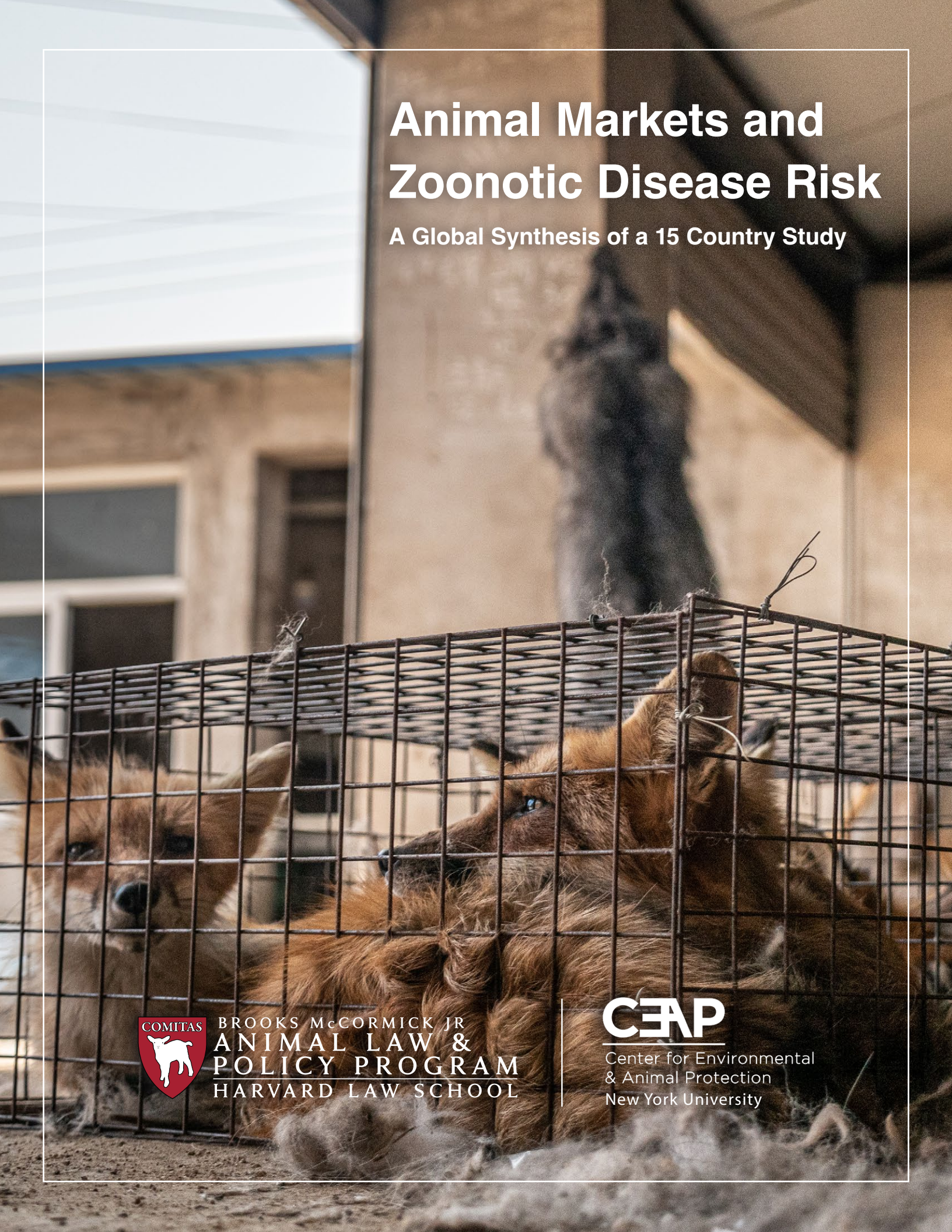

# Animal Markets and Zoonotic Disease Risk

## A Global Synthesis of a 15 Country Study


COMITAS

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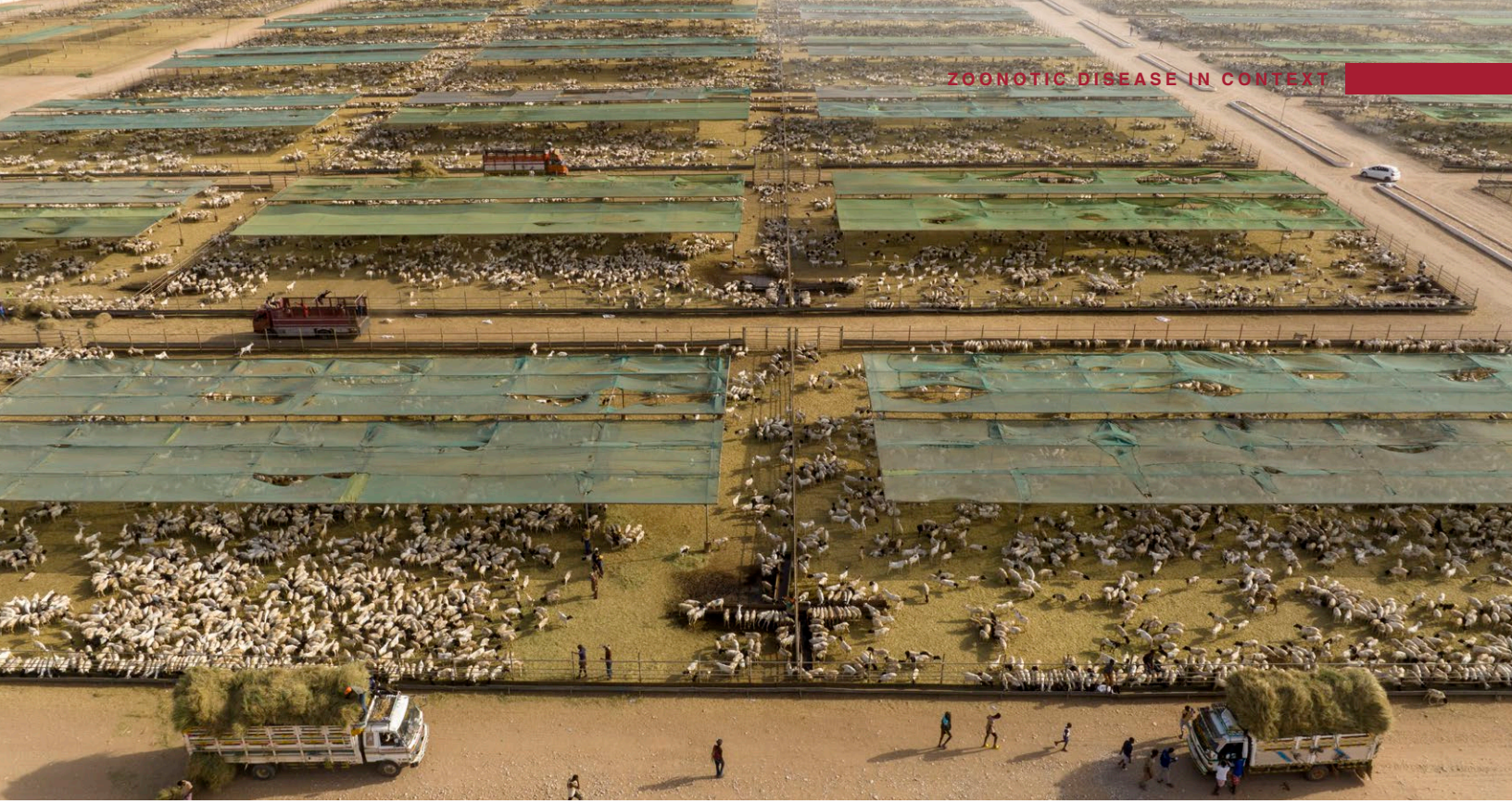
# INTRODUCTION

Zoonotic diseases—diseases that move from animals to humans—present deep and dynamic threats to global health. This report is a synthesis of a 15-country global study that investigates the systems of animal use that drive zoonotic disease risks and critically examines the regulatory frameworks that govern them. The purpose of this research is to shed new light on human-animal interactions and their broader implications for global health security. Observations drawn from these case study reports, grounded in original research and authored by in-country experts, form the foundation of this analysis.[1] This report brings forward new examples, gathered from across six continents, to describe the landscape of zoonotic risk from a global perspective.

This synthesis report begins with a descriptive analysis of animal markets, which are high-risk locations for zoonotic spillover, and explores the many forms that these markets can take. It then examines the sources supplying these markets, including the capture and trade of wild animals, the wildlife farming industry, and the livestock industry. In doing so, it seeks to sketch some of the most common pathways of zoonotic disease emergence and analyze the supply chains that move animals and pathogens across the globe. The report subsequently analyzes how the systems that are currently in place respond to the disease outbreaks that occur within these industries. Finally, the report focuses on the need to improve regulation in order to better address zoonotic risks and examines how some countries are undertaking this challenging task.[2]



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# ZOONOTIC DISEASE IN CONTEXT

Zoonotic diseases include some of the most common and most dangerous diseases on Earth, from rabies and Lyme disease to HIV AIDS, Ebola hemorrhagic fever, SARS, and Plague.[3] Spillover events, in which zoonotic pathogens jump the species barrier from animals to infect humans, are the dominant source of all emerging infectious diseases.[4] [5] [6] Such spillover events have ignited outbreaks that sprawl across the globe, leading to large-scale losses of life and trillions of dollars in economic damage.[7]

Spillover events often take place during a moment of close contact between humans and animals, either alive or dead. And many of the interactions that cause zoonotic spillover are driven by animal industries. Spillover events can occur at any point along animal supply chains: in pet stores and slaughterhouses, at live animal markets, on farms, in backyards, and at kitchen tables. And while the human-animal interactions that create opportunities for spillover pose serious risks to global health security, many of these interactions are poorly understood and poorly regulated, as are the supply chains along which they occur.

Human-animal interactions take place regularly in every country studied in this report, and each interaction contributes to global risk. Pathogens, spread through human movements and the movements of animals, can reach every corner of our interconnected world in a matter of days.[8] Diseases can move from the most remote places on Earth to the most densely populated ones, from the frontiers where new roads are being etched into the forest to the central spokes of cities that connect superhighways. Animals are transported across oceans and mountains, which were once natural boundaries, now erased by globalization.

Even in the face of these global threats, many countries fail to see themselves as contributors to global risk. Too often when confronting disease outbreaks, nations have regressed into the kind of nationalistic thinking that advocates sealing off borders and scapegoating other countries and their

*Human-animal interactions take place regularly in every country studied in this report, and each interaction contributes to global risk.*

cultures, behaviors, and practices. But this kind of us-versus-them thinking is harmful and counter to the type of collective action required to address these threats. Such an approach may also ultimately be ineffective at preventing the cross-border spread of pathogens that are ten-thousand times smaller than the head of a pen.[9] [10] In truth, a threat anywhere is a threat everywhere, and nationalistic thinking can only distract from, but cannot overcome, this fundamental point.

Animal commerce, in its various forms, is a dominant driver of zoonotic spillover. It is linked with the emergence of SARS, MERS, Nipah virus infection, H1N1 "swine flu," COVID-19, and others. Humans use animals and animal parts on an enormous scale. Some serve as food, others as fur or fiber, for pets, perfumes, or medicine, for decoration or dyes, for entertainment, for research, cosmetics, instruments, and hundreds of other uses as well. The largest of these industries is animal agriculture, but zoonotic risk can come from anywhere. Palm civets, for example, sometimes raised to produce perfume or specialty coffee made from their droppings, are thought to be the source of the SARS epidemic.

These human-animal interactions are set against a backdrop of environmental change marked by warming climates, population shifts and expansion, large-scale changes in land use, and growing demand for animal protein.[11] [12] [13] Each of these forces increases pressure on wild spaces, forcing wild animals into closer contact with humans and domestic animals, creating new opportunities for disease emergence and transmission. At the same time, the international trade in animals has introduced native species to exotic ones, and domestic animals to wildlife. In this way, animals are exposed to new pathogens, creating more potential pathways through which disease can reach humans.

Both the general public and policymakers lack knowledge about a wide range of animal industries, as well as the risks they carry, and yet, this information is essential to informing policy responses that aim to mitigate zoonotic risk.[14][15] From remote roadside vendors selling the meat of wild animals to industrial animal production facilities that hold millions of animals together in vast indoor warehouses, many forms of animal industry are poorly regulated, while others remain unregulated altogether. This is true even as animal use and consumption continue to increase globally, and as zoonotic outbreaks are becoming increasingly common, with diseases emerging faster than ever before.[16] [17] [18] [19]

*The global landscape of risk, driven by human use of animals, continues to evolve in ways that are both increasingly and unnecessarily dangerous.*

While the risk of zoonotic disease can never be eliminated, the global landscape of risk, driven by human use of animals, continues to evolve in ways that are both increasingly and unnecessarily dangerous. At many levels of government, policymakers must decide which of these risks they are willing to accept and how to make such determinations. But in order to engage in meaningful discussion about these choices, there must be a clear view of existing practices and the risks they entail. This report provides such a view and lays the groundwork for the kind of efforts required to reduce and mitigate global health risks posed by animal industries.

George Steinmetz / Hargeisa, Somaliland 2023

# ANIMAL MARKETS

Animal markets are formal or informal sites of exchange where animals or their parts and products are presented for sale to customers. The definition of animal markets is broad and blurry—perhaps best described by example. Animal markets, as this report defines them, include a roadside stand selling wild meat in Ghana, a traditional medicine market in China offering remedies made from animal parts, a livestock auction in the United States, a market offering dogs and cats for sale as pets in Israel, and one that offers different species of poultry for slaughter onsite in Hong Kong. At some markets, animals are slaughtered onsite for the purpose of human consumption. These are known in some regions as “wet markets,” but they are far from the only type of animal markets.[20] Some animal markets sell only live animals, while others sell only dead ones, including meat, skins, or other parts. Many markets sell both live and dead animals onsite. Animal markets may sell wild animals, domestic animals, or some of each. In some markets, animals may be sourced and sold both legally and illegally, sometimes by the same vendor. The diverse forms that animal markets take make them difficult to delineate and conceptualize.[21] One common element shared by all forms of animal markets is that they present a threat of zoonotic disease and facilitate opportunities for pathogens to move from animals into humans and other animals.

Zoonotic risk is found wherever these markets are found. The same is true of the source industries that feed these animal markets as well as the supply chains that run through them. When accounting for zoonotic risk, animal markets should be viewed longitudinally in their broader context to understand how zoonotic risks change and flare at different points in time along supply chains.

Structural qualities of animal markets make them particularly high-risk locations for zoonotic spillover, and those markets where live animals are present pose the greatest danger of spillover of viral pathogens. This is significant because viruses, more so than any other class of microbes, are considered

the most likely to ignite future pandemics.[22] For these reasons, this report primarily focuses on markets selling live animals.

*Animals of many kinds from many different places are aggregated in a single place for sale, providing those pathogens an ideal venue to mix, mutate, and move into new hosts.*

Animal markets where animals are stored alive and often slaughtered on site are critical touchpoints where pathogens can move and have moved from animals into humans. Here, in these markets, large numbers of people and animals, from a range of different species, are brought together in close proximity sharing space and exchanging pathogens. Animals of many kinds from many different places are aggregated in a single place for sale, providing those pathogens an ideal venue to mix, mutate, and move into new hosts.[23] SARS, MERS, H7N9 influenza, H5N1 influenza, and possibly COVID-19 all are believed to have first spread to humans in animal markets.[24] [25] [26] [27] In early 2020, as the COVID-19 outbreak advanced, in many places these markets were shuttered and splashed across headlines. It is important to acknowledge that animal markets operate in some form in nearly every country on Earth; they are not unique to any particular country or culture. For example, there are more than 80 such animal markets in New York City, where they are considered hotspots for disease transmission; several of these markets have had to kill every animal on site in recent months to contain the spread of another zoonotic virus, H5N1 avian influenza.[28]

### *LIVE ANIMAL MARKETS AS A SOURCE OF THE SARS EPIDEMIC*

*SARS is believed to have spilled over at an animal market in China, where wild civets were held in tight wire cages. A 2004 study found that approximately 80% of civets at an animal market in Guangdong Province of China tested positive for SARS-CoV-1 infection, while tests showed that civets tested during that same time period on farms were virtually free of the virus, suggesting that the market systems and conditions might have led to the increased rate of infection.[29] Another study a year later showed that the viral load (and associated risk of transmitting SARS-CoV-1 to humans) increased with each day a civet stayed at the market, which suggests that many civets were infected after arriving at the market by other animals carrying the virus.[30] SARS virus was also found in other species of wildlife at live animal markets including racoon dogs and Chinese ferret badgers.[31] Research found that wildlife traders and butchers who handled civet cats at the market tested positive for the virus at much higher rates than vendors selling vegetables.[32] These findings demonstrate some of the reasons why animal markets are a key nexus for the spread of pathogens among animals of the same and different species and for the spillover of pathogens to humans.*

Jo-Anne McArthur / The Ghosts in Our Machine /We Animals Media

Animal markets exist in some form in every country included in this study. They are present across the globe from China to South Africa to Peru and the US. The format, structure, and dynamics of each market are context-dependent, serving local needs and sometimes catering to particular cultural groups. These markets take myriad forms and bring together for sale some of the rarest and most common animals on earth, from monkeys, pangolins, bats, frogs, and owls to poultry, pigs, and dogs—caged or otherwise held near one another in conditions that facilitate disease transmission.[33]

Animal markets are supplied by each of the source industries explored in this report—livestock production, wildlife farming, and the wildlife trade. Yet, while animal markets are just one node on the supply chains that move animals and pathogens across the globe, they are nonetheless a critical one—a place where a confluence of risk factors come together at a single physical location. These markets have proven to be a flashpoint for zoonotic spillover and spread, marked by an unnatural mixing of species, dense quantities of humans and animals, and high-risk interactions between the two groups.[34] [35] [36]

*While animal markets are just one node on the supply chains that move animals and pathogens across the globe, they are nonetheless a critical one—a place where a confluence of risk factors come together at a single physical location.*

**ANIMAL MARKETS GENERATE AND INCREASE OPPORTUNITIES FOR ZOONOTIC TRANSMISSION BY:**

I. Aggregating Animals in Large Numbers from Many Different Sources
   - A. This increases the risk that one or more of the animals is carrying pathogens that could cause disease in humans.
   - B. It allows opportunities for rates of infection to spread along supply chains as animals are moved to market.

