual contact		2017: 501 cases; 104 deaths 2015-2016: 273 cases; 149 deaths case fatality ratio is 1-15% among hospitalized patients		WHO 2017b Mylne et al. 2015
Marburg Disease	Virus (Filovirus)	**Incubation time**: 2-21 days **Symptoms**: bleeding from nose and mouth, high fever, severe headache, severe malaise, muscle aches and pain, diarrhoea, abdominal pain and cramping, nausea, and vomiting	**Spillover from wildlife (e.g. bats) to humans**: spread by body fluids, such as blood and saliva **Human to human**: direct contact with blood or body fluids of sick persons	No cases incidence reported in Nigeria so far. Recently reported in Ghana (2022); Uganda (2014 and 2017), and Guinea (2021).	average case fatality rate is approximately 50% 2005-outbreak in Angola: > 200 people died 2 of 3 ill persons in Ghana died	**Priority for Government in Nigeria** NCDC's multi-sectoral, multi-partner and multidisciplinary Technical Working Group (TWG) on Emerging Viral Haemorrhagic Diseases (EVHD) are monitoring signals and epidemic intelligence on the disease closely.	Nigeria Centre for Disease Control and Prevention 2022 Sah et al. 2022 WHO 2022f WHO 2021b Markotter et al. 2020
Mpox (=Monkeypox)	Virus (orthopoxvirus)	**Incubation time**: 3-17 days **Symptoms**: e.g. fever, headache, muscle pain, skin lessons, pustules, lymphadenopathy, back pain, myalgia, weakness	**Spillover from wildlife to humans**: bushmeat (blood and secretions of infected primates, duikers & rodents)	2022 2020 -2017 1978 First case in 1971	2022: 21 confirmed (66 suspected) cases, including one death September 2017 to November 2019: 183 confirmed cases, including nine deaths	2022: ban of sale and consumption of bush meat, Minister directed hunters and dealers of bush meat to stop business; avoiding of contact with sick people	Nigeria Centre for Disease Control and Prevention undated b AfricaNews 2022 CDC 2022b Milbank & Vira 2022

Zoonosis	Type of pathogen	Symptoms	Means of transmission	Outbreaks (when?)	Extent (how many felt ill / died)	Measures by the Government (e.g., hunting ban, closure of bushmeat markets, education campaigns)	References
			Human to human: Direct contact with infected persons, saliva droplets, sexual contact		2017: 172 suspected & 61 lab-confirmed cases (largest documented outbreak of human Mpox in West Africa) First outbreak in 1971	2017: Enforcement of meat inspection legislation; enlightenment of the public 2017: National Mpox Public Health Response Guidelines published	Spiegel 2022 WHO 2022k Nigeria Centre for Disease Control and Prevention 2019b Ogoina 2022 Okareh & Morakinyo 2018 Nigeria Centre for Disease Control 2017b
T-cell leukemia	Virus (Simian retroviruses: STLV-1 / HTLV-1 and STLV-2 / HTLV-2)	**Incubation time**: 6 months – 20 years **Symptoms**: Often without symptoms; however, 5% of infected persons suffer from adult T-cell leukaemia / lymphoma and HTLV-1 associated myelopathy; higher risk for tuberculosis	**Spillover from wildlife to humans**: bushmeat, bites by non-human primates; blood, saliva **Human to human:** Blood, sexual contact, breast-feeding	Prevalence rate of up to 25.8 %	Incidence in 1993? Underreported	Not mentioned by NCDC, not prioritized	Anyanwu et al. 2018 ECDC 2015 Gessain & Cassar 2012 Williams et al. 1993
Avian bird flu	Virus (Influenca virus: H5N1, H5N8 & H7N9)	**Incubation time**: up to 21 days **Symptoms**: pneumonia; stomach and intestinal complaints; increase in liver enzymes; severe reduction of leukocytes (leukopenia), erythrocytes (anaemia) and thrombocytes	**Spillover from wildlife:** wild aquatic birds as primary host, poultry as secondary host, direct contact with infected	first cases in animals in Africa in 2006 (in Nigeria), spreading within Africa	Endemic in Nigeria Prevalence in humans in Nigeria: 18.9% case fatality rate is approximately 60% Zoonotic spillover in East Asia, spreading by	**Priority for Government in Nigeria** Priority in the livestock (specifically poultry) production	Spiegel 2023 Chieloka 2021 Ihekweazu et al. 2021 WHO 2017b FAO 2015

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		(thrombocytopenia), in severe cases renal failure, lung failure, multiorgan failure	birds (blood, feces, feathers)		migrating wild birds and poultry (so far no human-to-human infections known, but first possible mammal-to-mammal infection noted among minks in a fur farm in Spain in October 2022)	Current situation reports not found Not well recognized by NCDC Live bird markets are present all across the country	Wertheim et al. 2012 Gaidet *et al.* 2010 Cattoli *et al.* 2009 Seck et al. 2007 WHO 2006
Rabies	Virus (lyssa virus)	**Incubation time**: 1-3 months **Symptoms**: Fever, headache, vomiting, agitation, confusion, hyperactivity, excessive salivation, hallucinations, insomnia, partial paralysis	Bites or scratches mainly from dogs, but also from wild animals (e.g. bats, monkeys)	First discovered in Nigeria in 1912	Endemic in Nigeria Nigeria is considered a high-risk country, with 10,000 annual cases	**Priority for Government in Nigeria** Under-reported in Nigeria Lack of responsible pet ownership Significant risk to dog meat processors and indirect risk to eaters (majority in the South)	GARC 2022 Mshelbwala et al. 2021 Markotter et al. 2020 Public Health England 2020 WHO 2019a Nigeria Centre for Disease Control and Prevention 2017 WHO 2017b Hampson et al. 2015 WHO 2013 WHO 2012 WHO 2011
Corona / COVID-19	Virus (Corona virus: SARS-CoV-2)	**Incubation time**: 2-14 days **Symptoms**: fever or chills, cough, shortness of breath or	**Spillover from wildlife**: bats as primary host, wildlife (e.g.	2020-2023	Zoonotic spillover in China, but pandemic spreading by humans	**High priority for Government in Nigeria**	Nigeria Centre for Disease Control and

Zoonosis	Type of pathogen	Symptoms	Means of transmission	Outbreaks (when?)	Extent (how many felt ill / died)	Measures by the Government (e.g., hunting ban, closure of bushmeat markets, education campaigns)	References
		difficulty breathing, fatigue, muscle or body aches, headache, loss of taste or smell, sore throat, congestion or runny nose, nausea or vomiting, diarrhoea	civets, bamboo rats, primates) sold at wet markets discussed as secondary host; **human to human**: respiratory uptake of virus-containing particles (aerosols)		Corona viruses also found in wild bats in Cameroon and other African countries		Prevention undated a Worobey *et al.* 2022 Xiao *et al.* 2022 Fischhoff *et al.* 2021 Markotter et al. 2020
AIDS	Virus (lentivirus: SIV-1/HIV-1)	**Incubation period**: After 1-6 weeks acute retroviral syndrome; development of AIDS within 10 years **Symptoms**: Diarrhoea that lasts for more than a week; dry cough; memory loss; depression and neurological disorders; pneumonia; profound, unexplained fatigue; rapid weight loss; recurring fever or profuse night sweats; blotches on or under the skin or inside the mouth, nose or eyelids; swollen lymph glands in the armpits, groin or neck; white spots or unusual blemishes on the tongue, in the mouth, or in the throat; weakened immune system. Opportunistic infections	**Spillover from wildlife**: bushmeat, blood and body fluids of chimpanzees **human to human**: blood, body fluids, sexual contact	ongoing	Zoonotic spillover early in 20th century from chimpanzees to humans, but further spreading by humans While HIV detection rates decreased over time overall, children less than 15 years of age showed an annual increase from 6.7% in 2014 to 12.3% in 2018. Data from the largest tertiary facility in Liberia shows broad HIV detection rates that are much higher than national prevalence estimates.		Peeters et al. 2010 Hahn et al. 2000 Gao *et al.* 1999

Zoonosis	Type of pathogen	Symptoms	Means of transmission	Outbreaks (when?)	Extent (how many felt ill / died)	Measures by the Government (e.g., hunting ban, closure of bushmeat markets, education campaigns)	References
		may lead to weakening, coma and death.					
Anthrax	Bacteria (*Bacillus anthracis*)	**Incubation period**: 1 day – 2 months **Symptoms (3 forms of Anthrax):** a) **skin anthrax** (most common form): itchy blisters and bumps, ulcers, black sore; headache, muscle aches, fever and vomiting b) **inhalation anthrax**: fever, chest pain, confusion, shortness of breath, extreme tiredness **gastrointestinal anthrax**: diarrhoea (evtl. with blood), abdominal pains, vomiting of blood, severe diarrhoea	**Spillover from wildlife:** Direct contact with herbivorous wildlife & livestock, consumption, handling of hides **Human to human**: no transfers yet documented		Highly toxic (used as military weapon) Skin infections represent more than 95% of cases Without treatment the risk of death from skin anthrax is 23.7%, for intestinal infection 25-75%, respiratory anthrax: 50-80%	**Priority for Government in Nigeria**	Katani et al. 2021 WHO 2017b WHO 2016
Brucellosis	Bacteria (*Brucella* sp.)	**Incubation period**: 1 week – 2 months **Symptoms:** flu-like symptoms, including fever, weakness, malaise and weight loss	**Spillover from wildlife:** Contact with infected herbivorous wildlife & livestock, consumption, floodwaters >> **Human to human**: rare transmission		Prevalence in humans in Nigeria: 5.2–7.8%	**Priority for Government in Nigeria**	Ihekweazu et al. 2021 Katani et al. 2021 Simpson et a. 2021 WHO 2017b

Zoonosis	**Type of pathogen**	**Symptoms**	**Means of transmission**	**Outbreaks** (when?)	**Extent** (how many felt ill / died)	**Measures by the Government** (e.g., hunting ban, closure of bushmeat markets, education campaigns)	**References**
Bovine tuberculosis	Bacteria (*Mycobacterium bovis*)	**Incubation period**: months to years **Symptoms:** fever, night sweats, and weight loss, abdominal pain and diarrhoea. Can be fatal if untreated	**Spillover from animals:** direct or indirect contact with infected animals (mainly cattle, but also in many wildlife species of southern Africa); **Human to human**: inhalation of aerosol droplets of infected persons		BTB prevalence of 27.7% in the Kafue lechwe, but not assessed for many other wildlife species, regional differences	**Priority for Government in Nigeria**	Lakin et al. 2022 Hoffman et al. 2017
Leptospirosis	Bacteria (*Leptospira borgpetersenii, L. Interrogans, L. kirschneri*)	**Incubation period:** 2-10 days **Symptoms:** Weil's syndrome characterized by jaundice, renal failure, haemorrhage and myocarditis with arrhythmias; meningitis/meningoencephalitis; pulmonary haemorrhage with respiratory failure (often lethal).	**Spillover from animals:** Mainly contact with infected livestock, but also rodents and other wildlife, consumption of bushmeat **Human to human**: rare (via body fluids)	One of the most widespread zoonosis worldwide	Neglected but widespread: 2.3-19.8% of hospital patients with fever in Africa Case-fatality rates of 5 – 70% 8.4% prevalence among febrile patients in Oyo state, southwest Nigeria in 2019		Besong et al. 2022 Allan et al. 2015 Jobbins et al. 2014
Reptile-associated Salmonellosis	Bacteria (*Salmonella enterica* and *Salmonella typhimurium*)	**Incubation period**: 12-72 h **Symptoms:** diarrhoea, abdominal cramps, fever, occasionally nausea and vomiting. Bloodstream infections can be life	**Spillover from animals:** direct or indirect contact with faecal material from reptiles; handling of reptiles;	(No systematic records)	Remains often undiagnosed >> underestimated		Zajac et al. 2021 Pulford et al. 2019 Pawlak 2014 Gumpenberger 2000

Zoonosis	Type of pathogen	Symptoms	Means of transmission	Outbreaks (when?)	Extent (how many felt ill / died)	Measures by the Government (e.g., hunting ban, closure of bushmeat markets, education campaigns)	References
		threatening, especially in children under 5 yrs, the elderly, or in persons with weakened immune systems.	touching surfaces/objects that were in contact with a reptile				
Human visceral pentastomiasis (caused by *Armillifer armillatus*)	Endoparasite (worm) endemic to West Africa	**Symptoms**: Most human infections are asymptomatic (sometimes even over decades), but serious or even fatal infections are described. Calcifications, caused by died and calcified parasites, can accumulate in liver, lung, pleura or abdomen, causing pain.	Contact with snake secretions (e.g. as bushmeat), consumption of uncooked bushmeat Rodents and small primates as secondary host	(No systematic records)	infection rate in West Africa may be as high as 23%; numbers of infections increasing. In DRC, ~ 90% of snakes sold as bushmeat were infected with *A. armillatus*	greatly underestimated public health relevance; Pictured brochures on risks and hygienic measures are recommended	Milbank & Vira 2022 Hardi et al. 2017 Vanhecke et al. 2016 Adeyekun et al. 2011

2.3. Scientific background

2.3.1. General information

- **About 75% of all novel infectious diseases are zoonoses** (i.e. diseases transmitted from animals to humans) (WOAH 2022).
- **More than 70% of zoonoses originate from wild animals** (Jones *et al.* 2008).
- Legal AND illegal wildlife trade promote spreading of pathogens and zoonotic spillover events (IPBES 2020; Nijman 2021; Travis 2011).
- **New zoonotic diseases to come**: Probability for the emergence and spread of new diseases increases (Warren et al. 2022). According to WHO there has been a 63% increase in the number of zoonotic outbreaks in the African region in the decade from 2012-2022 compared to 2001-2011, e.g. Ebola, Mpox and corona viruses (UN Africa Renewal 2022).
- During a One Health Zoonotic Disease Prioritization workshop in December 2018, Economic Community of West African States (**ECOWAS**), including Nigeria, **agreed upon a list of seven priority zoonotic diseases for the region** – Anthrax, Rabies, Ebola and other viral haemorrhagic fevers (for example, Marburg fever, Lassa fever), zoonotic influenzas, zoonotic tuberculosis, Trypanosomiasis* and Yellow fever* (**Vector-borne diseases, not relevant for this project (see below);* Goryoka et al. 2021).
- "*Infections originating in animals and then jumping to humans have been happening for centuries, but the risk of mass infections and deaths had been relatively limited in Africa. Poor transport infrastructure acted as a natural barrier*," said Dr. Matshidiso Moeti WHO Regional Director for Africa (UN Africa Renewal 2022).
- Human zoonotic disease risk can be defined as a function of several factors, including transmission of infection and transition to disease. These components of disease risk rely on several factors (e.g. extrinsic factors, such as urbanization, agriculture, socioeconomic standing and intrinsic factors, such as life history, behaviour, and rapid evolutionary changes in animal hosts and pathogens) that are external to the host–pathogen system (Han *et al.* 2016).
- **Reptile-associated salmonellosis** has become a globally important epidemiological problem, in many countries caused by the boom of exotic pets (Waltenburg *et al*. 2022; Pawlak 2014). In Africa, reptiles are also consumed as bushmeat or for traditional medicine.
- *Leptospira* infection was reported in a wide range of domestic and wild animal species from across Africa. **Leptospirosis** is a substantial cause of human illness in Africa, representing 2.3-19.8% of hospital patients with fever (Allan *et al.* 2015).

2.3.2. Country-specific information

- „*Nigeria is among the top ten countries with the highest burden of infectious and zoonotic diseases globally*" (Ihekweazu et al. 2021).
- Many zoonotic infections are characterized to be endemic in Nigeria, including Lassa fever, tuberculosis, yellow fever, trypanosomiasis, rabies, toxoplasmosis, and taeniasis. In addition, there are parasitic protozoa (e.g. cryptosporidiosis) and food-borne zoonotic infections caused by *Campylobacter*, *Salmonella*, and *Escherichia coli*. Also, some sporadic cases of zoonotic infections occur in Nigeria, including ascariasis, scabies, strongyloidiasis, leptospirosis, pentastomiasis and African histoplasmosis (Muhammad 2020, Coker et al. 2000).

- Nigeria ranked rabies, avian influenza, Ebola Virus Disease, swine influenza and anthrax as the first five priority zoonoses (Ihekweazu et al. 2021). According to WHO (2017), Nigeria is also focusing on brucellosis, bovine tuberculosis, and Lassa fever. So far, no individual plans have been developed of published for these diseases (WHO 2017b). Additionally, Nigeria has a Viral Haemorrhagic Fevers Preparedness and Response Plan and a National Mpox Public Health Response Guidelines, both published in 2017 (Nigeria Centre for Disease Control 2017a; Nigeria Centre for Disease Control 2017b).
- **Disease reporting:** Presently, disease reporting in Nigerian public health institutions is often incomplete and untimely partly because of poor awareness among clinicians of the importance of their role in disease surveillance and notification activities for the prevention of infectious disease outbreaks (Isere et al. 2015). The country also possesses poor testing capacity with few laboratories having the equipment and expertise required to test for some zoonotic diseases. Most zoonotic diseases are under-reported, a typical example is rabies. (WHO 2013). There is no evidence that Nigeria routinely conducts surveillance of zoonotic disease in wildlife (WHO 2017b).
- An increasing number of Pentastomiasis infections are being reported in Congo, Nigeria, and Cameroon (Vanhecke et al. 2016).
- The increased incidence of Mpox in Nigeria since 2017 is likely due to a combination of population growth, accumulation of unvaccinated cohorts, and decline in smallpox vaccination (Nguyen et al. 2021b).
- In early June 2022, the Nigerian Government has banned the sale of bushmeat as a precaution to stop the spread of Mpox (AfricaNews 2022).

3. Relevant wildlife species

3.1. Key points on relevant wildlife species

In a nutshell:

- **Ungulates, primates, carnivores and bats are the major zoonotic reservoirs in wildlife trade**, as they host 132 (58%) of 226 known zoonotic viruses in present wildlife trade.
- At the same time duikers, primates, bats and pangolin were identified as the most frequently mentioned bushmeat species.
- The relative risk of disease emergence was found highest for bats, followed closely by primates, then ungulates and rodents.
- **Primates** represent the broadest group of species hunted for bushmeat. **As the closest relatives of humans, primates pose a particularly high risk of zoonotic transmission to humans**.
- In mammals and birds alone, the number of undetected viruses is estimated at 1.7 million, of which 540,000 to 850,000 may have the potential to infect humans.
- **Reptiles**: With the vast majority showing no symptoms, 12-85% of tortoises and freshwater turtles, 16-92% of snakes and 36-77% of lizards are carrying Salmonella pathogens.
- **Theoretically any wildlife species harvested for bushmeat could be a potential source of zoonotic disease.** While bats have been identified as major primary hosts for many pathogens, primates, racoon dogs, civets and other wildlife are potential secondary hosts.

3.2. Table: Relevant wildlife species traded in Nigeria

Species	IUCN Red List	Taxonomic group	Relevance in trade	Related zoonotic diseases	References
Chimpanzee *Pan troglodytes ellioti* eventually also *Pan t. verus*	**EN** decreasing	Primates	Hunted for bushmeat, traditional medicine; magic-religious rituals (against male impotency and epilepsy and is used for amulets and as concoction for ailments) Protected under First Schedule of the Endangered Species Act	Ebola multiple simian retroviruses STLV-1/ HTLV-1 SIV-cpz/HIV-1 AIDS? Anthrax?	Friant et al. 2022 WHO 2021a WildAid 2021 Mossoun et al. 2017 Humle et al. 2016 Soewu et al. 2012 Alves et al. 2010 Nyanganji et al. 2010 Peeters et al. 2010 Rouquet *et al.* 2005 Leroy et al. 2004a Hahn *et al.* 2000
Gorilla *Gorilla gorilla diehli*	**CR** decreasing	Primates	Eventually hunted for traditional medicine, magic-religious rituals (concoction for ailments, for charms	Ebola SIV-gor/HIV-1 AIDS?	WHO 2021a Maisels et al. 2018 Soewu et al. 2012 Alves et al. 2010

Species	IUCN Red List	Taxonomic group	Relevance in trade	Related zoonotic diseases	References
			or amulets, for victory in competition, strength and vitality for pregnant women/foetus)		Peeters et al. 2010 Rouquet *et al.* 2005 Leroy et al. 2004a Hahn *et al.* 2000
Monkeys **Tantalus monkey** *Chlorocebus tantalus* **Patas monkeys** *Erythrocebus patas* **West African Potto** *Perodicticus potto* **Central African potto** *Perodicticus edwardsi* **Calabar Angwantibo** *Arctocebus calabarensis* **Mona monkey** *Cercopithecus mona* **Putty-nosed monkey** *Cercopithecus nictitans ludio* **Sclater's guenon** *Cercopithecus sclateri* **White-throated guenon** *Cercopithecus erythrogaster* **Red-capped mangabeys** *Cercocebus torquatus*	 LC stable NT decreasing NT decreasing LC stable NT decreasing NT decreasing NT decreasing **EN** decreasing **EN** decreasing **EN** decreasing	Primates	Hunted for bushmeat, traditional medicine, pottos also sold as pets, Monkey species are used in traditional folk medicine and magic-religious rituals; Cercopithecus mona against male impotency, for quickening child walking, for charms and amulets, in funeral rituals; *Erythrocebus patas* against whooping cough, charm preparations and mental illness; *Chlorocebus tantalus*, used in magic-religiuos rituals*; Papio anubi*s used in cultural ceremonies; Protected under First or Second Schedule of the Endangered Species Act	Ebola Marburg possible reservoirs for Mpox	Friant et al. 2022 Alarape et al. 2021 WHO 2021a WildAid 2021 Cronin et al. 2020 Matsuda Goodwin et al. 2020c,d Svensson et al. 2020 Wallis 2020a Baker et al. 2019 Maisels et al. 2019 Oates & Svensson 2019 Svensson & Pimley 2019 Okareh & Morakinyo 2018 Akani et al. 2015b Svensson et al. 2015 Soewu et al. 2012 Olayemi et al. 2011 Alves et al. 2010
Olive colobus *Procolobus verus*	**VU** decreasing	Primates	Hunted for bushmeat (pop. in eastern Nigeria considered as EN due to hunting pressure) Also used in Traditional Medicine (e.g. in Togo)		D'Cruze et al. 2020 Oates et al. 2020 Covey & McGraw 2014
Drill *Mandrillus leucophaeus*	**EN** decreasing	Primates	Hunted for bushmeat; achieve higher prices than other commonly traded monkeys, due to their uniquely sweet taste and the larger size; Mandrillus leucophaeus is used in traditional folk medicine and magic-religious rituals		Gadsby et al. 2020 Alves et al. 2010 Eniang et al. 2008

Species	IUCN Red List	Taxonomic group	Relevance in trade	Related zoonotic diseases	References
Olive baboon *Papio anubis*	LC stable	Primates	Hunted for bushmeat		Alarape et al. 2021 Wallis 2020b
Antelopes **Roan antelope** *Hippotragus equinus* **Sitatunga** *Tragelaphus spekii* **Bates's pygmy antelope** *Nesotragus batesi* **Bushbuck** *Tragelaphus scriptus* **Red-flanked duiker** *Cephalophus rufilatus* **Bay duiker** *Cephalophus dorsalis* **Black duiker** *Cephalophus niger* **Ogilby's duiker** *Cephalophus ogilbyi* **Yellow-backed duiker** *Cephalophus silvicultor* **Maxwell's duiker** *Philantomba maxwelli* **Blue duiker** *Philantomba monticola* **Walter's duiker** *Philantomba walteri*	 LC decreasing LC decreasing LC stable LC decreasing NT decreasing LC decreasing LC decreasing NT decreasing LC decreasing LC decreasing DD unknown	Ungulates	Hunted for bushmeat, traded as live animals, cultural practices reported as the most commonly eaten species and most desirable animals Protected under First or Second Schedule of the Endangered Species Act	Ebola Anthrax (?)	Friant et al. 2022 Alarape et al. 2021 Katani et al. 2021 WHO 2021a WildAid 2021 Meseko et al. 2020 IUCN SSC Antelope Specialist Group. 2017 IUCN SSC Antelope Specialist Group. 2016a,b,c,d,f,g,h,i,j Akani et al. 2015b Friant et al. 2015 Soewu et al. 2012 Olayemi et al. 2011 Rouquet et al. 2005 Leroy et al. 2004a
Water chevrotain *Hyemoschus aquaticus*	LC decreasing	Ungulates	Hunted for traditional medicine, bushmeat		Friant et al. 2022 IUCN SSC Antelope Specialist Group. 2016e Akani et al. 2015b
Buffalo *Syncerus caffer*	NT decreasing	Ungulates	Hunted for traditional medicine, bushmeat		Alarape et al. 2021 IUCN SSC Antelope Specialist Group. 2019 Soewu et al. 2012
Bush pig *Potamochoerus porcus*	LC decreasing	Ungulates	Hunted for bushmeat Protected under Second Schedule of the Endangered Species Act		Alarape et al. 2021 WildAid 2021 Reyna et al. 2016 Akani et al. 2015b
Pigmy hippopotamus *Choeropsis liberiensis*	**EN** decreasing	Ungulates	Hunted for bushmeat		Alarape et al. 2021 Ransom et al. 2015