II. Increasing Interspecies Contact
   - A. This facilitates the transmission of pathogens between different species.
   - B. It increases the number of potential intermediate hosts.
     1. Enhancing the risk that a pathogen will obtain the capabilities necessary to infect and cause disease in humans.
   - C. It increases the number of potential pathways through which a pathogen can reach humans.

III. Fostering High-Risk Interactions Between Humans and Animals
   - A. Direct and indirect contact with animals at the market including handling, slaughtering, and processing facilitate the spillover of zoonotic pathogens to humans.

## Diversity of Forms and Uses

Animal markets are as ubiquitous as they are diverse, from the wild meat markets of Amazonia and Northern Indonesia, to the live poultry markets of New York City, the Kafr Qasim Bird Market in Israel, and the sprawling Faraday Muti Market selling traditional medicines and foods in Johannesburg, South Africa.

*Animal markets are as ubiquitous as they are diverse.*

In many of these locations, different types of live animal sales happen in parallel at the same site. Contributors in the UAE relayed that this is the case with the songbird markets of Abu Dhabi where brightly colored exotic birds are sold as pets near other birds who are sold for food. In some locations, such as, the Sharjah Livestock Market in the UAE and in many other sites throughout Kenya, animal markets are key locations where livestock farmers sell their animals to small production operations or to "middlemen" who then aggregate the animals and move them onwards for slaughter at major slaughterhouses, or for live export.[37] Some markets with live animals—such as the Canton, Texas flea market, hosting thousands of sales booths and attracting up to 500,000 shoppers per event—focus solely on animals sold as pets.[38] Each animal market reflects the local culture, diet, and socioeconomic conditions of the community it serves.

Jo-Anne McArthur / We Animals Media for The Guardian

Animal markets take different physical forms, and the physical features of the market, from its architecture, to its organization, to its location within the city, to the way animals are displayed and stored, can all affect the level of zoonotic risk. Some are established open air markets; others, informal collections of sellers on the side of a road. Others fill large permanent buildings or operate as small storefronts in metropolitan areas. In all of these markets humans and animals interact in some way. At each of these sites, live or freshly killed animals are sold for food, medicine, decoration, and other uses. Vendors may sell a broad range of species from domestic animals, such as dogs, cats, and livestock, to wild animals including northern pig-tailed macaques, large bamboo rats, brown hawk-owls, keeled box turtles, and green paddy frogs.[39] The size of these markets can vary considerably. In Vietnam, smaller live poultry markets may sell 66 birds a day, while larger ones sell more than 25,000.[40] The largest wildlife markets trade animals at similarly high volumes. Studies have observed as many as 90,000 snakes, 24,000 turtles, and 500 mammals at a single market site in China, although most trade volumes are considerably smaller.[41] [42] For example, wildlife markets in Laos sell between 22 and 931 wild animals per day, similar to numbers observed in markets in Equatorial Guinea and those in Myanmar.[43] [44] [45]

Aaron Gekoski / Asia for Animals Coalition / We Animals Media

Jo-Anne McArthur / We Animals Media

Markets are one of the key locations where multiple animal supply chains overlap and interact. While some markets specialize in selling only domestic animals or only wildlife, in other markets, vendors offer both kinds of animals for sale, sometimes at the same stall. Markets selling both livestock and wild animals have historically been more closely associated with rural populations than urban ones, but this may be changing, as wild meat markets that cater to urban demand become more formalized—a trend that may increase zoonotic risk.

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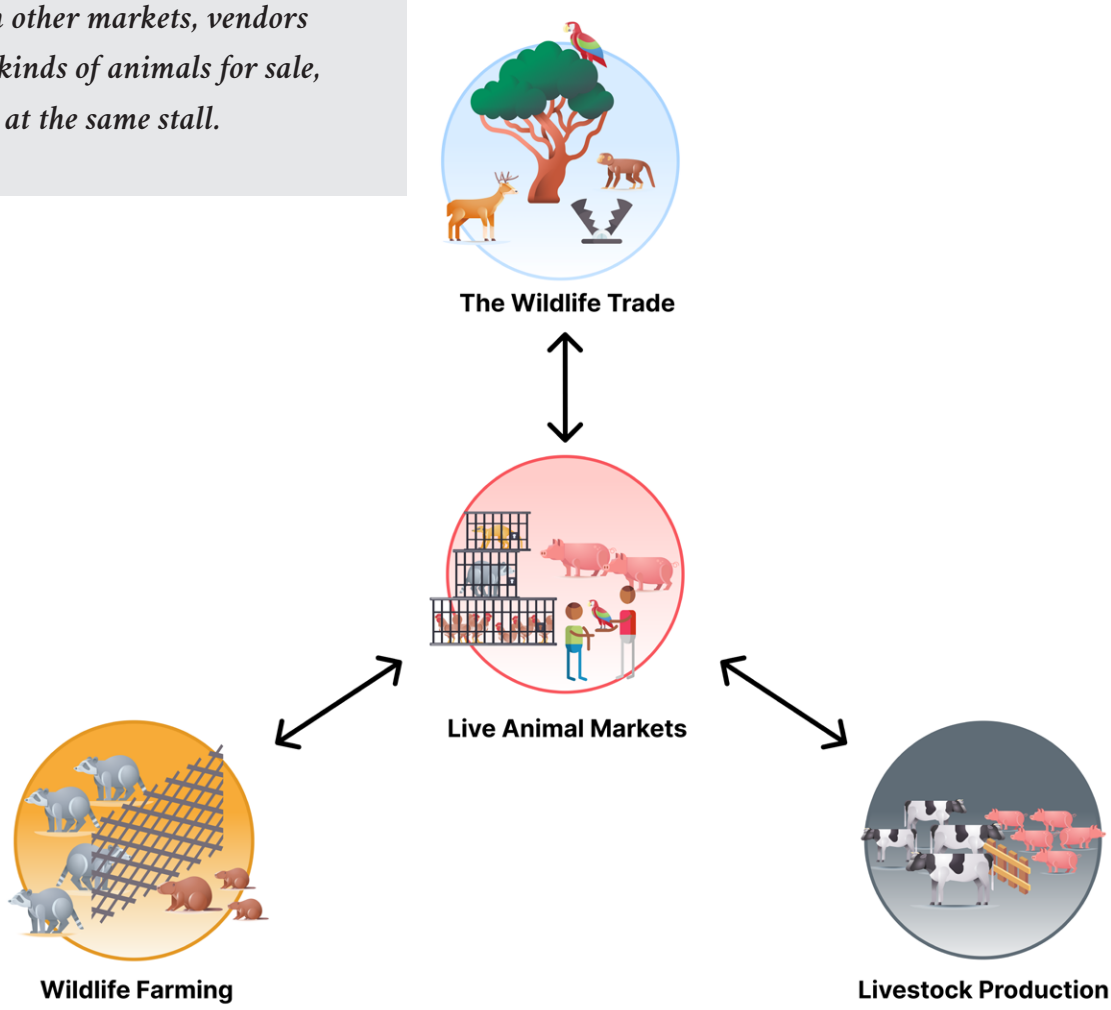

## Supply Chains

Animals sold at animal markets are sourced from each of the three major animal industries discussed in this report: livestock production, wildlife farming, and the wildlife trade. The movements of animals into and within animal markets are a major driver of disease transmission. Rates of infection can increase as animals move along supply chains; some of these supply chains are long and the risk of disease transmission is particularly high where more interactions between animals occur prior to entering the market.[46] [47] Similarly, the risk of disease transmission extends past the point of sale and can carry beyond the confines of the market. Traders may purchase animals and later resell them. Buyers sometimes take live animals home with them, and in addition, in cases when unsold animals from the market are sent back to nearby farms, pathogens brought back from the market may infect other animals or people at those locations.[48]

Resha Juhari / We Animals Media

*The movements of animals into and within animal markets are a major driver of disease transmission.*

## Market Operations and Zoonotic Risk

Animal markets have long been considered hot spots for the spillover and spread of zoonotic pathogens and have been linked to the emergence of several of the most deadly viruses of the last 30 years. Animal markets and the supply chains that support them facilitate the types of intimate interactions that allow for disease transmission. It is both the human-animal interactions and the animal-animal

Kelly Guerin / We Animals Media

interactions that drive risk at these locations, especially when they are densely populated by humans and diverse species of other animals. With a wide range of species present, there are more potential pathways through which a pathogen might reach humans.[49] For example, a flying fox might be infected with a virus but unable to transmit that virus directly to a person. However, if that animal infects other animals of different species at a market, one or more of them might provide a more effective pathway to transmit that virus to humans. One of the defining features that makes these markets particularly dangerous is this mixing of species, which can allow a pathogen additional opportunities—akin to a buffet of different intermediate hosts through which it might acquire the ability to infect humans.

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The following list describes some of the qualities of markets that increase zoonotic risk:

Kelly Guerin / We Animals Media

- **Wide Variety of Sources:** Animals pulled from a diverse set of sources and producers arrive at the market, bringing with them pathogens from those locations as well as other pathogens that they may have been exposed to in transit. Some animals are sourced directly from the wild, while others come from captive wildlife farms or livestock producers. It is common for animals to come from a variety of sources, ranging from large, industrial production facilities to small independent farmers. For example, in Pennsylvania, animal markets source poultry from an average of almost 30 different suppliers.[50] If animals at even one of those operations are infected, that disease may spread to others at the market.

- **Aggregation of Animals Along Supply Chains:** Producers might bring the animals to market themselves or sell them through a middleman, someone who collects animals from multiple locations, bringing them to market for sale.[51] En route for sale, animals might be put in cages or boxes, loaded in a car, truck, trailer, or walked along roadsides as is common in Rwanda. While some animals ride directly to the markets, others might be kept at a home or warehouse as they are awaiting sale allowing more time for any pathogens to spread from one animal to the next. Even when animals are no longer present, transport trucks that ferry empty crates back and forth from farms to markets have been found to carry pathogens.[52]

- **Conditions That Facilitate Pathogen Transmission Among Animals:** Along those supply chains and at the markets themselves, animals of different species, sometimes representing a broad range of taxonomic groups, are held together, often in poor conditions that can increase stress and make animals more susceptible to disease, weakening their immune response. Poor sanitation often associated with such conditions also make it easier for pathogens to spread through the environment from one animal to another. Animals may be displayed on long wooden tables, stacked in cages, or kept on the ground on tethers. Wire-bottom cages allow fluids from animals above to drip down and infect animals below. Blood, saliva, feces, urine, and waste can spread pathogens pre- or post-slaughter.

Christian Faesecke / We Animals Media

- **Carryover of Animals and Introduction of New Pathogens:** Often, there is significant carryover of animals from one day to the next, with some animals remaining onsite for weeks, allowing pathogens to persist despite any regular cleaning.[53] While animals stay at the market before being sold, they collect pathogens from other animals and from the environment. The viral load increases with time, and may peak around one week, as healthy animals are exposed to new shipments of sick ones. Daily introduction of new animals into this environment provides optimum conditions for pathogens such as influenza viruses to thrive.[54] And even when markets are deep cleaned, disinfected, left empty for days, and repopulated with animals from closely monitored sources, pathogens have been found to return to markets within a matter of weeks after the animals do.[55] [56]

- **Multiple Potential Pathways**: As animals are aggregated in these marketplaces for sale, so too are their pathogens, which come from different taxonomic origins, providing pathogens an ideal venue to mix and mutate.[57] This is one reason why animal markets where many species are held together have proved such potent places for infection. The wider the range of species present, the greater the risk of a pathogen making its way into humans.[58] Animal markets provide viruses numerous and different kinds of intermediate hosts through which to reach humans. The more species, the more potential pathways, the greater the chance of spillover.

Jo-Anne McArthur / We Animals

Jo-Anne McArthur / We Animals Media

- **Low Biosecurity**: Animal markets generally have very low biosecurity. Domestic animals such as dogs and cats sometimes wander the grounds, as well as wild animals including birds and rodents looking for food. While some markets limit sales to a single species, most do not. Some markets that sell both domestic animals and wildlife separate the two groups into different sections of the market; however, others allow sales to take place side-by-side, increasing the amount of contact between animals at the market. Some animals are sold alive; others are killed on site, chopped on wooden blocks and hung from ceiling racks or poles.[59] Live and dead animals are sometimes kept in close proximity.

- **Close Interactions with Humans:** Buyers often handle, hold, and examine the animals in ways that facilitate zoonotic transmission. Vendors do the same, in some cases slaughtering and processing animals on site for sale. These kinds of close interactions, particularly where there is direct contact between humans and animals, including their fluids, are precisely the kinds of interactions that facilitate the exchange of pathogens. In some cases, no precautionary measures are taken to prevent disease transmission during slaughtering and handling of the animals. For example, in the Ghazipur market In India, chickens often are skinned and de-feathered with bare hands and without protective gear.

- **Disposal Practices:** Disposal also presents disease concerns, with reports of gutted carcasses and blood improperly discarded, sometimes left in public spaces and in open trash cans.[60] Animal parts may be left on the ground, on tables, and in immediate contact with those working at the market or shopping. In Ghana, waste materials from the slaughtered animals are sometimes discarded on the ground just outside the abattoirs.[61]

- **Lack of Sanitary Precautions:** Sanitation and hygiene often are lacking at animal markets, amplifying the disease risk. Roadside markets in Angola, for example, sometimes keep cuts of meat looking fresh by repeatedly splashing them with the blood of more recently killed animals.[62] At the markets, there usually are few handwashing stations, and, in indoor markets, air flow is often limited.[63] Certain surfaces help foster the spread of pathogens. The wooden chopping blocks used for slaughter and butchering are of particular concern in facilitating disease spread, as these and other reused equipment can further distribute pathogens.[64] In Vietnam, wooden chopping blocks are repeatedly wiped down throughout the day with the same wet cloth rag.[65]

Jo-Anne McArthur / We Animals Media

## Cultural Drivers

Consumer demand supports animal markets across the globe, and these markets supply animals for many different purposes. Some customers value markets for the social functions they provide; others are driven by necessity or convenience, and others still seek out markets because of concerns about quality assurance or because these venues are the only ones that offer traditional remedies, illegal goods, or other hard to find products.

*Many people who seek out animal markets do so because they want to see the animal alive.*

These markets can function as important meeting places for people, serving as a social activity as much as an economic one—important to the individuals who attend them but also to the community at large.[66] Markets sometimes function as the focal point of a person's weekly routine, a one-stop shop for all food supplies as well as for social interaction. Animal markets can also act as part of a restaurant operation, where live captive animals, often from multiple species, are kept onsite for consumption—a practice that poses serious risks of disease transmission.[67] [68] [69] [70] For example, in Vietnam, customers drink rice wine mixed with the blood of snakes, goats, and tortoises, selecting a live animal kept at the restaurant, then witnessing or assisting with the animal's slaughter, before eating the animal's organs and drinking the blood.[71]

Dario Endara / We Animals Media

Many people who seek out animal markets do so because they want to see the animal alive. This desire may be because they want to inspect and appraise the animal's health or quality, or because they want to observe the animal being killed to ensure freshness or adherence to a particular religious custom, such as kosher or halal (which are drivers of live animal food markets, including in industrialized nations). Customers often handle or interact with the animals as they appraise them.[72] These markets are important sources of animals for religious ceremonies. For example, each year, more than 20 markets in Israel conduct onsite slaughter of chickens, more than 40,000 animals in total, for kapparot, a Jewish religious ceremony of atonement.[73] [74] These markets are also a source for animal products used in traditional medicines; at these sites, animal parts, both raw and processed from a range of species, are sold.[75]

Animal markets may also be driven by necessity. This is especially true where a lack of cold storage means animals must be brought to the market alive. Particularly in rural communities, live animal food markets sometimes provide one of the only accessible affordable food sources for local residents.[76] In Bangladesh, more than 90% of poultry is sold through these markets either alive or freshly killed.[77] On the supply side, these markets represent a key outlet for many small-scale producers whose harvest is

Dario Endara / We Animals Media

not large or consistent enough to sell to more formal commercial buyers. The clientele at animal markets is often diverse, from poor subsistence buyers to wealthy individuals seeking luxury goods and exotic meats. In some countries, such as Vietnam, the meat from these live animals, especially free roaming wild animals, is sometimes intended to signal personal wealth and status.[78]

Markets may also cater to those outside of the community where they operate. Roadside stands selling wild meat dot the countryside tracing the bus route from Accra

*The clientele at animal markets is often diverse, from poor subsistence buyers to wealthy individuals seeking luxury goods and exotic meats.*

to the Northern cities of Ghana. Animals are on display to sell to urbanites passing through on buses from one city to the next. Sometimes these animals are considered too valuable to be eaten by the hunters who caught them and are instead sold for profit to passing travelers. In other cases, markets cater to tourists from abroad. The types of goods sold at these markets may be rooted in cultural practices or merely a reflection of what sells to foreigners looking for exotic novelties and souvenirs from their travels—a monkey foot keychain, a dried bat, or a tiger tooth medallion threaded with a string.[79]

For some, for example, in urban communities in Ghana, these markets provide a link to the past—a way of sourcing the animals they ate as children and connecting to their roots, though they live in cities now.[80] In some cases, urbanization may actually increase bushmeat consumption in cases where urban demand is significant enough to foster the creation of consolidated supply chains supplying more-established, urban markets. And in some locations, such as West Africa, some animal market transactions are being replaced by online sale of bushmeat, often facilitated by social media sites such as Facebook.[81]


George Steinmetz / Berbera, Somaliland 2023

## Challenges of Regulating Animal Markets

The nature of animal markets—often fluid and transient—makes them difficult to regulate and police. In some cases, markets exist on the peripheries of regulation in hard-to-reach places. In many cases, vendors set up shop one day and are gone the next, making them unpredictable objects of regulation. Sales can be driven by chance: sellers seizing opportunities to market the animals they can find, on some days selling many animals, and on other days, none at all. The informal nature of some markets does not lend itself easily to formal regulation—does one bring the market to the regulatory system or the other way around?

George Steinmetz / Burgilo Payam, South Sudan 2023

Policymakers' attempts to standardize or formalize these markets are often rebuffed by sellers and consumers. Many officials are reluctant to enforce laws related to animals either because they do not believe them to be important, because of the sensitivities involved, because they are not confident in their own ability to identify species or handle animals, or for other reasons. This may be especially true in smaller communities, where enforcement officials have personal relationships with vendors or face strong social pressure from the community not to enforce the laws stringently. In some places, such as the shanty towns surrounding Cape Town, animals are used as a form of currency or, as they are in Kenya,

*Protected species are sold under the table often by the same vendors selling other animals legally.*

a means to build intergenerational wealth, making regulatory enforcement a more challenging task.

Some animal markets are less visible than others, known to people within the industry or community but not to the general public and regulators. At times, animals are hidden or never on display at all in cases where vendors take orders for specific species and procure those animals upon request. Protected species are sold under the table often by the same vendors selling other animals legally. For example, a seller in San Francisco may have a public storefront on ground level selling only fish and amphibians but also have a private area in the basement that houses additional rare or illegal species, such as civet cats or coatimundis.[82] In these cases, legal and illegal markets overlap as the illegal trade

George Steinmetz / New South Wales, Australia 2022

intermixes with and follows the legal trade. Where enforcement does exist, it can be half-heartedly enforced and easily thwarted. When inspectors visit wild meat markets in Amazonia, they often arrive in the afternoon, and sellers have learned to simply market their wild meat earlier in the day.[83]

Animal markets also pose unique regulatory challenges because of their cultural and religious significance. This shield may be strongest where traditional medicine and wild meat are involved. Policy can become politicized, and in some cases, can be used as a tool to target—or protect—particular groups. This can make regulating animal markets more challenging and politically fraught where doing so gives the impression of singling out particular minority groups. For example, in San Francisco, the animal markets of Chinatown have

*Policy can become politicized, and in some cases, can be used as a tool to target—or protect—particular groups.*

successfully avoided the enforcement of certain regulations by mobilizing the political power of Asian-American voters.[84] Cycles of mistrust, as well as fears of political incorrectness, can undermine regulation of the risks that markets pose.

Despite the deep and broad zoonotic disease risks that animal markets present, any attempts to close such markets completely is often met with strong resistance. China, for example, has been closing and reopening live poultry markets cyclically—taking up and then abandoning efforts to curb the practice of live poultry slaughter at markets in order to respond to the serious risks of zoonotic disease (particularly avian influenza) that these markets present.[85] Such prohibitions pose complicated trade-offs, felt most acutely in places where people are dependent on animal markets for food security.[86] Accounting for the diversity of these markets and disentangling animal vendors from those selling other foods and goods is an important first step towards understanding the zoonotic risks these markets pose, as is differentiating the types of animals sold and the purposes these sales serve. In many cases, there may be simple, practical regulations that could reduce the risk of disease transmission. Some of these measures might include:

Havva Zorlu / We Animals Media

- Better separation of animals and animal species. For example, rotating market days for each species may help to reduce risk (pigs on Tuesday, chickens on Wednesday).
- Separating livestock from wildlife and all animals from other types of food sold at the market, such as vegetables.
- Reducing the number of vendors and supply sources.
- Limiting the length of time that animals stay in the market.
- Increasing ventilation and adding handwashing stations.
- Improving the health of animals sold by providing them better conditions and minimizing interactions with them.
- Limiting customer interactions with live animals.
- Solid bottom cages that limit the exchange of fluids between animals awaiting sale.
- Regular cleaning (in places where running water is available).
- Reducing stocking densities to ensure adequate space between animals.
- Preventing multiple species of animals from being held together in close proximity or in the same cage.

*Animal markets are critical points for transmission for zoonotic pathogens. But they are just one point in a tangled, larger lattice that moves domestic animals, wild ones, and everything in between.*

In some cases, simple changes such as these have proven effective. With voluntary guidelines in place in 2003 in the US that included quarterly cleaning and disinfection, unannounced inspections, and enhanced record-keeping, the incidence of avian influenza in New York live bird markets fell from 60% of those birds tested in the early 2000's to zero in 2019.[87] [88] [89] Despite these improvements, there has been a spate of influenza outbreaks at US live animal poultry markets in recent years, suggesting that disease risks remain, some of which may be inherent in these markets' design.

Animal markets are critical points for transmission for zoonotic pathogens. But they are just one point in a tangled, larger lattice that moves domestic animals, wild ones, and everything in between.

Havva Zorlu / We Animals Media

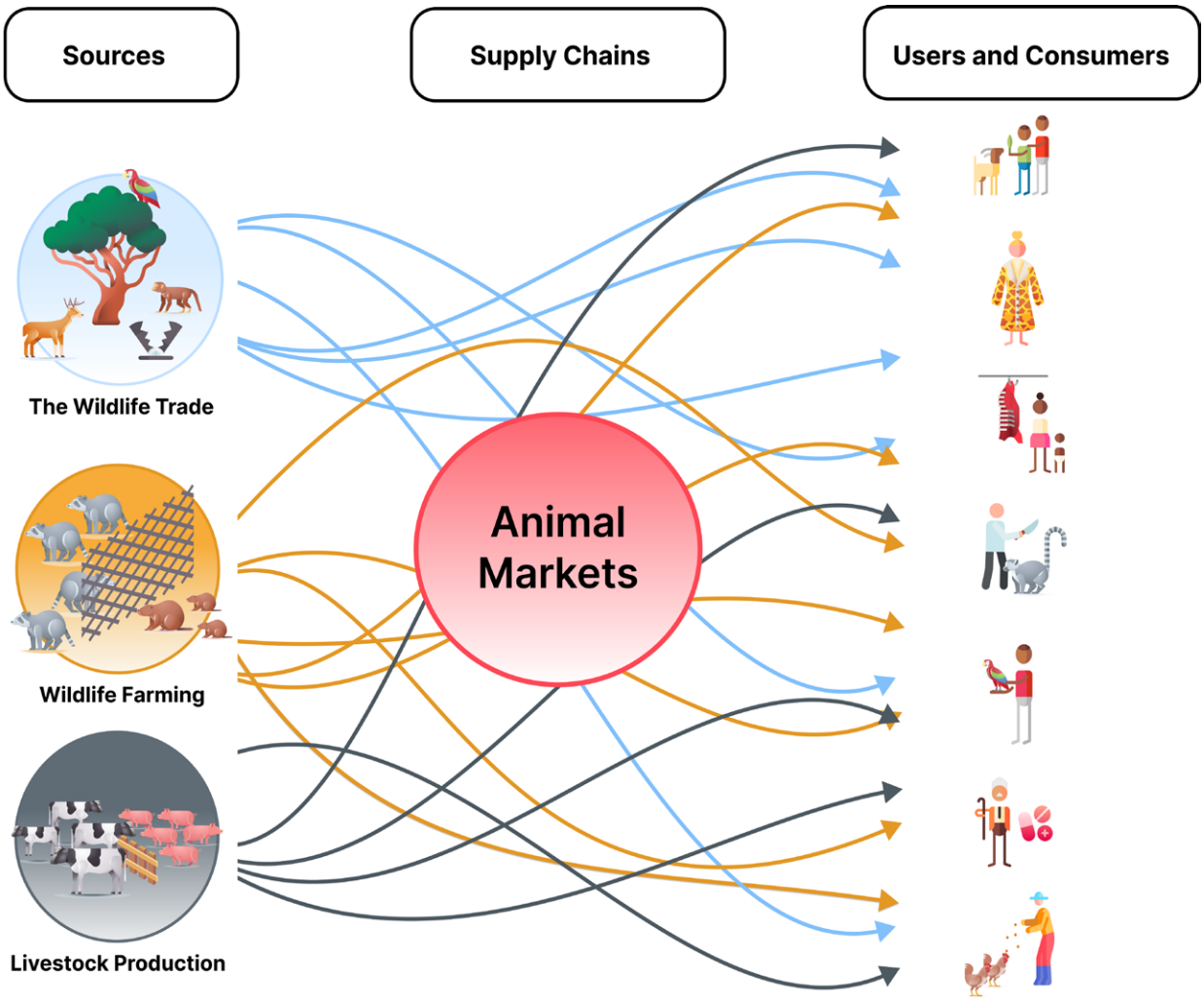
Jo-Anne McArthur / We Animals Media

# SOURCES OF ANIMAL MARKETS

Animals entering animal markets come from a variety of different sources. Most significant among these are the wildlife trade (undomesticated animals captured from the wild), wildlife farming (wild animals produced in captivity), and livestock production (captive production of domestic animals). Each of these source industries involve a unique set of practices and associated risks. But these three industries are not brightline categories, and at various points, the forms of production associated with them overlap and sometimes interact. For example, animals captured from the wild through the wildlife trade may later be sold to wildlife farms. In either case, zoonotic risk is inherent in many practices across all of these industries.

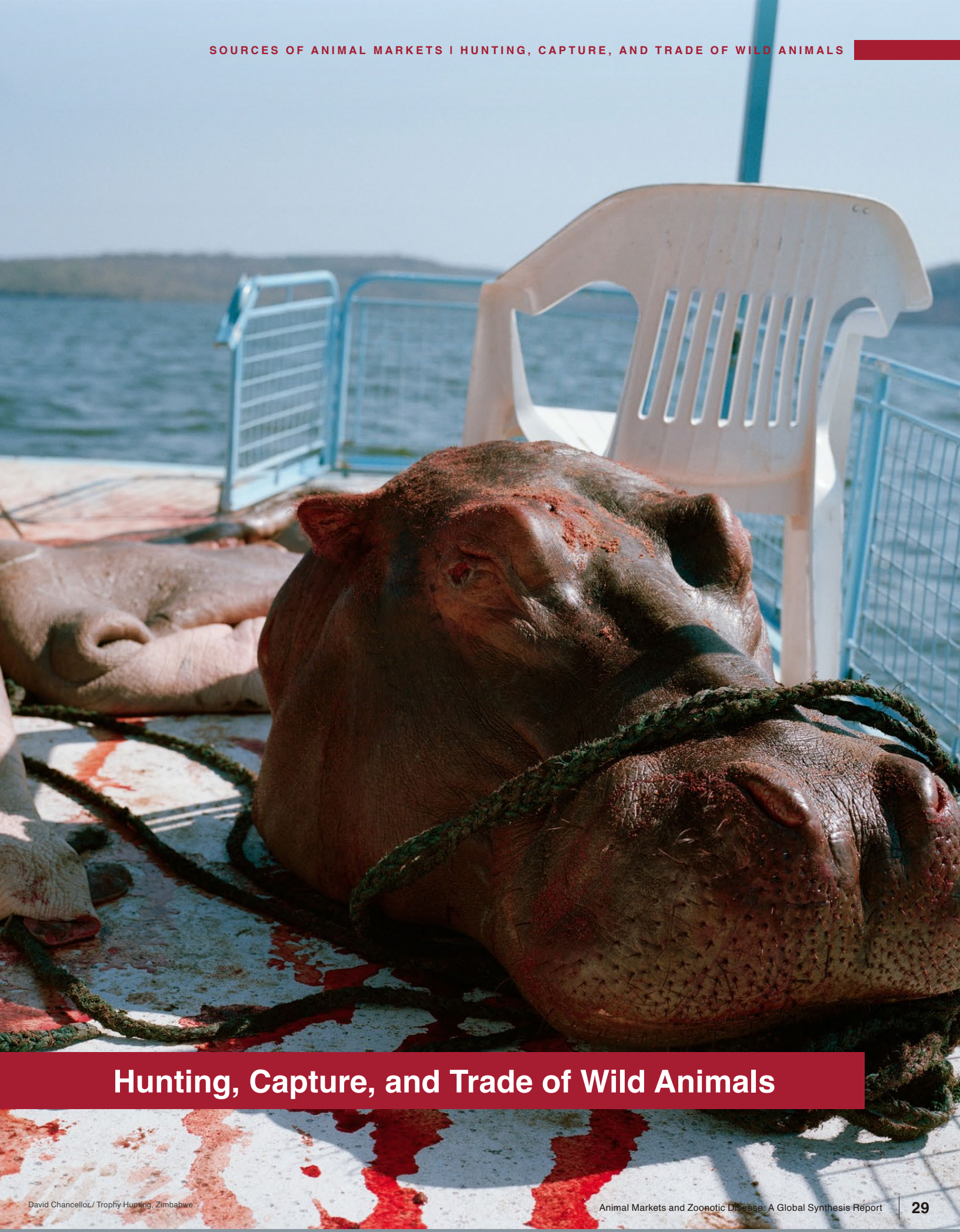
*Each of these source industries involve a unique set of practices and associated risks.*

Animals from these three sources—from the wild, from captive wildlife farms, and livestock production—move through a diverse set of supply chains to reach users and consumers. Each source supplies many unique supply chains. For example, a wildlife trapper might sell some animals through the online pet trade, others to restaurants or to traders as wild meat, and the remaining animals directly to his friends and neighbors for use in traditional medicine. Some supply chains feed animal markets; others do not.




*Many critical human-animal touchpoints occur long before animals ever reach markets.*

Examining these source industries and the supply chains through which animals move is essential to understanding the larger landscape of zoonotic risk. Many critical human-animal touchpoints occur long before animals ever reach markets. Other animals are themselves never brought to a market but nonetheless contribute to zoonotic risk at animal markets by interacting with animals, who *are* brought to market, prior to being sold. Rates of infection can grow along supply chains as animals are aggregated and transported together for sale. While animal markets are critical sites for zoonotic transmission, these markets do not exist in a vacuum, and for the purposes of a comprehensive risk analysis, should be placed and examined in context. Focusing exclusively on physical markets may overlook other high-risk interactions between humans and animals that are occurring elsewhere in the supply chain. It also ignores the risk from supply chains that never intersect with animal markets at all.[90] Examining markets, sources, and supply chains is the only way to fully account for zoonotic risk and to understand each within this broader framework and in relation to one another.



# Hunting, Capture, and Trade of Wild Animals

David Chancellor / Trophy Hunting, Zimbabwe

The wildlife trade describes the sale or exchange of wild animals—alive or dead—as well as their body parts and products. The trade encompasses hundreds of millions of animals a year and carries substantial zoonotic risk—driving an even greater number of opportunities for pathogens carried by wildlife to jump to humans.[91] [92] Spillover opportunities are present along wildlife supply chains from the caves, forests, ponds, nests, and dens where animals are captured to the restaurants, homes, and stores where they are consumed or kept. The wildlife trade presents a significant pathway for transboundary movement of pathogens and for the emergence of new outbreaks of infectious disease.[93] [94] Outbreaks of zoonotic diseases, including H5N1 avian flu, Ebola, SARS, AIDS, and mpox, have been traced back to the wildlife trade, where the potential for zoonotic spillover is high and well-documented.[95] [96]

*Outbreaks of zoonotic diseases, including H5N1 avian flu, Ebola, SARS, AIDS, and mpox, have been traced back to the wildlife trade, where the potential for zoonotic spillover is high and well-documented.*

The wildlife trade contains both legal and illegal factions. It is difficult to disentangle legal and illegal supply chains or to obtain precise estimates for either, but the legal wildlife trade is currently valued at over $300 billion annually, and the illegal trade is roughly estimated at $20 billion annually.[97] [98] [99] Although most of the wildlife trade is legal, much of it is poorly regulated, and profound gaps in both data and disease surveillance mean that much remains unknown about the trade and the zoonotic risks it carries.[100] [101] Where regulations do exist, often they are grounded in conservation, and few have any connection to public health.