Species	IUCN Red List	Taxonomic group	Relevance in trade	Related zoonotic diseases	References
Hippopotamus *Hippopotamus amphibius*	**VU** stable	Ungulates	Hunted for bushmeat		Alarape et al. 2021 Lewison & Pluháček 2017
Atlantic humpback dolphin *Sousa teuszii*	**CR** decreasing	Ungulates	Hunted for bushmeat		Collins et al. 2017 Van Waerebeek *et al.* 2015
Bats **Straw-coloured fruit bats** *Eidolon helvum* *Epomops franqueti* **Egyptian Fruit Bat** *Rousettus aegyptiacus* ***Hammer-headed Fruit Bat*** *Hypsignathus monstrosus*	NT decreasing LC stable LC stable LC unknown	Bats	Hunted for bushmeat, traditional medicine: consumption widespread in Nigeria, low-priced meat, traded as live animals, one of the most frequently consumed mammal in West and Central Africa	Ebola Marburg Lyssaviruses coronaviruses (SARS, MERS, COVID-19) paramyxoviruses reoviruses rotaviruses Hendra Nipah Filoviruses Pegiviruses Hepaciviruses more than 60 different viruses were identified in bats	Friant et al. 2022 Alarape et al. 2021 Kia et al. 2021 WHO 2021a WHO 2021b Cooper-Bohannon et al. 2020 Kityo & Nalikka 2020 Meseko et al. 2020 Korine 2016 Mildenstein et al. 2016 Tanshi 2016 Luis et al. 2013 Quan et al. 2013 Soewu et al. 2012 Mickleburgh et al. 2009
Rabbit Leporidae	--	Lagomorpha	Hunted for bushmeat		Alarape et al. 2021
Multimammate mice *Mastomys* spp. **Multimamate rat** *Mastomys natalensis*	-- LC stable	Rodents	Hunted for traditional medicine	Lassa Fever	WHO undated a,b Granjon 2016a Soewu et al. 2012
Grass cutter *Thryonomys swinderianus*	LC unknown	Rodents	Hunted for bushmeat, traded as live animals, traditional medicine		Alarape et al. 2021 WildAid 2021 Meseko et al. 2020 Child 2016 Akani et al. 2015b Soewu et al. 2012 Olayemi et al. 2011 Eniang et al. 2008
Giant pouched rats *Cricetomys spp.* **Emin's pouched rat** *Cricetomys emini* **Gambian rat** *Cricetomys gambianus*	LC stable LC stable	Rodents	Hunted for bushmeat, traditional medicine	possible reservoirs for Mpox nairoviruses	Friant et al. 2022 Alarape et al. 2021 Kennerley 2019 Okareh & Morakinyo 2018 Doty et al. 2017 Cassola 2016g Akani et al. 2015b Soewu et al. 2012

Species	IUCN Red List	Taxonomic group	Relevance in trade	Related zoonotic diseases	References
Elephant shrew Macroscelididae	--	Rodents		possible reservoirs for Mpox	Okareh & Morakinyo 2018 Doty et al. 2017
Shrew *Crocidiora* spp.	--	Rodents	Hunted for traditional medicine		Soewu et al. 2012
Giant otter shrew *Potamogale velox*	LC decreasing	Rodents	Hunted for traditional medicine		Friant et al. 2022 Stephenson et al. 2016
Porcupines **African brush-tailed porcupine** *Atherurus africanus* **Crested porcupine** *Hystrix cristata*	LC unknown LC unknown	Rodents	Hunted for bushmeat, cultural practices, traded as live animals, traditional medicine Protected under Second Schedule of the Endangered Species Act favoured species in wild meat markets of Nigeria meat of this species is also often the most expensive meat in many African cities	possible reservoirs for Mpox nairoviruses anthrax Salmonella	Friant et al. 2022 Alarape et al. 2021 Peros et al. 2021 WildAid 2021 Meseko et al. 2020 Amori & De Smet 2016 Hoffmann & Cox 2016 Akani et al. 2015b Friant et al. 2015 Soewu et al. 2012 Olayemi et al. 2011 Eniang et al. 2008
Squirrels **Tree squirrel** Sciuridae **Flying squirrel** Pteromyini **Rope squirrels** *Funisciurus* spp. **Red-legged sun squirrel** *Heliosciurus rufobrachium* **Striped ground squirrel** *Xerus erythropus*	LC unknown LC stable	Rodents	Hunted for bushmeat, traditional medicine	possible reservoirs for Mpox	Friant et al. 2022 Alarape et al. 2021 Okareh & Morakinyo 2018 Doty et al. 2017 Falendysz et al. 2017 Cassola 2016b,h Soewu et al. 2012 Olayemi et al. 2011
Savanna gerbil *Gerbilliscus validus*	LC stable	Rodents	Hunted for traditional medicine		Schlitter 2016 Soewu et al. 2012
Striped grass mice *Lemniscomys* spp.	--	Rodents	Hunted for traditional medicine		Soewu et al. 2012
Nile rat *Arvicanthis niloticus*	LC unknown	Rodents	Hunted for traditional medicine		Granjon 2016b Soewu et al. 2012
African pygmy mouse *Mus minutoides*	LC stable	Rodents	Hunted for traditional medicine		Child & Monadjem 2016 Soewu et al. 2012
Rufous-bellied rat *Lophuromys sikapusi*	LC unknown	Rodents	Hunted for traditional medicine		Cassola 2016i Soewu et al. 2012

Species	IUCN Red List	Taxonomic group	Relevance in trade	Related zoonotic diseases	References
Stripped mouse *Hybomys trivirgatus*	LC stable	Rodents	Hunted for traditional medicine		Cassola 2016j Soewu et al. 2012
Mongooses **Flat-headed kusimanse** *Crossarchus platycephalus* **Slender mongoose** *Herpestes sanguineus*	LC unknown LC stable	Carnivores	Hunted for bushmeat, traditional medicine		Friant et al. 2022 Alarape et al. 2021 Angelici & Do Linh San 2016 Do Linh San & Maddock 2016 Akani et al. 2015b Soewu et al. 2012 Olayemi et al. 2011
Leopard *Panthera pardus*	**VU** decreasing	Carnivores	Hunted for bushmeat, cultural practices, traditional medicine		Friant et al. 2022 Alarape et al. 2021 Stein et al. 2020 Soewu et al. 2012
African civet *Civettictis civetta*	LC unknown	Carnivores	Hunted for bushmeat, traditional medicine Protected under First Schedule of the Endangered Species Act		Alarape et al. 2021 WildAid 2021 Do Linh San et al. 2019 Akani et al. 2015b Soewu et al. 2012 Olayemi et al. 2011
African palm civet *Nandinia binotata*	LC unknown	Carnivores	Hunted for bushmeat		Akani et al. 2015b Gaubert et al. 2015 Olayemi et al. 2011
Genet **Rusty-spotted genet** *Genetta maculata*	LC unknown	Carnivores	Hunted for bushmeat		Angelici et al. 2016 Akani et al. 2015b Olayemi et al. 2011
African golden cat *Caracal aurata*	**VU** decreasing	Carnivores	Hunted for traditional medicine		Friant et al. 2022 Bahaa-el-din et al. 2015
Spotted hyena *Crocuta crocuta*	LC decreasing	Carnivores	Hunted for bushmeat, traditional medicine		Alarape et al. 2021 Bohm & Höner 2015 Soewu et al. 2012
African clawless otter *Aonyx capensis*	NT decreasing	Carnivores	Hunted for traditional medicine		Friant et al. 2022 Jacques et al. 2021 Akani et al. 2015b
Ichneumon *Herpestes ichneumon*	LC stable	Carnivores	Hunted for bushmeat		Do Linh San et al. 2016 Olayemi et al. 2011
Serval *Leptailurus serval*	LC stable	Carnivores	Hunted for traditional medicine		Thiel 2019 Soewu et al. 2012
Wild cat *Felis silvestris*	LC unknown	Carnivores	Hunted for traditional medicine		Gerngross et al. 2022 Soewu et al. 2012
Pangolins		Pangolins	Hunted for bushmeat,	coronaviruses	Friant et al. 2022

Species	IUCN Red List	Taxonomic group	Relevance in trade	Related zoonotic diseases	References
Long-tailed pangolin *Phataginus tetradactyla* **Tree pangolin/ White-bellied pangolin** *Phataginus tricuspis*	**VU** decreasing **EN** decreasing		traditional medicine, traded as live animals Protected under First Schedule of the Endangered Species Act White-bellied panoglin intensely used as bushmeat and in traditional medicine		Alarape et al. 2021 WildAid 2021 Meseko et al. 2020 Ingram et al. 2019 Pietersen et al. 2019 Akani et al. 2015b Soewu et al. 2012 Olayemi et al. 2011
Hyraxes **Tree hyraxes** *Dendrohyrax* **Rock hyraxes** *Procavia capensis* **Beecrot's hyrax** *Dendrohyrax dorsalis*	LC stable LC unknown	Dassies	Hunted for traditional medicine		Friant et al. 2022 Butynski et al. 2015a,b Soewu et al. 2012
African forest elephant *Loxodonta cyclotis*	**CR** decreasing	Proboscidea	Hunted for bushmeat, traditional medicine, cultural practices		Friant et al. 2022 Alarape et al. 2021 Gobush et al. 2021
African rock python *Python sebae*	NT decreasing	Reptiles	Hunted for bushmeat; among the most sold reptile species at Central and West African bushmeat markets; Proportion of snakes in bushmeat markets is increasing, traditional medicine Protected under First Schedule of the Endangered Species Act	visceral pentastomiasis	Friant et al. 2022 Alarape et al. 2021 Alexander et al. 2021 WildAid 2021 Hardi et al. 2017
Ball python *Python regius*	NT decreasing	Reptiles	Hunted for bushmeat; among the most sold reptile species at Central and West African bushmeat markets; Proportion of snakes in bushmeat markets is increasing Protected under First Schedule of the Endangered Species Act	visceral pentastomiasis (caused by *Armillifer armillatus*)	D'Cruze et al. 2022 WildAid 2021 Hardi et al. 2017
Gaboon viper *Bitis gabonica*	**VU** decreasing	Reptiles	Hunted for bushmeat; among the most sold reptile species at Central and West African bushmeat markets;	visceral pentastomiasis (caused by *Armillifer armillatus*)	Luiselli et al. 2021a Hardi et al. 2017