*Although most of the wildlife trade is legal, much of it is poorly regulated.*

Jo-Anne McArthur / We Animals Media

**THE WILDLIFE TRADE GENERATES AND INCREASES OPPORTUNITIES FOR ZOONOTIC TRANSMISSION BY:**

I. Aggregating wild animals from different sources and/or species together in ways or numbers that would not occur in nature:
   - A. This allows pathogens to spread from one infected animal into others of the same or different species.
     1. Increasing the spread of density-dependent pathogens.
     2. Heightening the likelihood of a pathogen acquiring new capabilities and generating new forms.
   - B. It drives interactions between different species of wild animals that would not otherwise interact but for human interference, creating opportunities for pathogens to move into new host species.
     1. Making species susceptible to diseases that might not otherwise affect them in nature.
     2. Creating additional pathways through which a pathogen might be transmitted to humans.

II. Driving High-Risk Interactions between Humans and Wild Animals
   - A. This allows pathogens to spread from animals to humans through direct and indirect contact.
     1. The frequency of human-animal interactions along the supply chain creates more opportunities for spillover.
     2. The nature and intensity of these interactions increase zoonotic risk.
        a) Facilitating contacts between humans and animals that would not occur in nature (such as hand-feeding an animal or manually slaughtering an animal).

III. Reducing and altering biodiversity in ways that can foster disease emergence.
   - A. This can increase the risk of spillover where animals, such as rodents, who may be more capable of transmitting zoonotic pathogens to humans, become overabundant.

## Zoonotic Disease Risks of the Wildlife Trade

The wildlife trade includes more than 7,500 species of mammals, reptiles, amphibians, and birds, and presents dynamic threats to global health security.[102] Wild animals are believed to be the source of more than 50%-70% of emerging infectious diseases, a number that appears to be on the rise.[103] [104] Strong evidence suggests that diseases from wildlife have been emerging and reemerging at unprecedented rates in recent decades, driven by human and livestock encroachment into wilderness habitat along with the globalization and the growth of online trade.[105] These outbreaks are not only

becoming more frequent but disease richness is also increasing.[106] [107] [108] Experts estimate that 1,670,000 viruses are said to exist in animal hosts, with the majority yet to be uncovered or documented.[109] [110] [111] Many of the viruses that we know the least about are carried by wild animals. The PREDICT project, which seeks to identify and catalogue new pathogens, has discovered over a thousand novel viruses since it began in 2009, including a new species of Ebola virus and new species of coronaviruses, among others.[112] [113] The highest number of these new viruses was found in areas with a high diversity of species, namely the tropical and sub-tropical areas of Asia, Africa, and to a lesser extent Latin America, all of which act as key suppliers of animals for the wildlife trade.[114] However, while the effort isolated hundreds of new viruses from "the usual suspects"—bats, primates, and rodents— they also found new viruses in 196 other species of mammals not previously known to serve as viral reservoirs, speaking to both the breadth and depth of risk.[115]

*The wildlife trade facilitates close interactions between species that might never occur in nature, and exposes native wildlife populations to new foreign pathogens, shuffling the deck of disease.*

The wildlife trade is truly global—practically no country or corner of the world is exempt from the trade or the zoonotic risks associated with it, and, currently, the volume of international trade in wildlife and wildlife products is expanding.[116] [117] [118] Sources indicate that the international legal trade in wildlife has increased in value by 500% since 2004, although part of this increase may be attributable to expansion in the trade of farmed wildlife.[119] Internet sales have propelled growth in the trade of wild species, and, in many ways, it is easier than ever to source a panoply of species from around the globe: bats from Indonesia, song birds from Brazil, porcupines from Ghana, and turtles from the US.

Increasing wildlife commercialization and tighter trade networks are contributing to an unprecedented scale and speed of zoonotic pathogen movement.[120] [121] The wildlife trade moves and intermixes wild animals through opaque and largely unmonitored global supply chains, posing significant

Ana Norman Bermudez / We Animals Media

risk of spreading zoonotic pathogens among animals and to humans. The wildlife trade facilitates close interactions between species that might never occur in nature, and exposes native wildlife populations to new foreign pathogens, shuffling the deck of disease. For the majority of these traded animals, there is no mandatory disease testing.[122] The diversity of human purposes that wildlife serve make it difficult to even describe the trade in tractable terms; many different industries from food to fashion rely on the similar supply chains.

## Wildlife Use and Supply Chains

The global wildlife trade is as old as or older than recorded history, driven by hundreds of types of uses of animals or their body parts and products. Its supply chains extend across all countries and borders, from the world's most remote places to densely concentrated urban settings, involving some of the most impoverished and wealthiest people in the world.[123]

That being said, it is primarily wildlife use and consumption habits of the wealthy that drive extractive practices elsewhere in the world, particularly the Global South where biodiversity is highest.

Jo-Anne McArthur / We Animals Media

*While only 20% of the rats sold by traders were infected, that number increased to 32% at animal markets, and by the time they arrived on customers' plates in restaurants, the percentage of rats carrying coronaviruses had more than doubled: 55% percent of those animals tested positive.*

However, the movement of wild animals takes place on a national level as well, for example, where wild meat is transported from rural communities along bus routes back to cities to feed the nostalgic tastes of urbanites who once made that same journey out of the countryside themselves. These supply and demand dynamics move animals across states, nations, and continents, transported in backpacks, boxes, on barges, or hitched onto the side of a motorbike. All the while, as these animals are carried along these trade routes, they are exposing humans or other animals to the pathogens they carry.

Viswaprem Anbarasapandian

Understanding wildlife supply chains is crucial to understanding the zoonotic risks of the wildlife trade because each of the human-animal touchpoints situated along these supply chains represents a potential opportunity for spillover.[124] [125] In addition, many aspects of the supply chain itself can shape and determine the level of zoonotic risk.[126] For example, supply chains that pull a large number of animals from a wide range of species and sources tend to present a greater danger than those that source only a small number of animals from a less diverse set of species and sources. Factors such as the number of animals involved, the number of different species included, the length of the supply chain, and the ways in which animals are sourced, shipped, stored, and processed can all contribute to zoonotic disease risk.

Wildlife supply chains vary in length and scale depending on consumers and their desires, and on the intended uses of the animals. In source countries such as Angola, Ghana and Brazil, some captured animals are transported for sale locally, while other animals are sold through major international routes

and transit hubs in cities such as Hong Kong and countries such as the UAE and Germany for use and consumption in other countries such as the United States.

As wild animals move through supply chains, risks can not only spread but grow—increasing as animals are aggregated together in greater numbers. Health declines and the strength of their immune systems wane as the stress and trials of transport take their toll.[127] Along these supply chains, with multiple species, or multiple individuals of the same species, injured and otherwise unhealthy animals are often transported together in close confinement over great distances.

In a study testing for coronavirus among wild-caught field rats in Vietnam, the presence of coronaviruses significantly increased along the supply chain from rats sold by traders, then sold in large markets, and finally served in restaurants.[128] While only 20% of the rats sold by traders were infected, that number increased to 32% at animal markets, and by the time they arrived on customers' plates in restaurants, the percentage of rats carrying coronaviruses had more than doubled: 55% percent of those animals tested positive.[129] These results demonstrate why understanding wildlife supply chains is critical to understanding the zoonotic risks posed by the wildlife trade—accounting for both human-animal and animal-animal interactions as both contribute to the overall risk of spillover. The increasing prevalence of coronaviruses along the supply chain indicates growing opportunities for inter- and intra-species viral exchange and recombination, and emphasizes how the interaction among animals in the wildlife trade can drive and determine the level of zoonotic risk.[130]

Given the range of scope and purpose, monitoring and accurately mapping trade routes and supply chains is extremely difficult, and has been compared to weapons trafficking in this respect.[131] Much trading is conducted not only illegally but also informally—amid local pop-up markets and on roadsides, for example. The clandestine, unmonitored nature of many wildlife supply chains contribute to zoonotic risks at every stage. Still, even where wildlife trade occurs in the open, through formalized legal networks, there is very little monitoring of zoonotic diseases.

Wild animals may come into contact with trappers, traders, middlemen, slaughterhouse workers, vendors, butchers, cooks, consumers, or

*Even where wildlife trade occurs in the open, through formalized legal networks, there is very little monitoring of zoonotic diseases.*

David Chancellor / Bear Hunting, USA

others while they make their way through the supply chain.[132] [133] Each touchpoint along wildlife trade supply chains provides multiple opportunities for the spread and spillover of pathogens from animals to people.[134] Some of the potential spillover points along supply chains are examined in greater detail below.

## Capture of Wildlife

Techniques for hunting and capturing animals are marked by high-intensity human-animal interactions that pave the way for the exchange of pathogens. Collectors wade into ponds to find rare amphibians, into dens to collect wolf pups, and into caves in the earth searching for salamanders or bats. They climb trees to gather parrot hatchlings from a nest or cover branches in glue and wait for the adults to return and roost.[135] Ungulates are caught in snare traps. Foxes, bobcats, and other animals step into steel leghold traps where they are held until they succumb to their injuries or until the hunter returns. Bats are killed with guns or slingshots or, sometimes, netted. In other cases, hunters will break off the tree branch that the bats hang from, jumping on top of their furry bodies as they hit the ground, wrestling with the bats as they try to escape and, sometimes, with other collectors who are trying to scavenge them.[136]

*Techniques for hunting and capturing animals are marked by high-intensity human-animal interactions that pave the way for the exchange of pathogens.*

Catching these animals presents vast opportunities for bites, scratches, and other close contact between humans and wildlife species. The process of killing and field dressing wild animals also presents significant risks of disease exposure, and many hunters may accidentally cut or injure themselves during this process, augmenting their risk of infection. Animals who are captured to be sold alive are collected in cages, baskets, boxes, or sacks. Those that survive are later sold, and profit margins tend to increase each time the animal changes hands—with the smallest earnings reserved for local hunters and collectors.[137] The amounts and kinds of animals collected are often determined opportunistically, although local or international traders may signal that there is demand for certain species that hunters then prioritize accordingly. While baby animals are prized for the live wildlife trade and easier to capture, handling young animals with weakened immune systems can carry

David Chancellor / Traditional Hunting, Xhosa People, South Africa

enhanced zoonotic risks. Collecting young animals often means killing adults; poachers seeking to capture baby mountain gorillas sometimes kill the whole family group in order to capture a single infant.[138]

There are also zoonotic risks that come from encroaching into wild habitats, for example, caves that are home to colonies of bats.[139] [140] As rare species diminish further in number, their sales price continues to rise, driving poachers deeper and deeper into wild spaces to hunt for the few animals that remain.[141] Along the way, they might happen upon other animals to catch and sell. Some of the animals they encounter may be alive, others they may happen upon might be dead, but may still be cut up and sold for parts—for their meat or bones, or valuable skin and scales. In Central Africa, outbreaks of Ebola have been ignited by hunters scavenging carcasses of gorillas, duikers, and chimpanzees that had succumbed to the disease a few days prior.[142]

David Chancellor / Trophy Hunting, South Africa

## Trade and Transport of Wildlife

Transporting live animals in overcrowded, confined, and unsanitary conditions results in increased stress and contact between animals, each of which facilitates the spread of pathogens. When combined with dehydration and poor nutrition, these conditions undermine animals' immune functions, which can lead to both increased shedding of pathogens by infected animals and increased susceptibility to infection by others.[143]

A great number of wild animals die in transit, and sometimes the ratio of deaths to surviving animals is as high as five or ten to one.[144] This so-called "hardening process," whereby weaker animals die in or prior to transit, may be an especially dangerous point in the supply chain for spillover risk and disease spread. Little is known about what becomes of these dead animals, how they are used or disposed of, or what zoonotic risks they may carry. There are minimal systems in place, where they exist at all, for monitoring the health of animals in the legal wildlife trade. And there is no surveillance of disease in the illegal trade.[145]

*Little is known about what becomes of these dead animals, how they are used or disposed of, or what zoonotic risks they may carry.*

David Chancellor / Elephant meat drying, Nyae Nyae Conservancy, Namibia

In places such as Angola and Ghana to Brazil, Vietnam, and Indonesia, often a trader or middleman will collect whatever animals are on hand or easily obtained, transporting as many different species in a single trip from a particular hunting region as might be available. To keep hunters near the borders working, and supply chains moving and feeding demand in major importing countries such as the US and China, professional traders and traffickers may incentivize poor farmers in rural areas. For example, in Vietnam, professionals provide the rural poor with a "credit" of phones and hunting gear to invest them in the trade.[146] These loans create a cycle of dependence whereby locals must continue hunting and trapping to pay off the cost of this equipment, perpetuating the trade and a system in which those who invest the most time and are at greatest risk of zoonotic disease due to direct contact with animals receive the smallest share of profits.

*Those who are at greatest risk of zoonotic disease due to direct contact with animals receive the smallest share of profits.*

**Common patterns of wildlife supply chains can be described as follows:**

- Wild-caught animals are hunted and consumed by the hunter or their family without ever being sold.
- Wild-caught animals pass directly from hunters to ultimate consumers. This includes sales to travelers or traders from small live wild markets or stalls, and accounts for a small percentage of domestic use

and consumption.

- Wild-caught wildlife is sold by hunters to wildlife farmers, who either sell wildlife locally to traders or buyers, such as restaurants, or as "founder stock" to other wildlife farming enterprises.

- Wild-caught and/or farmed wildlife is sold to a trader who transports animals to international borders and then onward to consumer nations.

- Wildlife is sold directly by professional hunters to local restaurants; animals are flown or transported via motorbike, car, or bus to restaurants.

- A hunter may sell wild-caught animals to traders, who sell them further along the chain to middlemen, who eventually sell them to wildlife meat restaurants and the consumer. When this route is used, larger numbers of animals—kept alive if possible, because it brings a higher price in restaurants and allows restaurant owners to hold the animal until that particular species is ordered by customers—are consolidated and sold up the chain.

- Hunters sell wildlife to middlemen, who sell directly to a live market or domestic restaurant and then to ultimate consumers. (This is one of the most common and important supply chains of illegal domestic wildlife supply and consumption, especially for wildlife meat.)

- Hunters sell to traders near the border, who sell wildlife further to domestic middlemen, who sell wildlife to professional international traffickers or traders/intermediaries for illegal exports.

*Zoonotic risk from the wild meat trade extends beyond those who consume the animals.*

Jo-Anne McArthur / We Animals Media

- International middlemen/professional traders or traffickers buy directly from the hunters or border traders; they then export animals to consumer nations and sell them either to wholesalers/importers or direct to sellers or consumers.

## Use and Consumption of Wildlife

Humans who use and consume wildlife do so for many reasons. Wild animals serve as food, others are used for fiber, fur, or skin, as pets, for medicine, for ornaments, decoration, or dyes, for entertainment, for research, for religious purposes, for cosmetics, and for hundreds of other uses too numerous to name.[147] [148] [149] [150] Two of the most common uses reflected across the 15 country case studies involve the trade of animals as wild meat (also known as "bushmeat" or "game" depending on the country of origin and sale) and as exotic pets. Each industry presents serious public health threats, and many of the case studies reflect the ways in which lack of regulation, underenforcement, corruption, lack of resources, and the intermingling of illegal and legal supply chains dynamically combine to exacerbate these risks.

Aaron Gekoski / Asia for Animals Coalition / We Animals Media

## Wild Meat Consumption

Wild meat describes meat sourced from non-domesticated animals, particularly those who are captured from the wild.[151] It includes meat from hundreds of species ranging from mammals to birds, reptiles, and others. Studies have found that even-toed ungulates, such as deer and antelope, are the most commonly consumed taxonomic group of mammals, followed by primates (28%), bats (15%), and rodents (15%).[152] Wild meat is consumed across the world for a host of reasons: it is eaten by indigenous communities and by impoverished people for whom it may be the primary source of protein, as is the case in certain areas of Brazil and Angola.