Species	IUCN Red List	Taxonomic group	Relevance in trade	Related zoonotic diseases	References
			Proportion of snakes in bushmeat markets is increasing		
Rhinoceros viper *Bitis nasicornis*	**VU** decreasing	Reptiles	Hunted for bushmeat; among the most sold reptile species at Central and West African bushmeat markets; Proportion of snakes in bushmeat markets is increasing	visceral pentastomiasis (caused by *Armillifer armillatus*)	Penner et al. 2021 Hardi et al. 2017
Black-necked spitting cobra *Naja nigricollis*	LC unknown	Reptiles		Salmonellosis	Jallow et al. 2021a Pulford et al. 2019
Puff adder *Bitis arietans*	LC stable	Reptiles		Salmonellosis	Wagner et al. 2021 Pulford et al. 2019
West African carpet viper *Echis ocellatus*	LC stable	Reptiles		Salmonellosis	Luiselli et al. 2021b Pulford et al. 2019
Chameleons	--	Reptiles	Hunted for traditional medicine		Friant et al. 2022
Tortoise *Kinixys erosa* **Home's Hinge-back Tortoise** *Kinixys homeana*	DD unspecified **CR** decreasing	Reptiles	Hunted for traditional medicine, bushmeat, due to a strong decline of this animals in the wild, they are less common in trade, traded as live animals Protected under First or Second Schedule of the Endangered Species Act		Friant et al. 2022 Luiselli et al. 2021c WildAid 2021 Meseko et al. 2020 Luiselli et al. 2013 Tortoise & Freshwater Turtle Specialist Group 1996
Sea turtle **Hawksbill turtle** *Eretmochelys imbricata* **Olive ridley** *Lepidochelys olivacea* **Green sea turtle** *Chelonia mydas* **Leatherback turtle** *Dermochelys coriacea*	**CR** decreasing **CR** decreasing **EN** decreasing **VU** decreasing	Reptiles	Hunted for bushmeat Protected under First Schedule of the Endangered Species Act		WildAid 2021 Wallace et al. 2013 Abreu-Grobois & Plotkin 2008 Mortimer & Donnelly 2008 Seminoff 2004
Nile Monitor Lizard *Varanus niloticus*	LC stable	Reptiles	Hunted for bushmeat Protected under First Schedule of the Endangered Species Act		Alarape et al. 2021 WildAid 2021 Wilms et al. 2021b
Crocodiles		Reptiles	Hunted for bushmeat, traded as live animals		Alarape et al. 2021 WildAid 2021

Species	IUCN Red List	Taxonomic group	Relevance in trade	Related zoonotic diseases	References
Nile Crocodile *Crocodylus niloticus*	LC stable		Protected under First Schedule of the Endangered Species Act		Meseko et al. 2020 Isberg et al. 2019
Guinea fowl Numididae	--	Birds	Hunted for bushmeat		Alarape et al. 2021

3.3. Scientific Background

- Although research has focused largely on mammals and, to a lesser extent, birds, theoretically any wildlife species harvested for bushmeat could be a potential source of zoonotic disease that can spillover during the hunting, butchering, and preparation process (Kurpiers et al. 2016; Karesh & Noble 2009).
- **Mammals and birds alone are thought to host an estimated 1.7 million undiscovered viruses and, of these, 540,000–850,000 viruses could have the ability to infect humans** (Shivaprakash *et al.* 2021; Carroll *et al.* 2018).
- In their assessment of the risk of disease emergence by taxa, Cleaveland *et al.* (2007) found that the relative risk of disease emergence was highest for bats, followed closely by primates, then ungulates and rodents – all of them heavily exploited for wildlife trade. Primates, ungulates, carnivores, and bats pose a high zoonotic risk, harbouring 132 (58%) of the 226 known zoonotic viruses in the current wildlife trade. Bats, rodents, and marsupials pose a significant zoonotic risk in future wildlife trade (Shivaprakash *et al.* 2021).
- According to Fa et al. (2006) mammals represented more than 90% of the bushmeat carcasses sold in Nigeria and Cameroon followed by reptiles while birds and amphibians were relatively rare.
- Duikers, primates and pangolin were identified as the most frequently mentioned bushmeat species (Ordaz-Németh *et al.* 2017; Jeffrey 1977). Sooty mangabeys (being a carrier for the AIDS virus) ranked only at No. 13 of taste preference of urban consumers (ODI 2004; Hahn *et al.* 2000).
- Wild animals are used for food, traditional medicine, and kept as pets, the most hunted species are rodents (95%), ungulates (93%), carnivores (93%), primates (87%), and bats (42%) (Friant et al. 2015).

3.3.1. Primates

- Primates represent the largest group of species hunted for bushmeat (Kurpiers et al. 2016). As the closest relatives of humans, they pose a particularly high risk of zoonotic transmission to humans (Mossoun et al. 2017). Nevertheless, parasite sampling is still too low, especially for arboreal and nocturnal species (Cooper & Nunn 2013).
- Researchers recently discovered a family of viruses that can cause fatal haemorrhagic fever in African primate populations. Since humans have a similar form of the receptor responsible, the researchers concluded that transmission of this disease to humans is very likely (Mactilda Mbenywe 2022; Warren *et al.* 2022).

- Due to population decline of larger primates now even smaller species, such as *Cercopithecus petaurista* are now hunted for commercial bushmeat markets, despite high costs for ammunition (Matsuda Goodwin et al. 2020a,b; Svensson et al. 2020).

3.3.2. Bats

- **Bats** are heavily over-exploited since at least three decades; hunting is particularly prevalent among the large-bodied fruit bats (Mildenstein et al. 2016).
- Bats are identified as the most likely primary host for outbreaks of SARS, MERS and COVID-19 outbreaks, with other mammals, such as civets, racoon dogs etc. as secondary host, causing spillover events to humans via wildlife markets (Worobey *et al.* 2022; Markotter *et al.* 2020; Banerjee *et al.* 2019). Bats are also hosts for Marburg, Ebola and many other viruses (Kia *et al.* 2021; Kajihara *et al.* 2019; Hayman *et al.* 2012; Leroy *et al.* 2009).
- Nigeria is a home range of the fruit bats belonging to the Pteropodidae family which are considered to be natural hosts of Marburg virus (WHO 2021b).
- **Fruit bats are heavily consumed in West Africa: In southern Ghana only, about 128,000 *Eidolon helvum* are sold each year as bushmeat** (Kamins *et al.* 2011; Mickleburgh *et al.* 2009). Hunting of bats is often underrepresented in surveys, due to separate commodity chains, and therefore underestimated (Kamins et al. 2011).

3.3.3. Others

- **Reptiles**: With the vast majority showing no symptoms, 12-85% of tortoises and freshwater turtles, 16-92% of snakes and 36-77% of lizards are carrying *Salmonella* pathogens. Under stressful unhygienic conditions risk of spillover to humans increases (Zajac et al. 2021; Gumpenberger 2000). Pulford *et al*. (2019) examined wild-caught snakes eight African countries and found 91% of them carrying *Salmonella*.

4. Relevant potential spillover pathways

4.1. Key findings on spillover pathways

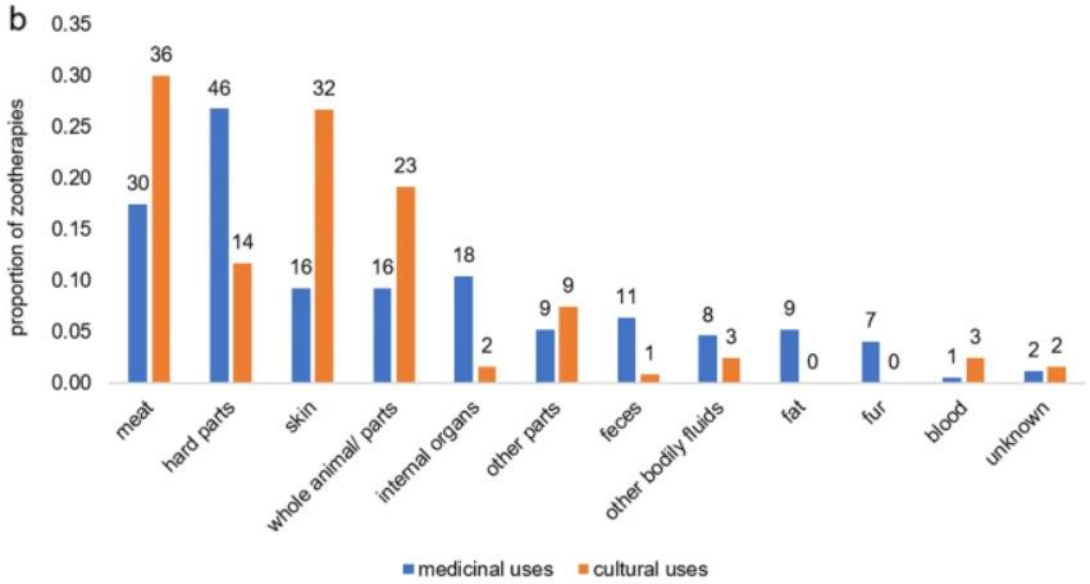
In a nutshell:

- **Legal AND illegal wildlife trade are contributing to the spreading of zoonotic diseases.**
- **Bushmeat**-related activities (hunting, butchering, cooking, consumption) have been linked to numerous EID outbreaks, such as Ebola, HIV, and SARS.
- Of 58 species of bushmeat globally investigated, 48 species were found to host one or more pathogens.
- Bushmeat is often smoked, dried or salted. But medical experts estimate that these processes are insufficient to kill viruses and other pathogens in the meat.
- **Increasing demand and commercialization of bushmeat is exposing more people to pathogens and facilitating the geographic spread of diseases**.
- Larger species, such as chimpanzees or duikers, are mainly destined for urban markets, while smaller species (guineafowls, greater cane-rats) are consumed locally.
- The consumption of bushmeat partly overlaps with the illegal trade of protected species. Nigeria has emerged as the primary transit hub in Africa for ivory and pangolin scales exported to Asian countries
- **Wildlife as pets:** Bites, scratches and contact with urine, saliva and feces pose a risk for disease transmission from e.g. pet monkeys to keepers.
- **Wildlife use in Traditional Medicine and religious rituals is common in West African countries**: 281 different wildlife species were recorded at a traditional medicine market in Togo, of which 140 were mammals, 33 were reptiles, 59 were bird species and 49 amphibians.
- At least 25 primate species are used in traditional folk medicine in Africa, in Nigeria for example *Pan troglodytes*. Use of pangolins in TM is reported from Ghana, Togo and Sierra Leone.
- **Be a model in your communication** (including social media): Don't post pictures holding wildlife, keep distance, wear masks and gloves)

4.2. Scientific background

- Legal AND illegal wildlife trade are contributing to the spreading of zoonotic diseases. Since the outbreak of COVID-19 wildlife markets are often seen as synonymous with illegal wildlife trade, but Nijman (2021) stresses that most of the wildlife offered at Wuhan wet market was legally offered. Stressful, unhygienic conditions during wildlife trade are fuelling pathogen levels in the animals.
- Hunting of wild animals and hunting with dogs are potential transmission routes for parasites, especially when infected animals are killed (Arotolu et al. 2020).

- In addition to bushmeat, cultural and medical practices must also be considered as potential transmission risks for zoonotic diseases. Friant et al. 2022 recorded 292 zootherapeutic uses, including 172 medicinal uses and 120 other cultural uses (e.g. ceremonial consumption, sacrifice, charms/juju, and poison) of animals (see figure). Animals were used as vessels for medicine, health promoters, and as traditional medicine for purposes including treatment for various injuries and ailments (e.g. burns and epilepsy), behavioural problems, mental



problems, and poisoning (Friant et al. 2022). According to Friant et al. 2022, 45% of participating men and women reported knowledge of use of wild animals for traditional medicine for both gender and different age groups, with 19% reporting using wild animals as medicine for themselves or their households. 75% of participants reported cultural uses of wildlife.

4.2.1. Bushmeat

- A review of global bushmeat studies (with a focus on Africa) found that of the 58 species of bushmeat investigated, 48 species were found to host one or more pathogens (Peros et al. 2021).
- Bushmeat-related activities (hunting, butchering, cooking, consumption) have been linked to numerous emerging infectious disease (EID) outbreaks, such as Ebola, HIV, and SARS. Increasing demand and commercialization of bushmeat is exposing more people to pathogens and facilitating the geographic spread of diseases (Kurpiers et al. 2016).
- Ebola-outbreak among chimpanzees after hunting and shared consumption of a red colobus monkey is proven; seropositive chimpanzees were found broadly throughout forested regions of Central Africa (Alexander et al. 2015).
- Bushmeat is often smoked, dried or salted. However, medical experts estimate that these processes are insufficient to kill viruses and other pathogens in the meat. For example, wildlife biltong may pose special challenges, given that the virus can survive over 50 days when dried and kept at 4°C (Alexander et al. 2015).
- The consumption of bushmeat partly overlaps with the illegal trade of protected species. Nigeria has emerged as the primary transit hub in Africa for ivory and pangolin scales exported to Asian countries (WildAid 2021, Martin & Lucy 2013).

- In Nigeria, the outbreak of Ebola led to a strong information campaign by the Nigerian authorities and strict restrictions on wild meat. Therefore, the bushmeat trade temporarily collapsed in 2014 (Funk et al. 2021, Akani et al. 2015a). However, shortly after the outbreak the trade rebounded to values exceeding those before the Ebola outbreak. The consumption of reptiles increased as mammal numbers declined. After 2017, the numbers of offered reptiles decreased and remained low, indicating population collapses and depletion (Funk et al. 2021).
- Bushmeat is an important nutritional resource in many rural communities (Friant et al. 2020). Bushmeat is mainly sold on weekends and during holidays, and sales of bushmeat are restricted to the early hours of the day (before 8 am) to avoid officials of law enforcement agencies (Eniang et al. 2008). According to Friant et al. (2020), a higher diversity of bushmeat species is consumed food-insecure households.
- Oluwe market, Epe, Lagos is the most notorious bushmeat market in Lagos funnelling bushmeat from rural communities near Lagos and neighbouring states in the Southwest. There are bushmeat markets spread across the Niger Delta region (Luca et al. 2013). In general, bushmeat is available in most markets so far there is supply from hunters.
- Eniang et al. (2008) identified women as the main buyers of bushmeat at bushmeat markets. Additionally, women play a significant role in processing, preservation, and trading of bushmeat (Eniang et al. 2008, Leroy et al. 2004b).
- Prices for bushmeat increased with distance from national park boundaries and were higher near the road network, as there were more opportunities for further trade. Trading sites closer to national parks acted more as wholesalers, with carcasses being smoked more frequently as they were not sold to end users (MacDonald et al. 2012).
- In Nigeria, bushmeat biomass extracted for sale (600 kg/km2 per year) was three times higher than in Cameroon. It is estimated that more than 900,000 reptiles, birds and mammals are sold each year by rural and urban populations in southeastern Nigeria and western Cameroon alone, equivalent to about 12,000 tons of terrestrial vertebrates (Fa et al. 2006).

4.2.2. Animal imports/ Wildlife as pets

- In many parts of the primate distribution range, the practice of keeping primates as pets is common. However, keeping of primates as pets can result in close spatial proximity and may lead to physical contact, thereby creating opportunities for zoonosis (Lappan et al. 2020; Muehlenbein 2017).
- Primate infants, as survivors of bushmeat hunting, are sold as pets or to private and public zoos, providing additional income for the hunter (Marx et al. 1991).
- Animal Imports: Nigeria has countless zoos. Many are funded with public money, but others are private; some consider themselves "game" or "safari parks" and are established by wealthy Nigerians, mostly northerners. Due to the paucity of surviving native wildlife, these places import wild animals, often from South Africa. The animals are not subjected to adequate quarantine or testing, and this must be considered another vector for exotic zoonoses – even if the species are found in Nigeria, they are typically different subspecies and/or have a different cohort of pathogens (PANDRILLUS 2023).
- It is well known locally that bush meat and other forest products cross the long, largely forested frontier from Cameroon to Nigeria every day, as well arriving on small private boats by sea. This implies that Nigerians are potentially exposed to zoonotic infections that are not

endemic in Nigeria but can be found in other countries on the continent (from which wild animals and their products are imported from). At Drill Ranch, for example, 2 of the chimpanzees we confiscated were from far outside the range of our endemic subspecies - one from Sierra Leone and another from Equatorial Guinea. A substantial number of our chimpanzees and some monkeys were known to have been brought to Nigeria from Cameroon (PANDRILLUS 2023).

- Wildlife as pets: In the North, citizens are passionate about keeping wild animals as pets. There are vendors and dealers in Kaduna, Kano and Katsina States who deal in live wild animals. Northerners are the primary traffickers in wild birds, such as parrots (PANDRILLUS 2023).

4.2.3. Traditional medicine and magic-religious rituals

- All ages grades and sexes use wild animals in traditional medicine (Soewu et al. 2012).
- According to Alves et al. (2010) 25 primate species are used in traditional folk medicine and magic-religious rituals in Africa: In Nigeria, *Gorilla gorilla* is used as concoction for ailments, for charms or amulets, for victory in competition, strength and vitality for pregnant women/foetus. *Pan troglodytes* is claimed to help against male impotency and epilepsy and is used for amulets and as concoction for ailments ("regarded as a sacred totem and a reincarnation of ancestors, considered sacred, piece of the dried bone of chimpanzees is tied around the waist or wrist of infants in the belief that it makes them stronger as they grow into adulthood, chimpanzee's central incisors procured to be worn as amulet around the waist of infants to protect them and give them power over others in their cohort, magic rituals"). *Cercopithecus mona* is used against male impotency, for quickening child walking, for charms and amulets, used in funeral rituals. *Erythrocebus patas* is used against whooping cough, charm preparations and mental illness; *Mandrillus leucophaeus* is used unspecified. *Chlorocebus tantalus*, as considered sacred, is used in magic-religious rituals. *Papio anubis* is used in cultural ceremonies, viewed as malicious, cunning, and dangerous.

5. Information relevant for awareness campaigns & programs

5.1. Key points for awareness campaigns

In a nutshell:

- **Longstanding cultural beliefs, livelihood, and food security challenges** mean that research findings alone would not have been successful in changing practices.
- **3 building blocks are needed for successful awareness campaigns**: 1) trust building – 2) awareness raising – 3) evidence through research.
- **Skepticism /opposition against information on zoonotic diseases and related measures to reduce risk for spillover events (after Ebola outbreak 2014-2016):** Traders and consumers argued that wildlife was eaten for generations without ever having caused, or been associated with, an epidemic in humans.
- **Possible counterarguments must be collected and debunked to best persuade.**
- **Urban consumers see bushmeat as a local, natural, and healthy food compared to livestock ⇨ need to be refuted in awareness campaigns.**
- **Promotion of the One Health approach:** Interconnection between humans, wildlife, and environment. In the long-term human health can only been assured together in a healthy environmental and with healthy animals.
- Wildlife must not be blamed for zoonotic diseases, instead highlighting a species' ecological role is needed. Living with wildlife, not destroying them, and wildlife conservation (including habitat conservation) as part of the solution!
- **Explain probabilities and statistical incidents:** Most events of bushmeat consumption or contact with wildlife will not lead to zoonotic diseases, but risks are significantly rising with increasing deforestation & intrusion into remote habitats as well as commercialization of bushmeat trade (incl. long transport routes to cities). Increased human density in cities and increased mobility of people support outbreaks and spreading of diseases as soon as a spillover event has occurred.
- **Communication of human health risks, combined with demystification of bushmeat (e.g. primate no more nutritious than other meat) caused strongest demand reduction**
- **Best arguments:** In demand reduction campaigns on wildlife as pets the aspects of illegality and human health risks have been proven more efficient than species conservation or animal welfare issues.
- **Messaging**: Positive messages are easier acceptable than negative; involve influential and credible actors; present appropriate alternatives
- **Food alternatives: Urban bushmeat consumers have a key role, as they can create a deadly suction effect for wildlife up to distant areas – but have a better choice.**
- **Enforcement AND persuasion are key to ensure long-term change of behaviour.**
- Respondents stated a strong preference for bushmeat over domestic meat, and strong cultural ties to the consumption of bushmeat.

5.2. Scientific background

- **3 building blocks are needed for successful awareness campaigns**: 1) trust building – 2) awareness raising – 3) evidence through research (for details see Machalaba 2022)
- **Ideal-reality gap**: Although many people are concerned about a problem (a stated preference, which can be triggered by education), this does not always translate into taking practical steps to perform an environmental behaviour (revealed preferences).
- Friant et al. (2015) reported a strong preference for bushmeat over domestic meat, and strong cultural ties to the consumption of bushmeat. Respondents referred to bats and other small prey as "children's meat", due to their small size they are given to children to play with and eat, potentially putting them at greater risk.
- The following circumstances were associated with becoming a hunter: Young age, lower education level, larger household size, having a father who hunts, and cultural group (Friant et al. 2015). Friant et al. (2015) reported that conservation and public health interventions should take socio-economic and cultural drivers into consideration, as interventions targeting consumption alone are not sufficient.
- Studies show that hunters and traders are aware of the illegality of hunting and bushmeat trade but continue because this trade is their main source of income (Friant et al. 2015, Eniang et al. 2008). Around 80 % are hunting wild animals for income generation while only around 20% carried out hunting activities for food (Alarape et al. 2021). According to Nyanganji et al. (2010), a hunter earns about the equivalent of a month's salary for a government employee with the sale of a chimpanzee carcass.
- In Idanre, Nigeria there is an annual festival where men of all ages catch bats in caves. A wide variety of catching methods are used, and scratching and biting may occur; protective equipment is rarely used. The captured bats are prepared as food, sold as bushmeat, or given to dignitaries in rituals. (Vora et al. 2014). The caves are also home to bats of the species *Rousettus aegyptiacus*, which serve as a reservoir for Marburg virus in other parts of Africa (Vora et al. 2014, Towner et al. 2007).

5.2.1. Awareness & Skepticism

- **!! Model safe and appropriate practices with primates in field settings, outreach, and social media materials:** Conservationists must follow safe distance and masking protocols when being observed or photographed. They should not be photographed holding primates (even in captive care settings) and should avoid sharing images showing close human–primate spacing in outreach materials, on social media accounts, or in public presentations. **Such images may create public perceptions that primates are appealing and tame, increasing the risks of inappropriate behavior toward wild primates, and increasing demand for primates as pets** (Lappan et al. 2020).
- Given the lack of awareness and precautionary measures taken among people who come into contact with bushmeat, the opportunity for new zoonotic pathogens to spillover into humans remains high. This is especially true, since the current rate of hunting wild animals will likely continue — at least until domestic animal production increases and can support the protein needs of the local people (Kurpiers *et al.* 2016; LeBreton *et al*. 2006).
- Bonwitt *et al.* (2018) underline that the **epistemic dissonance** between health risks in the context of Ebola and long-term experiences consuming bushmeat without personal incident would radically undercut the effectiveness of the bushmeat ban, which merely served to proliferate informal networks of wild animal trade and sale— hampering the development of

acceptable, evidence-based surveillance and mitigation strategies for zoonotic spillovers. "*People simply refused to believe that wild meat could pose any health risk. Informants argued that wild animals were hunted and eaten for generations without ever having caused, or been associated with, an epidemic in humans. The same argument was commonly heard in rural areas of Guinea*." Other argument for suspicion was the government would try to consolidate power and weaken villages in areas supporting opposition party (as wild meat is considered an important source of physical strength and energy) – or the rumour that conservationist introduced the ban to prevent poaching.