It is consumed as a staple across rural and urban communities in Indonesia, and by middle class individuals seeking to display their status and growing wealth in Vietnam. Wild meat from local species like wild pigs is eaten in Europe, as is meat that was illegally smuggled through airports to European markets from African countries. In the US and South Africa, wild meat is consumed as a byproduct of recreational sport hunting, which occurs on open lands or fenced-in game ranches. In many cases, wild meat consumption is deeply ingrained in the culture.[153] The trade in wild meat is vast and diverse. Estimates suggest that more than 12 billion pounds (6 million tons) of wild meat is harvested annually in Central Africa and the Amazon basin alone.[154] [155] [156] But wild meat consumption takes place around the globe, and hunters in the US also harvest and consume more than a billion pounds of wild meat each year.[157] [158]

*Estimates suggest that more than 12 billion pounds of wild meat is harvested annually in Central Africa and the Amazon basin alone.*

The capture, trade, and consumption of wildlife as wild meat has facilitated the transmission of viruses, including Ebola virus, HIV-1, anthrax, simian T-lymphotropic virus, and SARS-CoV-1 virus, and spillover associated with consumption of wild meat has been reported across all continents.[159] [160] [161] From 2000-2018, an estimated 68 spillover events driven by wild meat consumption were reported.[162]

Evan Price / We Animals Media

While more robust research is needed to describe the transmission pathways linking wild meat consumption to spillover events, it is clear that the zoonotic risk from the wild meat trade extends beyond those who consume the animals. This risk is present throughout the supply chain and spillover events can affect hunters, who kill or capture the animals; traders who transport them; butchers who prepare them; and vendors or restaurant workers selling them to customers. Zoonotic risk is present regardless of whether the meat of wild animals is consumed locally and immediately, or traded through middlemen regionally and internationally.[163] [164]

Lowest on the supply chain, local hunters capture and kill wild animals for subsistence or trade their meat for other food or essentials. In these cases in lower-income countries, it is often women or children who

are responsible for butchering and processing wildlife, which are sold in street markets freshly butchered, dried, or smoked.[165] Some research suggests that butchering and preparing wild animals for consumption may be the most dangerous point for zoonotic transmission along wild meat supply chains.[166] For example, researchers found two new forms of retroviruses in individuals who hunt or butcher monkeys or apes in Cameroon.[167] This risk is augmented by the fact that many individuals accidentally cut themselves during the process of skinning animals, removing their organs, and chopping them into cuts of meat.[168] In many cases, particularly but not exclusively in lower-income countries, the processing and consumption of wild meat includes little to no packaging, cooling, disease monitoring or surveillance, and animals are butchered and skinned informally, in homes, or in markets themselves.


Kindred Guardians Project / We Animals Media

*In some cases, laws lose their force, deflated and defeated by the complexity of practices on the ground.*

Slightly further up the supply chain, hunters and middlemen sell wild meat, which appears in local markets or stores, typically for consumers with more regular income and from slightly more urban areas. The venue for these sales range from itinerant "pop-up" markets, mobile markets (e.g., food trucks or taxis), to enormous, long-term markets where wild animals and wild meat are sold alongside other goods and livestock.[169] Urban centers in rural regions with high biodiversity represent a large and growing source of demand. It is estimated, for example, that the 62 urban centers in central Amazonia consume more than 21 million pounds (10,691 tons) of wild meat each year.[170]

Sanitary conditions at these meat markets can facilitate the spread of pathogens. In extreme cases, blood, bones, intestinal content, tissues, and skin may be scattered in piles around the marketplace, as in some informal markets in Angola, where buckets of blood are splashed over cuts of meat to keep them looking fresh, and where the animals consumed sometimes come from the highest-risk species groups for disease transmission, including primates and bats.[171] [172] In many cases, individuals preparing wild meat do not wear gloves, masks, or other personal protective equipment. They sometimes present meat on wood rather than stainless steel surfaces that are easily cleaned.

Higher still in the supply chain, wild meat appears as a menu item in urban restaurants in countries such as Indonesia, Ghana, and Vietnam. Supply chains bringing wild meat from native habitat to large urban areas involve multiple interfaces and risk of pathogen spread, especially when, as is often the case, live, dead, sick, and healthy animals are collected and transported together in confined and unsanitary conditions before being prepared and eaten. In these cases, contacts among animals, market

*Live, dead, sick, and healthy animals are collected and transported together.*

stakeholders, and consumers are direct and dispersed. In Brazil, for example, animals hunted from the Northeast, Amazon, and Central-West regions of the country are brought into population centers like Sao Paulo and Rio de Janeiro along roadways and floated down rivers, changing hands several times along the way.[173]

Some wild meat is also exported internationally. Simian foamy virus and members of cytomegalovirus and lymphocryptovirus genera have been found in wild meat from non-human primates imported illegally into the US from Guinea, Nigeria, and Liberia.[174] In West Africa, there are reports of illegal wild meat trade occurring over the border between Angola and the Democratic Republic of Congo even while the latter was experiencing an Ebola outbreak in 2022.[175] European countries also import wild meat smuggled from Africa; sometimes this meat is disguised or mislabeled.[176] Studies have estimated 10,000 lbs (5 tons) of wild meat passes through Charles de Gaulle airport in Paris each week while an additional 1,940 lbs (.97 tons) is brought in luggage through Brussels Zaventem airport in Belgium.[177] [178] While there have been few attempts to map the global trade in wild meat, recent research suggests that Central Africa and Southeast Asia may be among the highest risk regions for zoonotic

*An estimated 10,000 lbs (5 tons) of wild meat passes through Charles de Gaulle airport in Paris each week.*

David Chancellor /Elephant Meat Consumption, Nyae Nyae Conservancy, Namibia

spillover driven by the wild meat trade, with Equatorial Guinea, Guinea-Bissau, Liberia, Laos, and Vietnam described as notable "hot-spots."[179]

Where laws prohibit consumption of wildlife, a portion of activity is driven underground.[180] In response to an Ebola outbreak, for example, a 2013–2016 ban on wild meat may have contributed to covert hunting and trading of wild meat in some regions of West Africa.[181] This is particularly true where there is a lack of education around such laws or where the education that is provided runs contrary to personal experience. In such cases, individuals may reason away well-founded public health concerns: "We have eaten hundreds of bats, so it can't be dangerous. If it was, we would have gotten sick already." A survey, undertaken in the wake of Ebola, interviewing individuals in Ghana who hunt bats for consumption, found that less than a quarter perceived bats to be a source of disease risk, while all respondents reported direct contact with dead animals and blood.[182]

*Efforts to shift consumption from wild-sourced animals to captive-bred sources have varied in effectiveness.*

Efforts to shift consumption from wild-sourced animals to captive-bred sources have varied in effectiveness, but are less successful where consumers place a social premium on "wildness" or believe such animals to be healthier or increase virility more than their captive-bred counterparts. In urban centers in Vietnam, eating wild meat has evolved into a kind of gastronomic pastime, driven by increasing affluence and a perception that a person can absorb an animal's perceived strength or other qualities by consuming it.[183] Captive-bred animals, used either as a traditional medicine or as wild meat, fail to convey the desired message of status and power many consumers in that country believe come from wild animals.[184] [185] [186] There is no reliable way for consumers to verify whether the animals they are eating are wild-caught, but the expense associated with raising captive-bred wild animals makes it likely wild-caught animals are indeed on the menu. Consumption of live animals sourced

Resha Juhari / We Animals Media

David Chancellor / Bear Hunting, USA

directly from the wild communicates prestige, and intensifying concern about food safety in Vietnam leads some customers to suspect that wildlife that is already dead in a restaurant has been preserved with formaldehyde to keep it fresh (a practice wildlife hunters do sometimes engage in); for these reasons, customers prefer to select and kill the wild animal just before consumption.[187] [188] At both markets and restaurants, holding multiple species of live wildlife together carries serious public health risks.[189] [190]

The political complexities and food security issues associated with wild meat consumption have led to a reluctance on the part of many nations to regulate it. This is particularly true with respect to the shortest supply chains—meat that does not cross borders or jurisdictional lines. Where subsistence hunting and consumption of wild animals is allowed for the general public or for particular groups, this permission can manifest in an inability to enforce wildlife consumption laws writ large—acting as an exception that threatens to swallow the rule. If an individual hunts an animal and then sells it to feed their family, is this no longer "subsistence"? Authorities are ill-adept to handle these line-drawing issues. In some cases, laws lose their force, deflated and defeated by the complexity of practices on the ground.

*The political complexities and food security issues associated with wild meat consumption have led to a reluctance on the part of many nations to regulate it.*

## Use as Exotic Pets

Exotic pets are non-domesticated animals kept as pets for entertainment and companionship.[191] These animals are also used by some for breeding and selling, while others are kept primarily as status symbols or novelties.[192] They include thousands of species ranging from geckos and small mammals such as ferrets or prairie dogs, to parakeets, great apes, big cats, and falcons.[193] Animals imported to supply the exotic pet trade are often sourced from areas of high biodiversity, many of which are considered

*Animals imported to supply the exotic pet trade are often sourced from areas of high biodiversity, many of which are considered hotspots of emerging infectious diseases.*

hotspots of emerging infectious diseases.[194] The legal exotic pet trade is a multi-billion dollar industry, estimated at $15 billion annually in the US alone, and the trade is expected to continue to grow globally with increasing affluence.[195] In addition, the illegal exotic pet trade is worth billions of dollars globally and plays a key role in the sourcing of many types of animals in high-income markets.[196]

Affluent countries drive much of the demand for exotic pets, who have become common on social media as a means of signaling wealth or attracting followers. However, exotic pets are also kept in large numbers

Ana Norman Bermudez / We Animals Media

in many of the source countries where the animals are captured such as Brazil or Indonesia.[197] [198] Many source countries lack the resources and regulatory frameworks to monitor the capture and export of species not listed by the Convention on International Trade in Endangered Species ("CITES").[199] In the United States, the exotic pet industry is the largest importer of live wildlife.[200] Large commercial wholesalers, individual hobbyists, and pet stores together supply millions of animals for sale in the US alone each year. Some sell directly to consumers through digital sales, auctions, or trade shows, while others sell to pet stores or dealers. These trade networks can facilitate the spread of pathogens to a large number of people and places. For example, during an outbreak of tularemia (a serious bacterial disease) at an exotic pet distributor in Texas, the disease spilled over to humans, exposing dozens of individuals to the disease along with an unknown number of other wildlife species.[201] [202] The outbreak occurred in wild-caught prairie dogs, and the facility kept more than 3,600 of these animals.[203] During the month that the outbreak occurred, the distributor shipped more than 1,000 exposed animals across 10 different US states and exported them to five countries in Europe and two in Asia.[204]

Keeping wild animals as pets creates substantial and obvious risks for zoonotic spillover.[205] The practice provides a wide range of potential pathways for disease transmission from scratches and bites, to simply touching the animal or interacting with the animal's food, waste, or bedding. These sorts of contacts have given way to dangerous diseases such hantavirus pulmonary syndrome, hepatitis, psittacosis (parrot fever), mpox, tularemia, and salmonellosis.

*During the month that the outbreak occurred, the distributor shipped more than 1,000 exposed animals across 10 different US states and exported them to five countries in Europe and two in Asia.*

Deniz Tapkan Cengiz / We Animals Media

Jo-Anne McArthur / We Animals Media

Exotic pets, many of whom live inside the home, do not typically undergo health screenings prior to sale. Zoonotic risks are amplified by owners who are unaware of the unique medical, nutritional, behavioral, psychological, physical, and sanitary needs of these exotic animals. Poor husbandry leads to suboptimal health, stress, and diminished immune response creating conditions that foster zoonotic transmission. If animals become too large, too difficult, or too problematic, they may be sold or rehomed, changing hands again and again. Others are ultimately killed and disposed of or processed for parts.

Primates, increasingly taken from the wild and shipped from East Asia to the Middle East to be kept as pets pose a unique risk to humans due to the genetic similarity between our species and theirs.[206] Yellow fever, Ebola, dengue, simian immunodeficiency viruses, viral hepatitis, and pox viruses are all potentially dangerous if transmitted from primates to humans.[207] Past research has found that 80%–90% of macaque monkeys, one of the most popular primate species kept as pets, are infected with herpes B, a virus that can result in severe brain damage or death in humans.[208] [209] Monkeys have also been shown to transmit bacterial pathogens such as those that cause tuberculosis.

*A new variant of rabies virus spilled over in Ceará, Brazil and infected multiple individuals who were involved in the capture of marmosets for the exotic pet trade as well as one person who kept a marmoset as a pet.*

One in 30 households in the Amazon region keep primates as pets, and many owners and traders are unaware of zoonotic risks the animals pose.[210] [211] For example, a new variant of rabies virus spilled over in Ceará, Brazil and infected multiple individuals who were involved in the capture of marmosets for the exotic pet trade as well as one person who kept a marmoset as a pet.[212] Studies in Brazil have found that more than half of primates seized from the illegal wildlife trade carry Leptospirosis, a disease that, though usually mild in humans, can cause renal failure, severe pulmonary hemorrhagic syndrome, and sometimes death.[213] Other research has found that 18% of individuals living or working closely with primates in Brazil had been infected with simian foamy virus.[214] [215]

*The catalog of species and associated zoonotic diseases involved in the trade is extensive and ever-evolving.*

While the exotic pet trade is vast in scale, it operates largely online or out of sight. Many transactions happen out of public view and without adequate record-keeping.[216] The exotic pet industry is highly resistant to regulation, and benefits from this lack of visibility.[217] Exotic pets themselves are often kept indoors or out of sight—in attics, backyard sheds, or basements. As a result, there is very little data and monitoring of zoonotic risks posed by the exotic pet trade. There are other exacerbating zoonotic risks particular to the pet trade, especially as the trade grows via online networking and purchases, reaching distant and previously unlikely consumers. The catalog of species and associated zoonotic diseases involved in the trade is extensive and ever-evolving. As a result, law enforcement, doctors, and other first responders are generally unfamiliar and ill-equipped to deal with foreign or uncommon pathogens. Globally, demand for exotic pets is increasing in great part due to social media and online trade, where there are new challenges to regulation.[218]

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## Online Wildlife Trade

Online and digitally-enabled wildlife transactions are growing, offering an enormous range of species and anonymity for sellers, who are drawn to online retailers and social media platforms that allow them to operate largely outside the law.[219] These online forums have radically expanded the ability of sellers to market animals to new global audiences, connect with other sellers and traders, and collect payment for their transactions—all with little to no local, national or international regulation and enforcement. Wider audiences and trading networks allow pathogens present in trafficked wildlife to spread across countries and continents, opening up what were once local or regional markets to an international trade.

The internet has fundamentally changed the trade and sale of wildlife. Wild animals from both legal and illegal sources are available for purchase from anywhere in the world and finding either does not require more than a phone and a few minutes of searching. Traffickers arrange meetings on WhatsApp or other end-to-end encrypted platforms. Closed Facebook groups of traders organize transactions and trade events, while animals are advertised on Instagram or Snapchat, where a seller's phone number may appear overlaying a video of a baby orangutan and then disappear just as quickly.

*Wild animals from both legal and illegal sources are available for purchase from anywhere in the world and finding either does not require more than a phone and a few minutes of searching.*

Ana Norman Bermudez / We Animals Media

Yet much of the trade occurs in plain sight. Researchers have found that almost all illegal wildlife trade occurs on the so-called "surface web," through public websites indexed in search engines, rather than through the "dark web," a subset of the internet that is intentionally hidden and that requires a specific browser to access.[220] For example, a recent study in West Africa found hundreds of public Facebook pages advertising wild meat from local species, including body parts, raw meat, carcasses, and other products.[221] Although many of the 25 species identified in the study are protected by law, researchers found no instances of wild meat being advertised on the dark web, indicating that traders feel little need to hide their activities.[222]

*Technology has outpaced regulation across the globe, leaving enforcement lagging.*

This boldness is largely due to the extent to which social media companies and online retailers have disclaimed responsibility for ensuring the legality of animals or animal products sold through their platforms. The arguments made by some of these platforms—that they are unable to identify and remove wildlife listings—appear increasingly disingenuous, as new technology becomes available and as they continue to make significant progress in other areas, most notably, addressing child sexual abuse materials.[223] Content posted through videos on TikTok or YouTube is similarly loosely regulated and is largely dependent upon the awareness of the general public regarding the treatment and trade of wild animals as well as public willingness to report illegal activity.[224] Research of text and emoji responses on YouTube indicates a "predominantly positive global public perception" to the keeping of exotic wild cats and primates.[225] [226] Still, there has been some progress through voluntary corporate efforts such as the Coalition to End Wildlife Trafficking Online, which removed more than 11,000,000 listings for illegal wildlife in the first three years after its inception in 2018.[227] However, the legal online market for wildlife is much larger and seldom addressed through these interventions, though both the legal and illegal trade present zoonotic risks.

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In many industries, including the wildlife trade, technology has outpaced regulation across the globe, leaving enforcement lagging. Many of these technological advancements could be wielded by policymakers and enforcement authorities as well; however, private actors have proved far more capable users—driven by profit to find ever-more sophisticated and less-traceable ways to market and distribute animals.

Many high-risk species are included in the online trade. In October 2022, over 500 listings selling dead bats appeared on Etsy, some whole, others fashioned into decorations, Christmas ornaments, or hair clips.[228] A 2021 study documented 237 listings, selling 4,467 bats or bat parts, on eBay over a two-week period.[229]

When fewer and fewer transactions take place in open markets through traditional sales, their zoonotic risks grow harder to address, as online markets continue to siphon and circumscribe physical ones.[230] The locus of risk is moving from public spaces into online, sometimes private, areas. Regulation of online markets has proved more challenging and makes different demands of regulators—enforcement must be more savvy, with higher amounts of training and technological support. A policy playbook authored 20 years ago will do little today to stem the growing online trade, and interventions that ignore the online trade altogether will see their impact blunted.

*The growing role of technology companies—both social media companies and digital retailers—in facilitating the burgeoning online trade in animals may lead to a regulatory reshuffling.*

Jo-Anne McArthur / #unboundproject / We Animals Media

Understanding of and efficiently using social media are increasingly important skills for policymakers and enforcement officials in order to more effectively monitor and regulate the online trade of animals. Many of these platforms and technologies could be leveraged to combat the illegal trade and more effectively regulate legal sales. However, while there is some movement in this direction, policymakers have been largely content to shrug their shoulders at digital markets and suggest that they simply cannot be regulated.