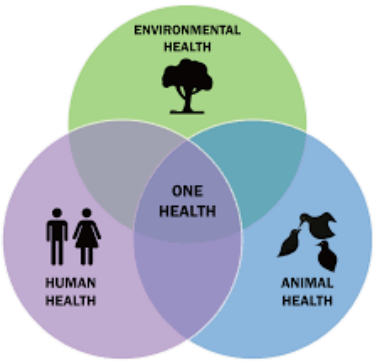
- Gaubert et al. (in print) interviewed bushmeat vendors in three west African countries and found that vendors generally did not believe that pangolins were involved in the pandemic, as people have always been eating pangolins and have never been sick. The authors recommend that future awareness campaigns through television and social networks also include education on microbial evolution and host shift.
- According to Friant et al. (2015), 55% of respondents were aware of zoonotic risks from wild animals, of which 89% said that they perceived an actual risk but only 26% reported to take protective measures (e.g. avoidance). Studies on knowledge, risk perception and mitigation measures towards Ebola virus in Nigeria found that traders have more knowledge about Ebola virus disease than hunters but still few applied mitigation measures against infection risks (Ozioko et al. 2018, Alhaji et al. 2017). Awareness campaigns and programs should include information on avoidance strategies, with specific attention to dispelling misconceptions about routes of transmission and promoting effective and accessible strategies for mitigating exposure (Friant et al. 2015).
- According to Luiselli et al. (2017), cultural importance consumption and of bushmeat decreased substantially in recent years after the Ebola crisis 2014. The great majority of urban respondents (especially young people under 25 years age) stated that they would not eat bushmeat at all or very rarely, even in rural areas less than 30% of respondents under 50 stated that they frequently eat bushmeat. Also, men consume significantly more bushmeat than women. Luiselli et al. (2017) assumed that very few, if any, people in southern Nigeria still rely on bushmeat to survive.
- The islam bans the eating of primate meat (Nyanganji et al. 2010) and Bachmann et al. (2019) indeed found that Muslims in Côte D'Ivoire consumed 86% less primate meat than Animists. The authors note that, while eating of great ape meat is restricted by certain taboos, those traditional taboos are increasingly breaking down because of an influx of immigrants from non-Muslim areas, and because of a commercialization of the bush-meat trade (Nyanganji et al. 2010).
- Nyanganji et al. (2010) documented striking differences between the Cameroon Border Area and the Park Support Zone. The area near the Cameroon Border was largely influenced by Christian culture with more intense agriculture and plantations, and cross-border trade activities, while the Park Support Zone was largely influenced by Muslim culture with more pronounced pastoralist activities in the more extensive savannah-woodlands and greater awareness concerning the existence and function of protected areas. These differences are probably due, among other things, to cultural practices, more frequent law enforcement and better information about nature conservation near national parks.
- To curb traditional medicine practices, the provision of affordable health care must be improved. It is also important to educate traditional medicine communities, i.e., hunters,

ingredient dealers, practitioners, and end users, about wildlife conservation and ecological consequences (Soewu et al. 2012).

- A study from 2012 revealed that women perceived benefits of trading in bushmeat to include high return (1st), raising social status (2nd), and cheap access to animal protein (3rd). Furthermore, the knowledge about the facts that hunting and trading of bushmeat are not a good livelihood activity and could destroy the environment was high. The study therefore highlighted that awareness campaigns are needed as they found a significant relationship between education and years of working experience with respondents' perception on bushmeat trade while age, household size, marital status and average monthly income were not significant (Adefalu et al. 2012).

5.2.2. Ecology and One Health Approach

- Major reasons behind the emergence and spread of zoonotic pandemics are related to activities such as habitat fragmentation, deforestation, biodiversity loss, intensive agriculture and livestock farming, uncontrolled urbanization, pollution, climate change and wildlife trade, including wild meat markets (Mishra et al. 2021; Dobson et al. 2020).
- People **need to understand the role of different wildlife species in the ecosystems** and that deforestation, agricultural and infrastructure expansion even into formerly remote habitats, biodiversity loss bring people and livestock into closer contact with wildlife which significantly increases the risk of spillover events (Keesing & Ostfeld 2021; Everard 2020; IPBES 2020).
- For example, bats comprise the highest risk among all wildlife for harboring emerging diseases; increased human encroachment in recent decades has driven some bat species to become peri-domestic, which increases the risk of zoonotic spillovers (Kurpiers *et al.* 2016).
- However, the **ecological benefit of bats is immense:** In their natural ecological roles they perform valuable ecosystem services beneficial to humans, seed dispersal maintaining local watersheds, all of which are reduced when bats are hunted. Reductions in bat populations as a result of hunting could have expensive ramifications on local communities' water supplies, agriculture, and eco-tourism industries (Mildenstein et al. 2016).
- Furthermore, persecution of bats, including the destruction of their roosts and culling of whole colonies, has led not only to declines of protected bat species, but also to an increase in virus prevalence in some of these populations. Educational efforts are needed in order to prevent future spillovers and to further protect bats from unnecessary and counterproductive culling (Schneeberger & Voigt 2015).



- The **One Health approach** - considering the health of people, animals and the environment – has been already promoted since the 2010s (Karesh & Vora 2010; Travis *et al.* 2011; Mackenzie *et al.* 2014). Since COVID-19, this approach received much more attention (Zowalaty & Järhult 2020, Everard *et al.* 2020; Mishra *et al.* 2021; Berthe *et al.* 2022, Schwensow *et al.* 2022).

5.2.3. Role of urban consumers / food alternatives

- Africa has the fastest urban growth in the world. The continent's population is projected to double between 2020 and 2050; with 2/3 will be living in urban areas (OECD/SWAC 2020).

- During a survey in Nigeria, Togo, Burkina Faso, and Niger the proportion of persons not consuming any bushmeat was highest in urban areas, especially among young people. Nevertheless, existing demand from a large urban population can create an immense pull and support very long-distance wild meat trade (Luiselli et al. 2019).
- Subsistence hunting occurs many in local and rural areas, involving small sized animals (e.g. rodents, bats, etc.) while commercial hunting is driven by cultural reasons, with wealthy and middle-class people of urban areas being the main consumers (Luiselli et al. 2017, Fa et al. 2002).
- According to Luiselli et al. (2018), 62.2% of men and 72.1% of women said they would never eat bushmeat, whereas 12.8% of men and 8.8% of women said they liked bushmeat and ate it regularly. Younger generations of both sexes tended not to eat bushmeat, regardless of their city of origin.
- Urban consumption is now considered a key intervention point; urban citizens have a choice in their consumption behavior (many other food items, such as fish and domestic meat, are available and may be even cheaper), which can contribute to demand reduction (Ingram et al. 2021).

Understanding motives and barriers:

- Ingram et al. (2021) underline: "*City dwellers may consume wildlife for many reasons, including a desire for traditional cuisines and to maintain a cultural connection to a rural heritage, or a perception of wild meat as fresh, healthy, tasty, exotic, and/or as a marker of status. Therefore, reducing demand in metropolitan areas is rarely a question of providing affordable and accessible substitutes, as these already exist. Instead, it is about changing consumer attitudes and practices*."
- Chausson et al. (2019) found that "*the perception of bushmeat as natural, tasty and healthy, and a rare luxury product functioning as a symbol of social status, underpins social norms to provide bushmeat. The main barriers to purchasing were cost and availability. Locally produced fish, meat, and poultry were positively perceived as organic and healthy, whereas frozen imported animal proteins were perceived negatively as transformed, of poor quality and taste, and unhealthy*."
- A survey by WCS found that "traditional" conservation campaigns and messages may be counterproductive and even reinforce negative perceptions of conservation, because perceptions held by urban African bushmeat consumers and those held by actors in the conservation sector are often incongruent: "*For example, in Pointe Noire (Kongo Brazzaville), bushmeat consumers associated bushmeat with their culture, status, and hospitality – and they don't want to give this part of their social life up. They were suspicious of conservation as a foreign preoccupation, putting more importance on animals than humans and imposed by outsiders who do not appreciate Congolese life and culture. They felt they were helping rural people and hunters make a living by buying bushmeat. … In Kinshasa (DRC), eating bushmeat was considered expression of status and cultural identity. … The limited supply, long transport and maintaining the bushmeat quality make it expensive and more desirable. …They resisted being told what to do by international conservation organizations. They had more immediate urban problems such as pollution, the pandemic, and the social and economic pressures of their daily lives*" (Yocum et al. 2022).
- WCS recognized that **for calls to reduce bushmeat consumption to be accepted by bushmeat consumers, behavior change strategies such as communication campaigns**

needed to be oriented to how the intended audiences perceive conservation issues and bushmeat consumption (Yocum et al. 2022).**:**

- In Pointe Noire's pilot campaign, the new frame aimed to reorient audiences from resistance to acceptance and a sense of ownership about conservation. The campaign shared "good news" instead of bad news that denies the consumers' interests and pleasures and gave reasons for optimism and pride to positively reorient perceptions about conservation and reducing bushmeat consumption.
- In Kinshasa, the new frame aimed to shift indifference to interest in conservation that has a closer connection to urban life. Small, feasible actions, and moments of success were offered as chances to make daily life better and at the same time be part of a conservation initiative… Reducing bushmeat consumption was offered as a way to enhance social life and feel more successful.

5.2.4. Demand reduction strategies

- **Arguments for demand reduction:** According to Moorhouse et al. (2017) human health risks (via zoonotic diseases) and legal aspects (protection status of a species and potential legal consequences) were more convincing for potential clients not to buy, compared to conservation (rarity of a species) or animal welfare aspects.
- The need for education programs to include understanding of the risks of zoonotic diseases, and to stimulate behaviour change is obvious (MacFarlane et al. 2022; Veríssimo et al. 2018; Moorhouse et al. 2017).
- **Food preferences and habits are formed in large part through childhood experiences and actually persist throughout the course of an individual's life**, helping to maintain memories and strengthen connections with traditional origins and territory (van Vliet et al. 2015).
- Van Vliet (2018) warns that stigmatization of bushmeat may foster a "cultural backlash", accusing protectionist behaviours of "cultural imperialism" and recommends to analyse and consider the complex cultural dimension. Cawthorn & Hoffman (2015) also underline potential ethical collisions and the need to provide alternative sources for food and income.
- Campbell et al. (2021) from TRAFFIC highlight main factors for the success of demand reduction strategies, e.g.:
  - "*In general, target audiences respond better to **positive social messages** than to negative environmental messages. This is in line with the experience from communications targeting climate change deniers, which have proved more effective when focusing on the social welfare improvements of mitigating climate change, rather than the risks and realities of climate change."*
  - ***"The perceived credibility and pick-up of behaviour change messaging are influenced by who presents the message.** Locally influential actors and institutions should be engaged as messengers to change perceptions and bring about effective behaviour change. These messengers can have a strong voice in promoting alternative products or forms of consumption. In the Republic of Congo, for example, Protestant Christian groups are growing in influence, and have significant social and political influence to connect with target audiences" (see also https://changewildlifeconsumers.org/toolkit/choosing-the-right-messenger/).*
  - *"**Proposing suitable alternative options** is important for any behaviour change intervention, and the right alternative product for wildlife consumers will vary based on*

local preferences and local availability. In the Republic of Congo, imported frozen meats are seen as poor quality and unsafe, often making consumers sick. Local organic poultry and livestock and locally caught fish are seen as fresh, tasty, and healthy, satisfying the main motivators for why people consume wild meat in this area. Fresh fish may be a good alternative protein source in similar urban coastal areas if fish can be sustainably sourced.

- For the WWF, Nicolas (2021) also noted that "demand reduction campaigns that focus on diminishing the purchase of specific wildlife products work best when they target consumers and develop messaging based on research of consumer motivations. This allows campaigns to target consumers more effectively and develop appropriate messaging."

- MacFarlane *et al.* (2022) highlight: "*In light of the devastation caused by the current coronavirus pandemic, and the aforementioned associated risks, there may be a* ***moral responsibility for conservationists to incorporate factual health-risk warnings into communications that concern many wildlife trade activities…*** *Thus, by communicating that consuming primate meat is both high in risk (e.g., of contracting disease) and low in benefit (no more nutritious than other forms of protein) we can use both elements combined to reduce people's perception of its value.* ***Indeed, a recent experiment found that while the perceived value of an ineffective health remedy could be reduced by communicating either its lack of benefits (by 23%) or its potential health risks (by 30%), communicating both produced the greatest reduction in perceived value (by 50%).***

- WildAid leads the campaign "Nigeria for Wildlife against the demand for illegal bushmeat in the urban centres of Nigeria. The campaign is based on fame celebrities like the singer Davido, Nollywood actress Stephanie Linus, comedians Emmanuella Samuel and Josh2Funny, Miss Tourism Nigeria Mercy Jessica Odjugo and religious leaders of the Inter-religious Council of Nigeria (NIREC) and was developed in collaboration with the Nigerian Ministry of Environment and other government agencies (Ngounou 2022).

- Main findings of WildAid (2021):
  - The consumption of bushmeat partly overlaps with the illegal trade of protected species like elephants and pangolins.
  - 70% of urban Nigerians have consumed bushmeat in their lives, 45% within the last year.
  - 51% claimed taste and flavour of bushmeat as one of the primary reasons for their choice. More than half of respondents believe that less bushmeat is available now compared to five years ago.
  - Federal and state laws that prohibit hunting and trading of species were found to be poor deterrents on consumer behaviour. 54% believed that all bushmeat is legal and 88% believed that all bushmeat should be legal.
  - 98% of urban bushmeat consumers claimed fish and chicken as suitable alternatives to bushmeat.
  - 75% of respondents claimed to eat bushmeat in the future, despite the Corona pandemic.
  - 51% of the respondents believed that lack of hygiene is the primary cause for zoonotic diseases followed by contact with wild animals (44%) and research (43%).
  - 38% of urban consumers are concerned about the extinction of wildlife and therefore would avoid bushmeat.
  - 80% of respondents feel that federal or state governments have a responsibility to protect Nigerian wildlife.

6. Relevant stakeholders & potential partners

Involvement of relevant stakeholders in the government is critical. Relevant federal stakeholders for the campaign (e.g. Ihekweazu et al. 2021):

- Nigeria Center for Disease Control (NCDC)
- Nigerian Environmental Standards & Regulations Enforcement Agency (NESREA)
- Department of Veterinary and Pest Control Services, Federal Ministry of Agriculture and Rural Department (DVPCS, FMARD)
- National Veterinary Research Institute, Vom, Plateau State (NVRI)
- Federal Ministry of Health
- Federal Ministry of Environment
- Nigerian Customs Service
- Cross River State Ministry of Health
- Cross River State Department of Veterinary Services
- Cross River State Ministry of Environment
- State Department of Veterinary Services for all other states
- State Ministry of Health for all other states (SMOH)
- State Ministry of Environment for all other states
- State Ministries of Agriculture (SMOA)
- CITES-Specific Authorities for Nigeria:
    - Forestry Research Institute of Nigeria (FRIN)
    - National Institute of Oceanography and Marine Research (NIOMR)
    - National Institute of Freshwater Fishery Research (NIFFR)
    - National Park Services (NPS)
    - National Horticulture Research Institute (NIHORT)
    - Nigerian Conservation Foundation (NCF)
- Academia:
    - Ahmadu Bello University (ABU)
    - University of Ibadan (UI)
    - University of Jos (UJ)
    - University of Lagos (UNILAG)
    - Usman Danfodio University (UDUS)
    - Akwa Ibom State University (AKSU)
    - Bayero University, Kano (BUK)
    - University of Calabar (UNICAL)
    - Nigeria Field Epidemiology and Laboratory Training Program (NFELTP)

Various studies found that the following stakeholders are important to raise awareness and educate people (Nguyen et al. 2021a, Nche 2020, Nasir et al. 2014, Jegede 2007):

- Political leaders
- Religious leaders, involving imams, Islamic school teachers, Catholics, Anglicans, and Pentecostals

- Traditional rulers
- Doctors
- Journalists
- influential celebrities

6.1. Role of stakeholders

- Religious leaders in Africa can have a central role in awareness campaign (e.g. vaccination, prevention of diseases, climate change), but also have the potential to undermine awareness or vaccination campaigns (Nche & Agbo 2022; Jegede 2007). Therefore, they need to be convinced first before becoming an active and helpful player (Agbo & Nche 2022; Nche 2020; Remes et al. 2012).
- During the COVID-19 pandemic religious leaders (Christians and Muslims) in several African countries were involved in Governments' public health education campaigns – including spots on TV and speaking on radio (WHO Africa 2020).
- In northern Nigeria, a **coalition campaign involving imams, Islamic school teachers, traditional rulers, doctors, journalists, and polio survivors** was gradually turning the tide against polio vaccine rejection (Nasir et al. 2014).
- The polio immunization campaign demonstrated that the commitment of traditional and religious leaders in northern Nigeria was critical (Nasir et al. 2014).
- Baker et al. (2017) investigated the impact of local belief systems and taboos on the conservation of Endangered Sclater's monkeys in Nigeria. The study highlights the conservation importance of local cultural protection, as local taboos continue to be effective regardless of social, economic, religious and cultural changes. At the same time, however, this protection also has its limitations, as species-focused taboos that do not extend to habitat and critical resources which could lead to an increasing number of animals in habitats that are decreasing in size and quality which in turn could lead to an increase of human-wildlife-conflicts and disease transmission.

6.2. Health Alliance partners

Who:	**Wagening University & Research**
What:	**"Health risks associated with urban wild meat in Nairobi, Kenya and Lagos, Nigeria"**
Contacts:	Samuel Akpan (iykesamuel187@gmail.com)
	Phyllis Masudi (phyllisssheril@gmail.com; Phyllis.Masudi@wur.nl)
Link:	https://alliance-health-wildlife.org/projects/health-risks-associated-with-urban-wildmeat-in-nairobi-kenya-and-lagos-nigeria/
Who:	**GIZ Nigeria**
What:	eventually helpful for networking with authorities?
Contacts:	GIZ Office Nigeria, No 12, Charles de Gaulle Close Asokoro, FCT, Abuja, Nigeria
	giz-nigeria@giz.de; +234 (0) 8055299996
	Portfolio Manager: Katja Lehmann: katja.lehmann@giz.de
	Country Director: Markus Wagner: markus.wagner@giz.de
Link:	https://www.giz.de/en/worldwide/1902.html

7. Studies on national use of (social) media tools

7.1. Key points on media tools

In a nutshell:

- **Radio remains the most used mass-communication medium in Africa**.
- Studies show that education via social media is crucial for awareness and public health campaigns.
- In Nigeria, social media helped to curtail the Ebola-outbreak in 2014 by disseminating accurate information about the disease and correcting hoax messaging.
- **The top 5 most popular social media platforms in Nigeria (excluding messaging platforms) are Facebook, Instagram, Twitter, Telegram, and TikTok.**
- 38-51% of population in Nigeria is using the internet and 32.9 million people are active social media users.
- There were 109.2 million internet users in Nigeria in January 2022, meaning that 49.0 percent of the population remained offline at the beginning of the year.
- There were 32.9 million **social media** users in Nigeria in January 2022, which is equivalent to 15.4 percent of the total population.

7.2. Scientific background

- **Radio remains the most used mass-communication medium in Africa**. It has the widest geographical reach and the greatest audiences compared with the Internet, television and newspapers - reaching millions who have no access to the internet (UN 2022).
- **On COVID-19**: Adanlawo (2020) revealed that media, especially social media, play a critical role in curbing the spread of Coronavirus. The study concluded that crisis risk communication is an important step contributing to changing individual behaviour and control of the virus. The study recommends the need for each stakeholder to indulge in the use of social media in communicating Coronavirus crisis to the public to achieve behavioural epidemiology control.
- **On COVID-19:** In the context of COVID-19, Porat et al. (2020) highlight an **infodemic — an over-abundance of information, of which some is accurate, and some is not, making it hard for people to find trustworthy and reliable guidance to make informed decisions**. They propose five practical guidelines for public health communication that will cut through the infodemic and support well-being & sustainable behaviour change: (1) create an autonomy-supportive health care climate; (2) provide choice; (3) apply a bottom-up approach to communication; (4) create solidarity; (5) be transparent & acknowledge uncertainty.
- **On Ebola emergency**: In Nigeria, social media, including Facebook and Twitter, obviously helped to curtail the Ebola-outbreak in 2014 by disseminating accurate information about the disease and correcting hoax messaging (Fayoyin 2016; Carter 2014).
- **Role of social media campaigns**: A study by Duong et al. (2021) underscored the need to leverage the power of social media and interpersonal communication in public health campaigns to prevent infectious outbreaks. They found that interpersonal communication mediated the effect of social media campaign exposure on risk-reducing behaviour.

- Nigerian students use social media, among others, for entertainment, education, information, discussions on national issues (Ezeah et al. 2013).
- Nigeria tops the list of African countries with the highest number of mobile phones (FurtherAfrica 2022). In 2022, 37.3 percent of the Nigerian population accessed the internet via mobile device. This share is projected to grow to 48 percent in 2076. In 2021, the number of mobile internet users in Nigeria amounted to over 80.93 million (Statista 2023).
- According to Bartlett (2015) **Facebook** penetration in Nigeria only stood at six percent in 2014, around 11 million users. This figure, however, has been growing rapidly. Awareness and use rates are much lower among older and less educated Nigerians – 51 per cent of those 35 or older have heard of social networking services and just 13 per cent of this age-group said they used such a service in the week the past week.
- There were 109.2 million internet users in Nigeria in January 2022. Kepios (2023) analysis indicates that internet users in Nigeria increased by 4.8 million (+4.6 percent) between 2021 and 2022. For perspective, these user figures reveal that 104.9 million people in Nigeria did not use the internet at the start of 2022, meaning that 49.0 percent of the population remained offline at the beginning of the year (Kepios 2023).
- There were 32.9 million **social media** users in Nigeria in January 2022, which is equivalent to 15.4 percent of the total population, but it's important to note that social media users may not represent unique individuals. According to Kepios (2023), **Facebook** had 26.1 million users in Nigeria in early 2022, **Facebook Messengers** 4.05 million users, **YouTube** 32.9 million users, **Instagram** 9.05 million users, **Twitter** 325,400 users, **Snapchat** 9.5 million and **LinkedIn** 6.3 million users. For more details see https://datareportal.com/reports/digital-2022-nigeria
- **Websites**: The third most visited site in Nigeria, **Sahara Reporters**, relies heavily on reporting by citizen-journalists for its content and has been at the forefront of publishing multimedia content on social platforms including Twitter, Facebook, Instagram, Tumblr and YouTube. Its popularity as a news platform (with over 1.5 million likes on Facebook) is testament to the influence that social media can have (Bartlett 2015).
- The top 5 most popular social media platforms in Nigeria (excluding messaging platforms) are Facebook, Instagram, Twitter, Telegram, and TikTok (Dokua Sasu 2022a). PANDRILLUS – Drill Ranch will be using these platforms for outreach simultaneously through a third party post scheduling platform. WhatsApp is the most popular instant messaging app and it shall also be used, especially with Ambassadors serving as amplifiers for the key messages shared. LinkedIn will be used to reach health professionals and to induce actions in favour of zoonosis education in their various domains – human, animal or environmental health.
- The social media outreach will target mainly urban Nigerians in order to discourage bushmeat consumption and involvement in wildlife trade. In addition, the campaign will enlighten them about the potential risks as well as the legislations that speak to wildlife conservation. There will be a schedule for posting on these media and each message will be adapted for the various social media platforms before release. Ambassadors shall play a key role in amplifying the dissemination of messages on the various platforms.
- Bartlett et al. (2015) recommend using **social media** for education including the identification of potentially influential voices, accounts, and emerging events (physical and digital).
- 38-51% of population in Nigeria is using the internet (Statista 2022; World Bank Group 2023) and 32.9 million people are active social media users (Dokua Sasu 2022b).