The growing role of technology companies—both social media companies and digital retailers—in facilitating the burgeoning online trade in animals may also lead to a regulatory reshuffling. The importance of social media and the internet may move the locus of regulation away from particular national governments towards private technology companies or the nations in which those companies reside.

Many of the country reports of this project demonstrate the limits of what national governments can do to limit the transnational power of social media and the internet. This is perhaps even more true with respect to smaller nations or those with fewer resources. In Indonesia, regulatory attempts to address the flourishing online wildlife trade in primates have been met with mixed success, making clear the point that even where there is political will to address the threats posed by the online trade, the question remains: Who regulates the internet and how does the government of a country like Indonesia reach them? The responsibility to meaningfully address these issues may fall disproportionately to those countries such as the United States, with the weight and regulatory authority to do so.

The online trade has reshuffled wildlife commerce in other ways as well. It has generated new types of demand and new forms of animal use while reinvigorating existing platforms such as roadside zoos and other facilities that allow customers to photograph themselves touching and holding animals. Social media provides new motivation for people to seek out animals to create clickable content: paying to touch and hold animals for selfies, staging videos by attracting or capturing wild animals, or sourcing rare and dangerous animals to keep in their homes as pets in order to attract more followers to their accounts. Each of these interactions increases zoonotic risk, and many would not take place but for social media. In Dubai, private dealers allow individuals to rent exotic animals like cheetahs or macaques overnight, delivered to luxury hotel rooms for use by influencers and wealthy visitors. Some of these animals are brought in baskets and boxes from the horn of Africa, moved overseas along with other species by long boats that land on the beaches of Saudi Arabia, before being driven in vans or SUVs overland to the UAE.[231] The UAE is a destination and transit hub that is situated at the center of the international exotic pet trade, and although a 2017 law prohibits individuals from owning, trading, or transporting exotic animals, this law is generally overlooked among elite clientele, whose social media presence generates millions of followers.[232] [233] Demand for animals to create social media content drives zoonotic risks upstream in the supply chain, but much of this picture falls outside of frame. The lack of data and monitoring by both the private and public sectors only serve to amplify this risk.

*Social media provides new motivation for people to seek out animals to create clickable content.*

## Legal and Illegal Trade

The legal wildlife trade is often used to introduce and facilitate illegal activity.[234] In many places, the legal and illegal trade exist side by side and are difficult to disentangle and distinguish. Limited research does indicate a positive association between the number of legally traded animals and the size of the illegal trade.[235] [236] The boundaries that define “legal” and “illegal” trade vary by country and context.

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*In many places, the legal and illegal trade exist side by side and are difficult to disentangle and distinguish.*

The clearest lines exist where the trade in certain species is flatly prohibited, although generally these prohibitions are made on conservation grounds and only rarely for reasons related to public health. More often what distinguishes the legal and illegal trade is circumstantial: relating to, for example, how the animal was sourced—i.e., from the wild or a captive breeding operation? Other times legal status depends on whether the individual has a permit or if they followed regulations when collecting and selling the animal.[237]

Wherever legal and illegal trade overlap, reliable documentation is often scarce, even when regulation and enforcement do exist.[238] This makes it difficult to gauge and impossible to estimate the real risk of zoonotic transmission posed by the illegal trade—a problem that is confounded by a severe lack of data and the other difficulties associated with measuring illegal activity.[239] [240]

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In broad strokes, the illegal wildlife trade ranges from small-scale poaching to highly-formalized international criminal networks.[241] Like drug or arms trafficking, illegal wildlife trafficking carries high profit margins.[242] However, compared to other black market trades, the penalties for wildlife trafficking are relatively mild, though there has been a concerted effort to change this in recent years.[243]

Since 1990, 240 different pathogens have been documented in the illegal wildlife trade, including 85 viruses; the majority of these pathogens have known zoonotic potential, meaning they may spread to humans.[244] Still, this number reflects only the small percentage of cases where wildlife shipments were intercepted and tested. Like the legal wildlife trade, the illegal trade carries risks for both source and consumer countries, but also those that operate as transit hubs that connect them.[245] In many cases, there is a risk of introducing novel pathogens to new areas and new populations of humans, wildlife, or livestock. For instance, H5N1 influenza virus reached Belgium in a pair of infected crested hawk-eagles smuggled in wicker baskets and the same virus was brought to Taiwan on a flight from China carried by 38 infected birds stuffed together in a single suitcase.[246] [247] Studies examining zoonotic spillover events from the illegal wildlife trade found the highest numbers in countries including the US, Brazil, France, and China, but also countries such as the UAE, who act as both consumer nations and points of transit, funneling animals to and from Asia, and up from the hills of Africa.[248]

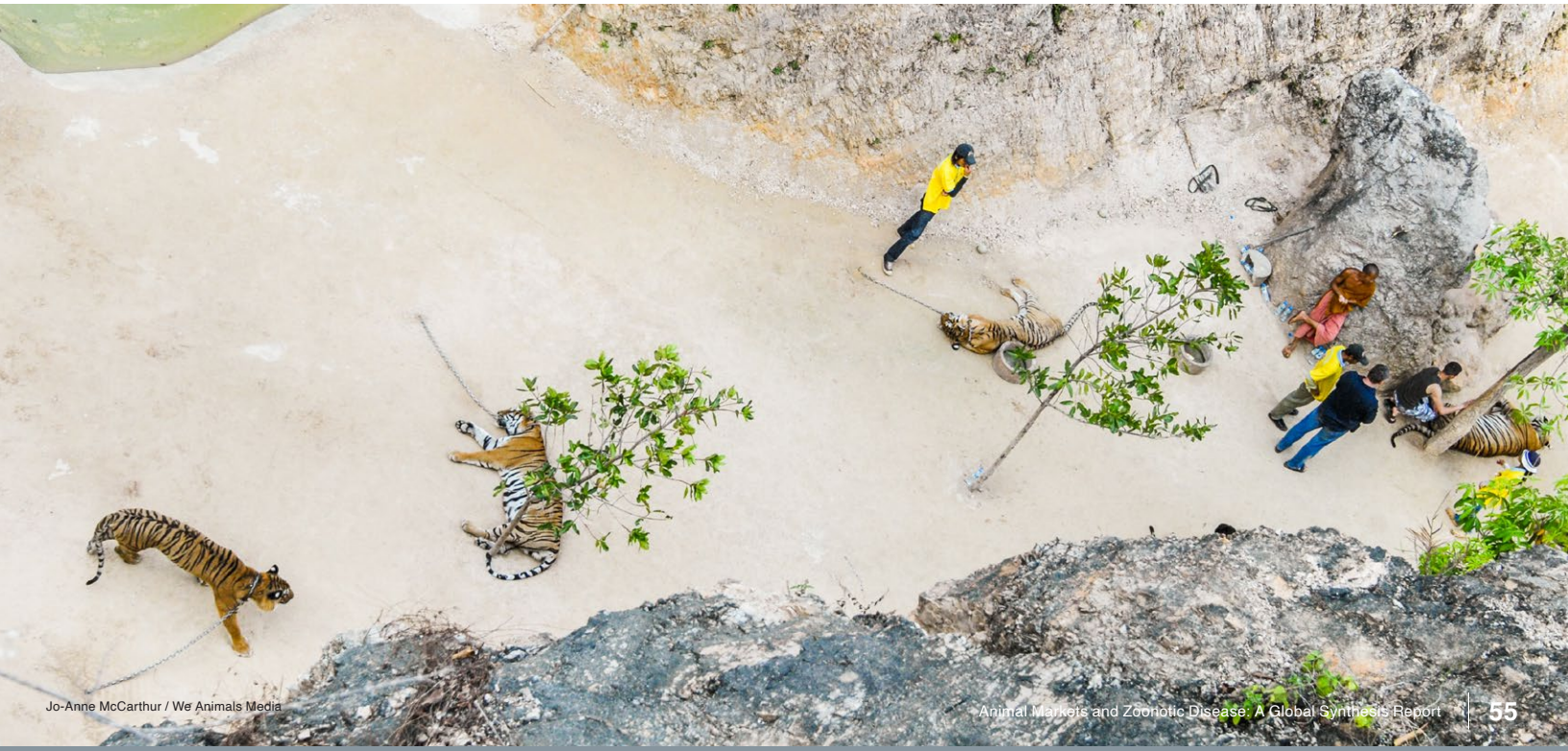
The illicit nature of the illegal trade amplifies some aspects of zoonotic risk.[249] Animals, for example, receive no veterinary care and are smuggled in poor conditions—parrots stuffed into socks or

ziplock bags and primates or big cats stored in trunks of cars or in boxes labeled “washing machine.” Still, conditions in the legal trade are often only marginally better, and the legal trade itself may be only marginally better documented. In many countries without meaningful regulation and enforcement, the legal and illegal trades may look quite similar in terms of their practices and the kinds of zoonotic risks that they pose, though it is difficult to distinguish these risks empirically.

Any suggestion that only the illegal wildlife trade carries zoonotic risk is false.[250] And, in places such as China, where such reasoning is common, scapegoating of the illegal wildlife trade may deflect attention away from the substantial risks posed by the *legal* trade—a market that is roughly 15x larger.[251] [252] Given its size, it is the legal wildlife trade that likely presents the more significant public health threat. And, unlike the illegal trade, many consumers presume the legal trade is safe—and that the animals they purchase have been screened for disease, though this is often not the case. Pathogens, including mpox and Ebola Reston, have been brought to the US and spread through legal networks.[253] [254]

Though many suggest that the illegal wildlife trade is unreachable through regulation as a black market, better regulation of the legal trade would likely be felt across the board. There is good reason to believe that the illegal trade can be reduced by more effectively regulating the legal one, which provides cover for illegal trafficking and a mechanism through which illegally caught animals can be laundered into legal markets.[255] (For more one the zoonotic risks posed by this practice, *see* discussion on wildlife farming below.) Regulation and enforcement that increase the transparency of wildlife supply chains and require disease surveillance would go a long way towards mitigating risk of spillover.

*In many countries without meaningful regulation and enforcement, the legal and illegal trades may look quite similar in terms of their practices and the kinds of zoonotic risks that they pose.*



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## Regulation of the Wildlife Trade

No international law governs the public health risks posed by the wildlife trade.[256] The only existing treaty, the Convention on International Trade in Endangered Species of Wild Fauna and Flora ("CITES"), places import or export conditions on a select group of listed species based on their conservation status.[257] [258] However, a species' conservation status—how rare or common that species is—is entirely unrelated to the level of public health risk it poses. Bats can transmit lyssaviruses, henipaviruses, ebolaviruses, and coronaviruses, and while there are over 1,400 species of bats, just 47 are regulated by CITES.[259] [260] The others can be packaged, shipped, and transported all over the world without concern for international law.[261] Overall, CITES covers only 10.5% of the world's amphibian, bird, mammal, and reptile species.[262] It does not require disease-testing by import or export countries, and this convention does little to stem the flow of foreign wild animals and their diseases, lacking both a public health directive and binding enforcement mechanism, though a recent study found that by reducing

Adam Oswell / We Animals Media

*No international law governs the public health risks posed by the wildlife trade.*

the trade of CITES-listed animals, the convention "inadvertently reduces" the volume of zoonotic pathogen movement.[263] [264] [265] [266] [267] [268]

This task of regulating public health risks posed by the wildlife trade, instead, has been the work of individual nations,

who take it on with varying degrees of aptitude and appetite. Even when trading in CITES-listed species, nations are independently responsible for surveillance and monitoring traded wildlife for disease, and most lack the regulatory framework, resources, and/or political will to do so.[269]

*Once animals arrive in-country, most often, regulators have only a vague sense of where they go.*

Novel or foreign pathogens carried by imported wildlife pose enormous threats to both livestock and human health, as well as to native wildlife populations.[270] However, compared to the global trade in livestock, the wildlife trade is poorly documented and loosely regulated. Given the under-regulation at both the national and international level, there is a meaningful lack of zoonotic disease risk monitoring and mitigation with respect to the legal trade. As a result, the great lengths that nations go to, in order to protect the biosecurity of both their people and livestock populations, risk being undermined by a lackluster disease surveillance system for wildlife. The commercial wildlife trade also presents vast vulnerability as a possible channel for bioterrorist attacks.

The US and China remain the premiere destination markets for legal and illegal wildlife imports respectively, and neither appears to have a comprehensive grasp of what animals are entering their borders, where those animals are coming from, or how they will be used.[271] [272] [273] Disease surveillance of legal wildlife imports ranges from cursory to non-existent for most species, and yet, border control is one of the few natural points where legal wildlife could be more effectively regulated, far more easily than pursuing a search of people's homes or smartphones.

For most wildlife entering the US, unlike for dogs and cats, there is no disease testing or quarantine required.[274] Officials can approve shipments for entry on paperwork alone, without ever laying eyes on the animals themselves.[275] Where animals are cheap, they become dispensable. It is not uncommon for shipments of wildlife from overseas transport to reach the US with 60% of the animals dead on arrival.[276] While these losses have become routine in certain corners of the trade and may be written off as a "cost of doing business," they carry unseen public health costs as well. The live, sick, and dead animals, held together in the same shipment container for days or weeks before arriving in the country, present substantial opportunities for disease spread among animals and to humans.

*Officials can approve shipments for entry on paperwork alone, without ever laying eyes on the animals themselves.*

Ana Norman Bermudez / We Animals Media

Even where officials do review incoming wildlife shipments, few zoonotic diseases can be diagnosed by visual inspection alone, and pathogens can be carried by seemingly-healthy animals as well. Visual import inspections can verge on security theater, cultivating a sense of safety while doing relatively little to prevent the import of foreign pathogens. In countries like the US, the sheer volume of the trade can make inspections performative rather than functional. Without a clear public health mandate, those officials charged with approving

shipments of wildlife coming into the US sometimes lack authority to detain diseased shipments, or are under heavy top-down pressure from animal industries to approve shipments despite the risks.

In the US, part of the lack of oversight can be attributed to regulatory siloing, with a mix of agencies sharing responsibility for oversight of imports, some of which may lack the expertise or capacity to evaluate disease risk and inspect and handle live wildlife. Information is lost and dropped between the cracks of shared authority, while agencies are unsure of their own enforcement abilities and the responsibilities of others.

*The supply chains that feed the wildlife trade are rarely linear but instead fan out once animals pass across borders.*

Once animals arrive in-country, most often, regulators have only a vague sense of where they go. When mpox was introduced to the US in a shipment of exotic rodents destined for the pet trade, health authorities, despite their best efforts, were able to track down less than half of the exposed animals—the others sold without record and dispersed through opaque channels.[277] The supply chains that feed the wildlife trade are rarely linear but instead fan out once animals pass across borders, such that one importer may supply a wide range of sellers and types of markets. In the case of mpox, the infected animals were brought to a wholesaler in Texas before being shipped to an Illinois distributor who supplied pet stores, swap meet, and flea market vendors, as well as direct-to-consumer sales, spreading mpox across six different states.[278] At swap meets, exotic animal auctions, and other venues selling wildlife, closed entry requirements and prohibitions against journalists or photography sometimes make these spaces difficult to monitor. The same is true of online wildlife trading communities that are closed to the general public.

The difficulties of containing dispersed outbreaks and tracing back complex, poorly-documented supply chains, weighs in favor of targeting regulatory interventions earlier in the process while animal shipments are still aggregated in great numbers. Wholesalers often keep thousands of animals in settings that range from well organized filing systems to indiscriminate barrels and tubs full of various kinds of live wildlife species.[279] Rarely are these operations limited to one species, but instead bring


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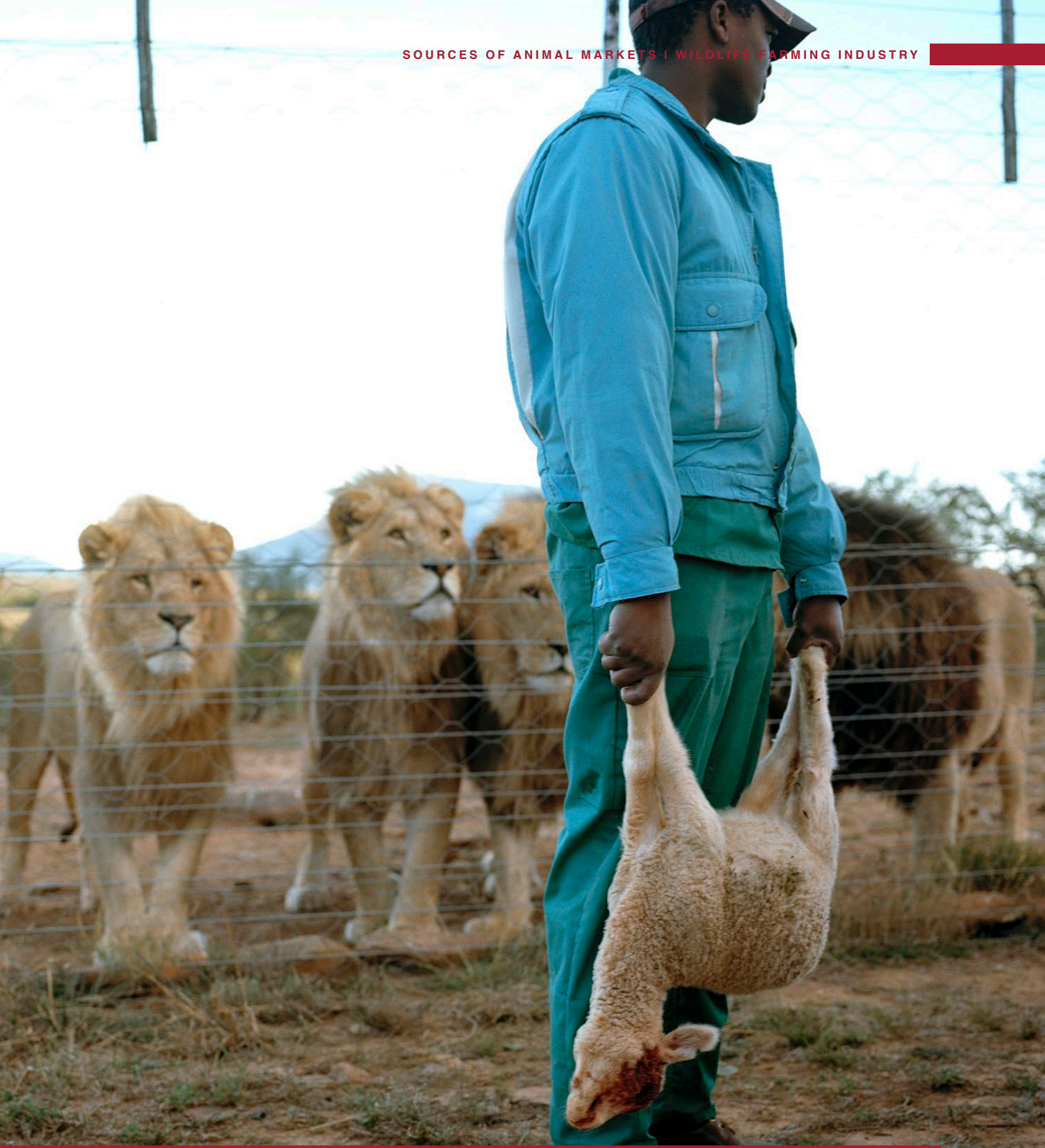
together a range of animals in close proximity allowing for cross-species disease transmission. This may be especially true with respect to "pocket pets"—small, "low-value" animals like hamsters and ferrets—as well as amphibians and reptiles. Passing through import checkpoints is often the first and last time that regulators have an easy opportunity to intervene.

However, in some places, challenging terrain and geography can make borders porous and difficult to police in areas like Northern Vietnam or the mountainous regions of Peru. Relaxed wildlife laws in neighboring countries incentivize smuggling animals across the border. States with very little regulation can act as magnets, attracting illegal wildlife traffickers from neighboring countries on all sides and serving as a safe haven for trade. For example, captive wildlife slip easily across borders from Brazil to Suriname and Guyana where they can be sold legally.[280]

Where authorities are successful in intercepting illegal shipments, it is not always clear what to do with them. Sometimes, officials attempt to return the animals to the wild; other times, they deliver them to state-run or private rehabilitation centers. This step can carry additional health risks particularly where rehabilitation facilities are overwhelmed and lack resources, such as, in the Brazilian state of São Paulo, where 30,000 animals are confiscated from the illegal wildlife trade each year.[281] Frequently, in many places, the animals seized from the wildlife trade are destroyed, though this too presents zoonotic risks. In extreme cases, wildlife officials may be reluctant to enforce the law and confiscate wild animals because of the difficulties associated with placing or disposing of them.[282] In other cases, enforcement is undermined by corruption or a lack of resources, and in many cases wildlife traders do not understand the regulations or the risks of non-compliance. Beyond the national level, there are many significant corporate actors—from Facebook/Meta to major airlines—that share responsibility for addressing and regulating the wildlife trade, even and perhaps especially when that trade is legal. This is particularly true of the burgeoning online trade, enabling an astonishing scale of global demand for wildlife that is particularly difficult to regulate.[283]

*Wildlife officials may be reluctant to enforce the law and confiscate wild animals because of the difficulties associated with placing or disposing of them.*

There is broad scientific consensus that to prevent future epidemics among humans and livestock, long-term structural changes to the wildlife trade and associated markets must be made, including measures that restrict or otherwise regulate the killing, breeding, transport, buying, selling, storage, processing, consumption, and use of wild animals.[284] [285] Indeed, the solution to zoonotic risks posed by wildlife is not a world without animals, and, in fact, studies have shown that killing large populations of wildlife to stem the spread of disease often has the opposite effect.[286] Instead, policymakers must find a way to better protect human health by better providing for theirs and to preserve the fragile ecosystems upon which both depend. The threat of pandemics is, afterall, braided together with other existential challenges—climate change and the sixth mass extinction of wildlife.



# Wildlife Farming Industry

David Chancellor / Lion Farming, South Africa

Wildlife farming, the practice of breeding and raising non-domesticated animal species in captivity for commercial purposes, poses serious, under-examined zoonotic risks.[287] The practice also carries possible connections to two of the most significant disease events of the 21st Century—SARS and COVID-19.[288] [289] [290] Historically, wild animals, valued for their meat, hides, or other parts, were obtained solely by hunting or trapping free-roaming wildlife from nature. Wildlife farming has been promoted as an alternative production method in which wildlife are bred and raised by humans in captivity, though in many places, wildlife farming and the trade of wild-caught animals exist side-by-side and overlap.[291]

Jo-Anne McArthur / We Animals Media

**WILDLIFE FARMING GENERATES AND INCREASES OPPORTUNITIES FOR ZOONOTIC TRANSMISSION BY:**

I. Aggregating Wild Animals in High Densities Not Found in Nature
   - A. This increases the spread of density-dependent pathogens.
   - B. It heightens the likelihood of a virus changing and generating new forms.
   - C. It makes species susceptible to diseases that might not otherwise affect them in the wild where they are too spread out to sustain the disease's spread (i.e., where the host density threshold is not met).

II. Aggregating Pathogens at High Concentrations
   - A. A large population of animals in close confinement can expose humans to pathogens at higher "doses," making them more likely to become infected as the frequency or intensity of exposure increases.

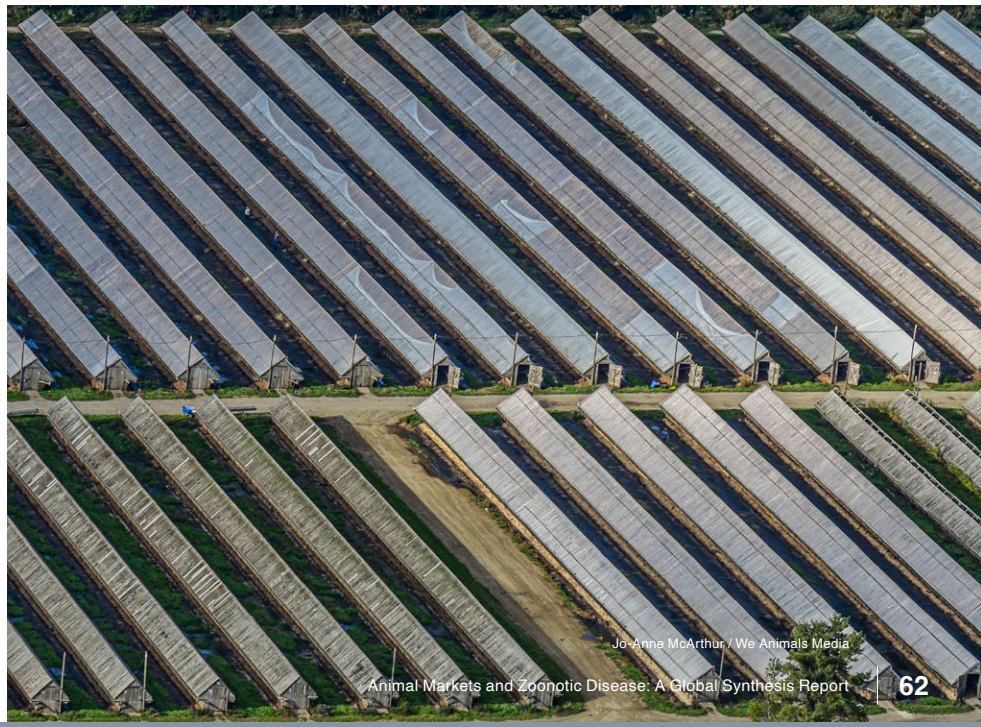
III. Increasing Opportunities for Spread by Expanding the Amount of Interspecies Contact
   - A. Contact between farmed wildlife and domestic animals increases disease transmission.
   - B. Contact between farmed wildlife and humans increases disease transmission.
   - C. Contact between different species of farmed wildlife increases disease transmission.

Wildlife farming shares common elements with traditional livestock production, including many of the same types of human-animal interactions and husbandry practices that give rise to disease transmission.[292] But moving past this initial similarity, everything starts to look different and more diverse. If livestock production operates on a spectrum from extensive to intensive, wildlife farming seems to operate on a host of different spectrums, varying in a vast number of ways that make the practice difficult to regulate or even define. For example, while traditional livestock production focuses on a small handful of species, whose pathogens humans have been exposed to for thousands of years through the process of domestication, wildlife farming encompasses more than a thousand species: a wide and growing range of new taxa, including birds, mammals, reptiles, amphibians, and others.[293] These are species about whom we know considerably less—less about how to care for them in captivity, less about their biology, and less about the diseases both known and unknown that they may carry.[294] In 2022, at least 900 million, but likely billions, of wild animals were bred in captivity on wildlife farms to supply human demand for fur, food, pets, medicine, entertainment, research subjects, as well as a host of other parts and products.[295] [296]

*These are species about whom we know considerably less—less about how to care for them in captivity, less about their biology, and less about the diseases both known and unknown that they may carry.*

The practice of wildlife farming has grown rapidly and far outpaced the development of regulation governing it.[297] Relatively little is known about the nature and degree of zoonotic risks posed by wildlife farming or about the industry itself. Data in this area is extremely scarce, and where it exists, may not be generalizable as the variance in production practices across species, regions, and operators is profound.[298] [299] Still, the basic contours of the industry suggest that it poses a serious risk of zoonotic spillover events, in particular where high-risk species are raised through intensive methods of production, combining some of the most dangerous elements of both the wildlife trade and traditional livestock production.[300] Some experts have warned that the wildlife farming industry "may constitute by far the greatest infection risk from all

*The practice of wildlife farming has grown rapidly and far outpaced the development of regulation governing it.*



Jo-Anne McArthur / We Animals Media

Jo-Anne McArthur / We Animals Media

wildlife in the region" of Southeast Asia, and the same might be true in other regions as well.[301] In *Science*, researchers warn that, "[f]armed wild animals become reservoirs for pathogen genetic diversity to accumulate" while "[t]he diversity and scale of wildlife farming make zoonosis control almost impractical. Spillovers are destined to happen."[302]

## Economic Motivations and Growth of the Wildlife Farming Industry

Wildlife are farmed to fulfill a variety of uses in both industrialized and non-industrialized nations, ranging from basic needs like food production to expensive perfumes and luxury fur pelts. The production process varies widely with end-use, as many animals are farmed for a specific part or product. Asiatic black bears are farmed for their bile, which is used in traditional medicine; addax antelope are farmed for recreational hunting; sika deer are produced for the velvet from their antlers; tigers are raised for their bones; snakes for their skin; bison and bamboo rats for their meat; cockatiels for sale as pets or to private collectors; minks for their furs; and long-tailed macaques as subjects of medical research. Some types of animals, like civet cats, are farmed for a number of different uses—as pets and for meat, fur, musk, and even specialty coffee, which is made from the partially-digested coffee berries harvested from their droppings.[303] An individual producer may supply animals for multiple different use markets. While a majority of wildlife farms slaughter and process animals onsite, some sell live animals to restaurants or animal markets for processing, while others supply live animals for the pet trade. Production processes also vary by region and by species. Some operations are large and formalized, such as white-tailed deer production in the US; others

*Policies that encourage wildlife farming, whether grounded in conservation or job creation, frequently overlook the public health risks they carry and the murkier reality on the ground where wild-caught animals are illegally hunted and passed off as farmed ones.*

are informal and exist within the home, such as a reptile breeder in Germany who breeds dozens of species in plastic tubs in a basement under heat lamps.

In East and Southeast Asia, the practice of wildlife farming was originally conceived of as a tool for rural economic development, whereby countries such as China and Vietnam encouraged citizens to capture wild animals and commercially farm them as if they were domestic livestock.[304] Today, as strong consumer demand for wildlife and wildlife products has driven many species to and past the brink of extinction, policymakers frequently present wildlife farming as a conservation strategy, a supply-side solution that would take pressure off wild populations by providing captive-raised alternatives.[305] [306] But policies that encourage wildlife farming, whether grounded in conservation or job creation, frequently overlook the public health risks they carry and the murkier reality on the ground where wild-caught animals are illegally hunted and passed off as farmed ones. In sanctioning wildlife farming, policymakers risk creating a one-way ratchet—igniting demand for wild animals and products, but also creating an industry that cannot easily be taken away once producers become economically dependent on it.[307] [308]

In 2003, when the SARS epidemic clogged emergency rooms and grounded air travel throughout Guangdong, the Chinese government ordered wildlife farms across the province to cull more than 10,000 civet cats, suspected to be the carriers of the SARS virus. The animals were drowned, clubbed,

Jo-Anne McArthur / The Ghosts In Our Machine / We Animals Media

electrocuted, and buried as provincial officials closed down highways and implemented checkpoints to prevent producers from trying to smuggle civets out of the quarantine area.[309] But as global attention on the virus waned, so too did regulation, and in the years since, the wildlife farming industry has exploded.[310]

*As global attention on the virus waned, so too did regulation, and in the years since, the wildlife farming industry has exploded.*

Adam Oswell / We Animals Media

Through the help of promotional policies, wildlife farming has quickly taken root. After being formally legalized in China in 2003, subsidies, tax deductions, and low-interest loans helped grow what might have once been conceived as a side-hobby into a full-blown industry.[311] [312] Prior to this development initiative, an estimated 100,000 people were employed in China's wildlife farming industry, but by 2016, that number had swelled to 14 million, a 140x increase in less than 20 years.[313] [314] [315] [316] Similarly, between 2014 and 2016, under a policy intended to support wildlife farming "as a tool for conservation and fighting hunger and poverty," the number of wildlife farms in Vietnam nearly tripled in twenty-four months.[317] [318] [319] This growth is poised to continue. But thousands of new operations have led to problems, including understaffing and underenforcement across the industry.[320]

In some cases, policymakers have fostered development of the wildlife farming industry in more subtle ways, such as, by changing the definition of "livestock" and "wildlife." In 2019, in order to pave

*In a new industry composed of new producers, the learning curve is steep and sometimes dangerous.*

the way for captive wildlife production and utilization, South Africa reclassified 33 species of wildlife as "farm animals," with lions, rhinos, zebras, and cheetahs among them.[321] [322]

Baked into this paradigm shift is transitional risk—risk that derives from the process of moving from one form of production (hunting) to another (farming). In a new industry composed of new producers, the learning curve is steep and sometimes dangerous.[323]

David Chancellor / Lion Farming, South Africa

In order to start wildlife farms, many operators source or capture animals from the wild for breeding stock and experiment with how to raise them in new captive environments.[324] The process inevitably contains trial and error and large numbers of animals may become sick, injured, or die as a result from producers who know very little about the animals' biology or how to raise them. In a survey of civet producers

in Vietnam, all respondents reported losing animals to disease and 12% reported losing their entire stock of animals to disease.[325] [326] With high rates of turnover, producers often restock with wild-caught animals, which allows for a constant influx of new animals, new pathogens, and new risk.[327] [328] [329] Studies have found that 90% of cane rat producers in Ghana source animals from the wild to restock captive supplies; 50% of porcupine producers in Vietnam, and 76% of green python farmers in Indonesia do the same.[330] [331] [332] Species are often treated as cash crops, susceptible to the shifts and spikes of consumer preference.[333] Producers might switch species or add new ones based on changing demand, but these changes also carry risks—a porcupine producer might know little about raising arctic foxes.[334] [335]

Kelly Guerin / We Animals Media

## Zoonotic Disease Risks of Wildlife Farming

Zoonotic risk is inherent in the process of breeding and keeping captive wildlife under human control. In China, licensed wildlife farming operations produce an estimated 254 species, 69 of which are listed by the World Organization for Animal Health (WOAH, formerly known as the OIE) as possible host species or vectors for at least one zoonotic disease.[336] [337] [338] Represented among them are animals from high-risk taxa, such as rodents and primates, who are considered more dangerous because of their propensity to share disease with humans. Others, such as mink, have demonstrated an ability to act as viral mixing vessels, combining two strains of virus (for example one from humans and one from pigs) to create a new third one.[339]

On wildlife farms, producers are responsible for handling, housing, feeding, breeding, killing, and cleaning these animals.[340] Unlike industrial meat processing facilities, which are highly mechanized and

species-specific, slaughter on wildlife farms is often performed manually, sometimes with knives, through blunt-force trauma, or other means that require close physical contact and easily lend themselves to disease transmission.[341] In some cases, animals are transported and sold alive to restaurants or through vendors at animal markets; some are shipped on motorbikes, on cargo boats, or through the US mail.[342]