8. Other relevant information

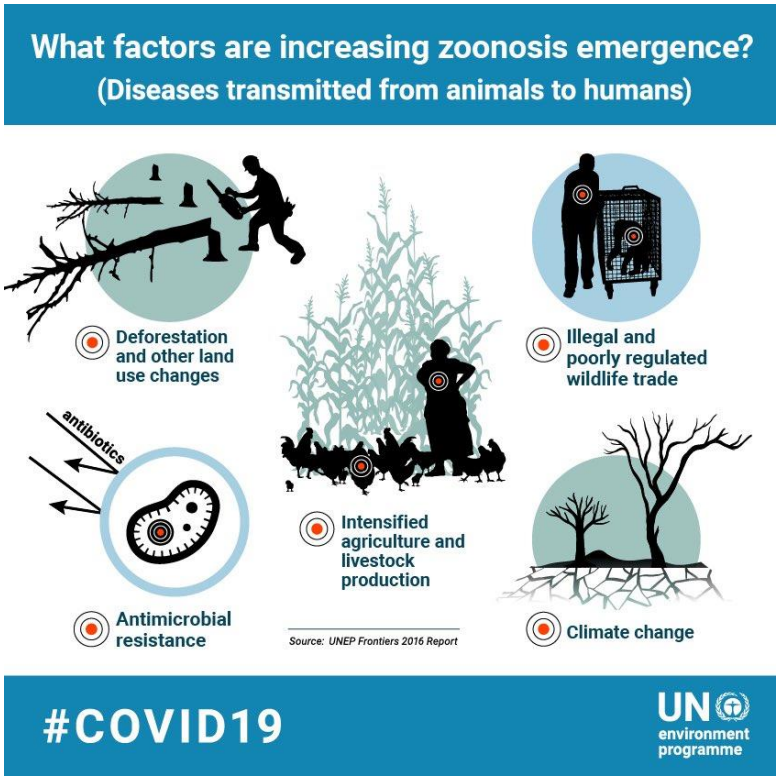
- **A critical explication of the functions and limits of taboos and customary practices attached to wildlife harvesting is needed to see what the society stands to gain from various taboos and how these taboos can be constructively repositioned to achieve ultimate wildlife conservation**, according to a study in Nigeria (Obioha et al. 2012). For example, the endangered sclater's monkey, endemic to Nigeria, is locally protected in a community complex by long-standing social taboos, which remained largely intact until nowadays (Baker et al. 2017).
- The Islam's prescribed method of slaughter for halal means de facto that all bushmeat species are prohibited for strict Muslims (van Vliet & Mbazza 2011), including the eating of primate meat. However, Nyanganji et al. (2010) note that, while eating of great ape meat is restricted by certain taboos, those traditional taboos are increasingly breaking down because of an influx of immigrants from non-Muslim areas, and because of a commercialization of the bushmeat trade.
- Bachmann et al. (2020) found that Muslims in Côte D'Ivoire consumed 86% less primate meat, 90.6% less duiker meat and 94.1% less rodents than Animists.
- Hunting pressure is unsustainable due (in part) to non-selective guns and traps placed around farms and forests. At present, hunters only avoid killing **totemic animals**. For instance, Nimba hunters, avoid killing of chimpanzees and some other primates, leopard, some species of mongoose and the yellow-backed duiker. These avoided species serve as totems, are considered dangerous, have mystical value (especially chimpanzees and leopards), are of known conservation value or are known to be rare (Conservation International undated).
- In central Ghana, two primate species (the ursine black and white colobus and the Campbell's monkey) are locally protected by a **hunting taboo**, thought to date back to the 1830s (Saj et al. 2013). The authors conclude from their research that the monkeys serve as a totemic mechanism to preserve the villagers' social world.
- According to a second study in Ghana, hunters are often more aware of existing **taboos and myths** than of legal aspects, such as closed hunting season and license requirements. However, existing rituals as a remedy for the violation, serving as an antidote against the intrigue, are undermining efficiency of taboos. Rather than integration of the myths and taboos into biodiversity management, increased efforts for enforcement of laws are needed (Emieaboe et al. 2014).
- **Local hunting practices, often accompanied by several taboos, were practiced for centuries, but this does not apply to commercial bushmeat trade into urban markets**, where new consumption aspects have been developed (Zhou et al. 2022).
- State-enforced quarantine, with a mandatory prohibition of movement, raised condemnation, strengthened stigmatization, created a climate of fear, mistrust and denial that did not help people to understand the causes, ways of transmission, and prevention strategies. An understanding of the drivers of fear and mistrust in the affected communities which ultimately result in behaviour that may increase disease transmission, appear to be a crucial and substantial part of an outbreak control (Arthur *et al.* 2022; Pellecchia *et al.* 2015).

9. Examples for Visualizations & Graphics (for internal use only)

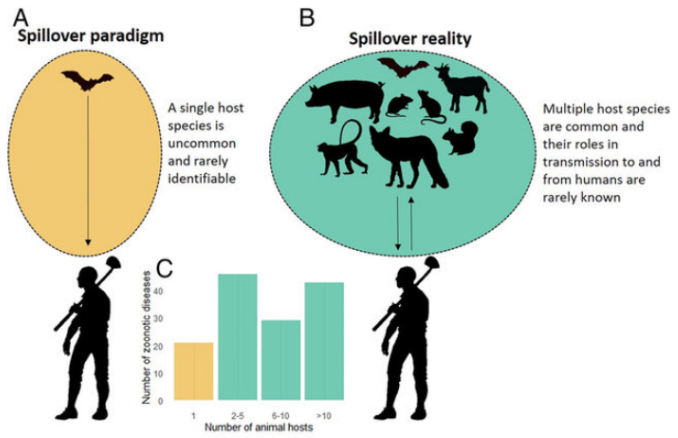
One Health concept

>> GIZ: https://www.giz.de/en/worldwide/95590.html

Biodiversity loss & zoonosis emergence
(https://twitter.com/GlobalGoalsUN/status/1251562406624374784/photo/1)



Complexity of hosts
(https://www.researchgate.net/publication/350665803_Impacts_of_biodiversity_and_biodiversity_loss_on_zoonotic_diseases/figures?lo=1)



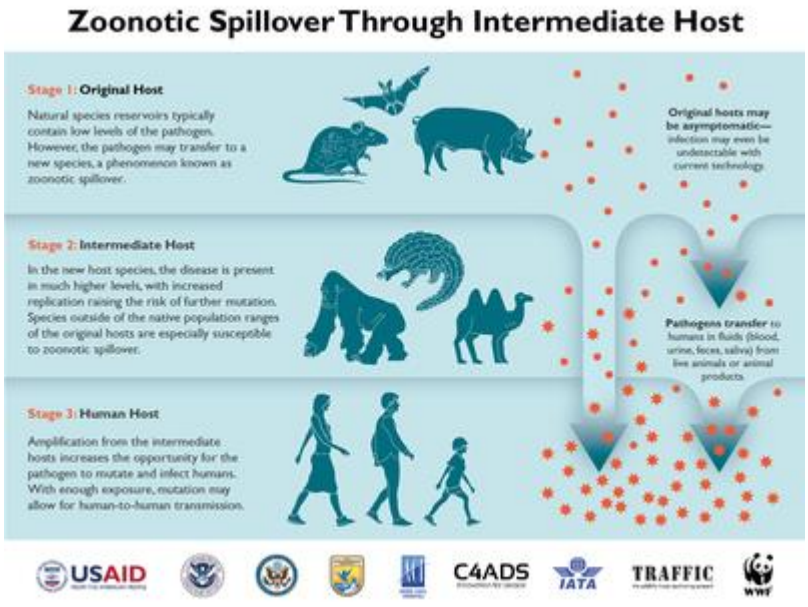
Figure

Caption

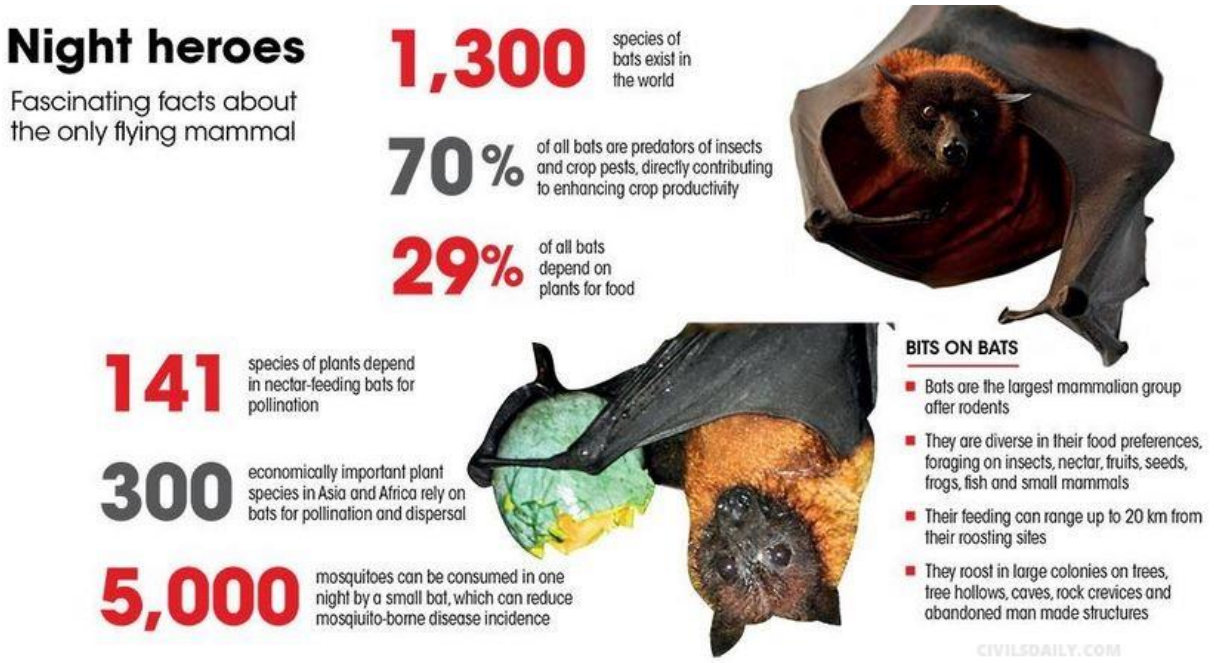
Fig. 4. The paradigm and the reality for research on spillover of zoonotic pathogens into humans. (A) The paradigm emphasizes a single animal host species for a zoonotic pathogen and an original spillover event, though the event and the species are rarely identified. (B) In reality, most zoonotic pathogens have multiple host species whose specific roles in transmission to and from humans are rarely known. (C) The number of viral zoonotic diseases that have 1, 2 to 5, 6 to 10, or 11+ known animal host species other than humans. Plotted from data made available in supplementary materials from Johnson et al. (21); see caveats about these and similar data in SI Appendix.

Zoonotic spillover through intermediate hosts

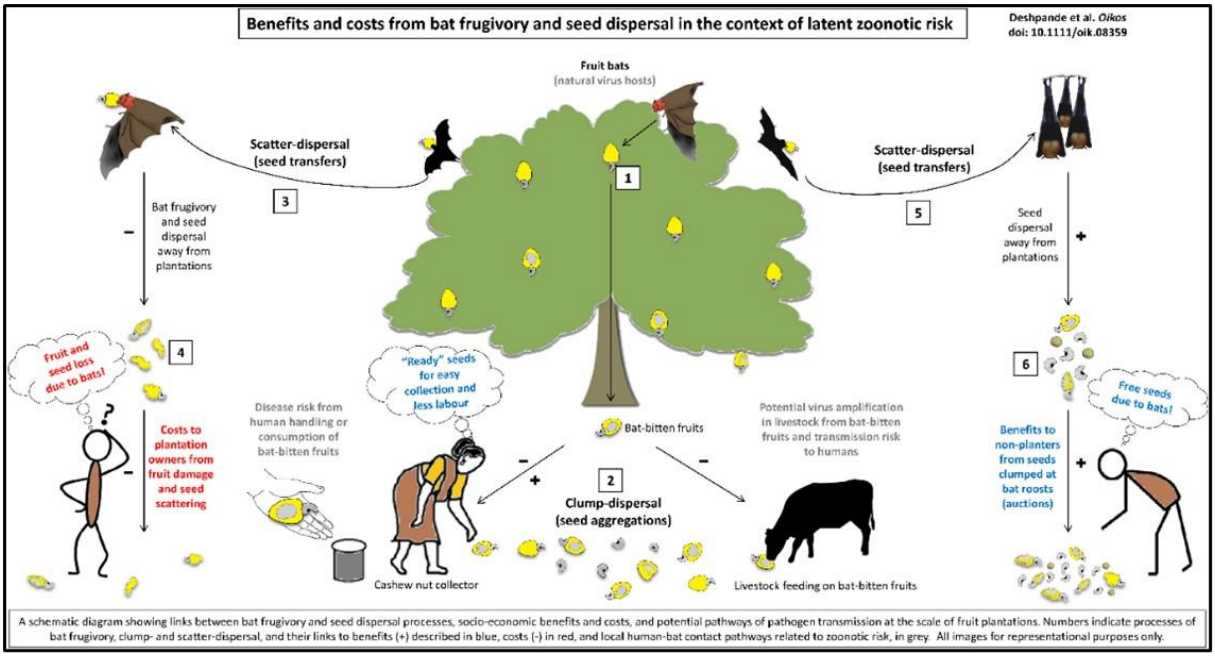
(https://routespartnership.org/news-room/covid-19-underscores-global-need-to-combat-animal-smuggling-in-aviation)



Ecological role of bats: https://www.civilsdaily.com/news/bats-and-their-ecological-significance/



https://www.oikosjournal.org/blog/fruit-bat-people-interactions



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