Andrew Skowron / We Animals Media

*In Southern Vietnam, an estimated 70% of wildlife farming operations also raise domestic livestock on the same premises.*

Wild animals are by definition not domesticated and are fearful of humans. Captive wildlife act unpredictably and sometimes aggressively, making it more likely that producers will be bitten or scratched, or that animals will escape, potentially spreading disease to others beyond the facility. Wild animals experience high levels of stress in captivity, and this stress undermines their immune systems and makes them more susceptible to disease. It can drive animals to injure themselves trying to escape and cause behaviors such as self-mutilation or cannibalism, both of which present opportunities for infection to spread to and from open wounds. When an animal dies on a wildlife farm, the carcass may be removed by producers, left in the cage to decompose, or consumed—by the other animals in the enclosure, by free-roaming wildlife, or scavengers, including cats, dogs, and rodents.[343]

Aaron Gekoski / Asia for Animals Coalition / We Animals Media

Wildlife farms tend to have low levels of biosecurity. Larger animals are often contained by open pens and fencing, while smaller animals are kept in wire cages, tubs, or pens, and might be housed in an outbuilding or open shed. Captive wildlife are exposed to other wild animals as well as domestic ones. Producers often raise more than one species, increasing the risk of inter-species disease spread. In Southern Vietnam, an estimated 70% of wildlife farming operations also raise domestic livestock on the same premises.[344] A study of bamboo rats and porcupine farms in the region found that “dogs, cattle, pigs,

*Ninety-four percent of bat guano farming sites sampled in Vietnam and Malaysia tested positive for coronaviruses.*

chickens, ducks, pigeons, geese, common pheasants, monitor lizards, wild boar, fish, pythons, crocodiles, deer, civets, non-human primates as pets or part of private collections, free-flying wild birds, and free-ranging peri-domestic rats" were also present at one or more of the facilities included in the study.[345]

This research, which took place from 2013 to 2014, also found high rates of disease: 60% of wildlife farms included in the study yielded samples positive for coronaviruses, with an average of 6.3% of individual animals of wildlife farms testing positive for some form of coronavirus.[346] The results, which indicated the presence of both avian coronaviruses and bat coronaviruses circulating among the farmed porcupines and bamboo rats, sometimes simultaneously in the same animal, speak to the magnification of risk that occurs when multiple species and multiple strains of virus are present.[347] [348] In many of these cases, the same operations producing captive rodents were also farming bat guano for fertilizer, attracting the bats with artificial roost sites made from hanging palm leaves.[349] Ninety-four percent of bat guano farming sites sampled in Vietnam and Malaysia tested positive for coronaviruses.[350] [351]

Aaron Gekoski / Asia for Animals Coalition / We Animals Media

Risk is compounded along wildlife farming supply chains. When farmed field rats are slaughtered and processed in Vietnam, leftover parts of the animals (heads, tails, and discarded organs) are fed to domestic livestock or other captive wildlife, such as snakes, frogs, and crocodiles.[352] Unlike traditional livestock who do not require meat in their diets, many captive wild animals are carnivores, adding another layer of disease exposure both for the animals and for the humans who handle and prepare their food.

For example, producers raising falcons for sale often keep their own stocks of prey to feed to the animals, killing live pigeons and quail by hand and carving them up into small pieces with a knife.

*Feeding an infected animal to a healthy one can result in disease transmission.*

Feeding an infected animal to a healthy one can result in disease transmission. In 2009, when a shipment of houbara bustards infected with H5N1 influenza was imported by Saudi Arabia to be used as prey for captive falcons, 62.5% of the falcons who had contact with or consumed carcasses of the infected birds later died of H5N1.[353] Subsequent studies have also documented interspecies

disease transmission between falcons and their prey, including one from 2018 that identified a novel delta coronavirus in captive falcons and two more novel coronaviruses from the species used to feed them, pigeons and houbara bustards.[354]

Captive mink, foxes, and racoon dogs are frequently fed raw poultry byproducts from slaughterhouses. In China, infected birds have entered the food supply at these fur farms, igniting outbreaks of avian influenza among captive mink.[355] Mink on a Canadian fur farm contracted H3N2 swine influenza after being fed raw pork by-products from slaughterhouses and similar outbreaks have occurred

Jo-Anne McArthur / Djurrattsalliansen / We Animals Media

in the US as well.[356] [357] After mink are slaughtered and their pelts removed, their carcasses, too, are often used to feed other captive animals, and sometimes, humans.[358] Other times, they are sold for use as fertilizer.[359] Upcycling entrails and other animal products demonstrates how risk can move across supply chains especially when raising carnivorous animals that are highly-susceptible hosts.

*Upcycling entrails and other animal products demonstrates how risk can move across supply chains especially when raising carnivorous animals that are highly-susceptible hosts.*

Research suggests that the way infection moves in and out of wildlife farms where animals are densely concentrated, along supply chains, and across animal markets is not the same way infection cycles among natural, free-ranging populations of animals. The crowded, stressful environments of wildlife farms lend themselves to pathogen transmission across species, including pathogens with pandemic potential.[360] [361] For diseases that are density-dependent, more contact between animals means more spread. Wildlife farms concentrate animals at high densities not found in nature, making those animals susceptible to diseases that do not affect them in the wild.[362] In addition, wildlife farms might make it more likely that zoonotic diseases will pass on to humans by exposing them to high levels of particular pathogens, making it more likely that the disease will successfully jump the species barrier to infect humans. For example, a hunter who kills a wild deer might be briefly exposed to a small dose of a pathogen carried by the animal, but a wildlife farmer raising a herd of 300 infected deer could be exposed to the same pathogen at far greater levels and over a longer period of time.Wildlife farms create opportunities for pathogens to change and become more dangerous.[363] In the wild, mink are solitary animals, but on fur farms, they are housed together by the tens of thousands. Whereas a wild infected mink would be unlikely to transmit a virus beyond its immediate kin or have any contact with humans, in captivity, infection can spread rapidly.[364]

By aggregating animals in high numbers and close confinement on wildlife farms, humans have created ideal conditions for viruses to evolve and adapt. For example, in October 2022, an H5N1 avian influenza outbreak among mink on a Spanish fur farm may have been ignited when one of the mink caught an infected bird and pulled it into its cage. Within the close confines of the fur farm, the virus soon began spreading rapidly among the 50,000 captive mink.[365] [366] H5N1 influenza, which has historically affected avian species, seems to have changed as it moved through the captive mink, acquiring at least one new mutation, which allowed it to replicate and spread more easily in mammals.[367] Allowing viruses the chance to change and adapt as they cycle through large captive populations of animals gives these pathogens more rolls of the dice and more opportunities to

*By aggregating animals in high numbers and close confinement on wildlife farms, humans have created ideal conditions for viruses to evolve and adapt.*

Ira Moon / We Animals Media

gain the capabilities necessary to infect humans. In this way, wildlife farms can make viruses themselves more dangerous.[368]

Mink and ferrets are used as human models in viral research because their respiratory systems so closely resemble those of humans and tend to be affected by many of the same diseases in much the same way.[369] [370] [371] [372] [373] [374] But the same qualities that make mink good models for human disease research also make them acutely dangerous as possible vehicles for disease transmission to humans.[375] Inside of biosecure laboratories, mink are infected with influenza A and other dangerous pathogens in controlled experiments and sterile settings. Outside of research labs, on fur farms, mink can unintentionally become infected with some of the same dangerous pathogens, housed together by the thousands or hundreds of thousands in unhygienic environments with little biosecurity and no disease surveillance. On these farms, where animals may be afflicted with open wounds, where live animals are stored alongside or on top of dead ones, and where waste from cages above drips down through the thin wires onto the ground or other animals below, dangerous human-animal interactions take place without regulatory supervision and without basic safety measures. There are an estimated 3 million mink farmed in the US, 20 million in China, and 4.5 million in Poland.[376] [377] [378] [379] [380]

*The same qualities that make mink good models for human disease research also make them acutely dangerous as possible vehicles for disease transmission to humans.*

Jo-Anne McArthur / We Animals Media

Exposure is greatest for those who work within these facilities feeding, slaughtering, and skinning the animals. In China, 7.6 million people are employed in the fur industry, a number greater than the total population of Libya, Denmark, or Paraguay.[381] Thousands of blood samples collected during the slaughter process from mink on 34 fur farms across Northern China indicated that more than 76% had been infected with influenza viruses, and of these, roughly a third were infected with multiple strains, including both human and avian influenza viruses.[382] [383] These

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Andrew Skowron / We Animals Media

results demonstrate how common infection can be at wildlife farming facilities, but they also demonstrate how mink can simultaneously be infected with multiple types of viruses, increasing the chance of developing a new dangerous pandemic strain and passing it to humans. Unlike livestock operations, there is very little disease surveillance of wildlife farms. A handful of independent research studies, such as this one, provide only a glimpse of the disease risks and biosecurity threats posed by wildlife farming.

Biosecurity concerns on wildlife farms cut both ways. Free-roaming wildlife can spread diseases to farmed wildlife, but farmed wildlife can also spread diseases to free roaming wildlife, at which point such diseases become almost impossible to contain. For example, in 2020, when activists released 2,000 mink from fur farms across Utah and Idaho, roughly one-third of the animals were infected with SARS-CoV-2, and as escaped captive mink mixed with wild ones, they infected them with the virus as well.[384] Scientists found an unusually high prevalence of other forms of coronaviruses from animals sampled on or around Utah fur farms, with more than 70% of these creatures—from raccoons to cats to deer mice—carrying some form of coronavirus.[385] [386] Scientists from the CDC and USDA who carried out the research warned that these results indicated that "mink farms could be potential hot spots for future trans-species viral spillover and the emergence of new pandemic coronaviruses," but no change in either policy or practice has followed.[387]

*Biosecurity concerns on wildlife farms cut both ways. Free-roaming wildlife can spread diseases to farmed wildlife, but farmed wildlife can also spread diseases to free roaming wildlife, at which point such diseases become almost impossible to contain.*

In some cases, wildlife are farmed for the purpose of releasing them into the wild to be

*In the US, 40 million wild birds are raised on wildlife farms annually for release on private and public lands to fill demand from recreational hunters.*

subsequently hunted. Each fall, 48 hours before hunting season begins in Pennsylvania, 200,000 ring-necked pheasants are set free from cages by officials across the state. In the US, 40 million wild birds are raised on wildlife farms annually for release on private and public lands to fill demand from recreational hunters.[388] In some cases, the state itself acts as a buyer, a seller, and as a regulator, purchasing wild birds from breeding farms for $13 a piece while also selling permits to the hunters who will shoot and, later, eat them.

New York and other states have taken direct control of this process by raising the birds themselves in state-run farming facilities, which can house up to 50,000 animals on-site.[389] Many, if not most, of the millions of birds bred at these facilities are ultimately consumed by Americans, but they do not undergo the same health and safety checks required of conventional meat production.[390] Raising captive wild birds in close contact with humans also carries risk of influenza, a threat that increases during the later stages of production when the animals are moved from indoor barns to crowded outdoor pens, where they are susceptible to pathogens from free-roaming wild birds passing overhead.[391] Since H5N1 influenza arrived in the US in 2022, outbreaks of H5N1 avian influenza have occurred at twenty-six commercial game bird farms in the US, across 10 states from Alabama to California.[392] [393] [394] [395]

Apart from common game species, rare exotic animals are also bred in the US for sale to private captive hunting ranches. At these facilities, hunters can pay to shoot species from across the globe, brought together and housed in high-fenced menageries, which include a mix of native species and exotic ones, sharing food and water and pathogens as well. Hunters come into contact with the blood and fluids of the captive wild animals they kill. In Texas, where four million acres are devoted to exotic animal

Jo-Anne McArthur / Born Free Foundation / We Animals Media

ranches, wildlife stocked for private hunting are classified by the state as "livestock," allowing operators certain tax benefits and shielding them from regulations that might otherwise apply. At the same time, they are not subject to public health regulations that govern traditional livestock production, allowing captive hunting facilities to operate in a regulatory twilight zone as neither true wildlife nor domesticated livestock.[396] [397] [398] [399] [400]

## Farmed Wildlife and the Illegal Wildlife Trade

While the term "wildlife farming" generally refers to legal production, in some cases, wildlife farms also can be used as a vehicle for the illegal wildlife trade. Most often, this activity manifests through the illegal taking of wild animals by farm owners to restock their captive supply, but wildlife farming is also used to launder illegally-caught wild animals and pass them off as legal captive-bred ones, creating a loophole that threatens to swallow the rule.[401] [402] At times, wildlife farms serve as little more than a front to cover a thriving illegal trade.

In wildlife farming, the legal and illegal supply chains can intermix, two river channels diverging and coming back together. Limits between the legal and illegal trade are leaky, and their boundaries porous, particularly where enforcement is undermined by corruption or a lack of resources.[403] More than 75% of civet farmers in Vietnam reported giving illegal payments to the Forest Protection Department officials who are charged with enforcing the laws, so that they would overlook violations.[404] Where such problems persist, captive breeding facilities can both sap wild populations and increase demand for wildlife products by creating a legally-sanctioned market that provides cover for illegal sales.

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*It is estimated that as many as 75% of the four million songbirds registered as captive-bred with the Brazilian Ministry of the Environment are sourced illegally from the wild, relying on forgery and false declarations; nearly 70% of their identifiers, small silver bands worn around their ankles, are fakes.*

Tracing an animal's origin is a problem that plagues enforcement efforts wherever a legal market exists.[405] It is estimated that as many as 75% of the four million songbirds registered as captive-bred with the Brazilian Ministry of the Environment are sourced illegally from the wild, relying on forgery and false declarations; nearly 70% of their identifiers, small silver bands worn around their ankles, are fakes.[406] [407] [408]

Legalized sources of wildlife, namely wildlife farms, complicate enforcement efforts. Authorities have to determine not just an animal's species, but whether an animal came from a legal or illegal source. By the time wild animals or animal parts are sold to consumers, making these kinds of distinctions is even harder, as consumers are often

unaware of the legal status or origin of the animals they purchase such that enforcement efforts may be limited to the supply side of wildlife trade. In particular in areas where wildlife use is driven by extreme poverty, the legal and illegal trade may be impossible to unravel.[409]

Still, in some cases, wildlife farming operations that are illegally laundering captured animals from the wild can be identified through data alone. For example, Cambodian exports of long-tailed macaques to the US increased from 10,000 to 30,000 animals in a single year in 2019—a jump far outpacing what was possible given natural reproductive levels—and it was later confirmed that many of these facilities were selling wild-caught animals and passing them off as captive bred.[410] In extreme cases, wildlife farming operations purport to produce animals that have never been successfully bred in captivity.[411] [412] Big-head turtles are a species that cannot be effectively bred in captivity, yet studies found seventeen registered breeding facilities for these animals in Vietnam alone.[413] [414] Some estimates have suggested that as few as one third of wildlife farms in Vietnam have the capacity, facilities, and equipment needed to successfully breed the species they purport to raise.[415] Without DNA barcoding or reliable monitoring, it is impossible to know how many wild caught animals move through wildlife farms illegally.[416] However, there are strong indications that this is a widespread problem throughout the global wildlife trade—one that allows for the continued introduction of new pathogens from wild populations and makes the zoonotic risk from wildlife farming greater.

Jo-Anne McArthur / We Animals Media

## Lack of Data Regarding Wildlife Farming


Ana Norman Bermudez / We Animals Media

Both the legal and informational infrastructure around wildlife farming are lacking. Very little is known about the health status of animals in this industry. Many countries, including the US, require little to no disease sampling of farmed wildlife populations. But on a more fundamental level, many of the tests needed to do so are not validated for use on wildlife species. A report by FAO examining the wildlife farming industry in Vietnam found that, "there is a significant number of wildlife that dies at farms and there is no veterinary care or oversight provided, including a lack of diagnostics and necropsies to determine the cause of deaths," going on to note that this lack of monitoring poses concerns for food safety.[417] Although animals produced in wildlife farms carry both known and unknown zoonotic pathogens and wildlife farming is an established route for zoonotic spillover to humans, there seems to be little political appetite or funding for studying these risks.

*There is no global database or mapping system for wildlife farming operations that produce high-risk species. In many countries and in many cases, these operations are uncounted and undocumented.*

But information gaps are even more profound. There is no global database or mapping system for wildlife farming operations that produce high-risk species.[418] In many countries and in many cases, these operations are uncounted and undocumented.[419] The US does not know how many fur farms exist within its borders. It does not know where they are or how many animals they contain.[420] And when, in the fall of 2020, captive mink at these facilities began dying of SARS-CoV-2 and infected workers on a Michigan farm with a new strain of the virus, which spread beyond the farm to the broader community, there was no clear federal authority in charge of regulating them.[421] [422] [423] [424] In the event


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*Many, if not most countries, do not have any data as to the number of wildlife farms in their jurisdiction, the number or types of animals raised in those farms, or the locations of these facilities.*

of an outbreak, information gaps and unclear jurisdiction can critically undermine containment efforts. Response efforts may be severely hampered or delayed where no clear regulatory authority exists or where this authority is divided between agencies that are unsure of their responsibilities and the responsibilities of others. The US is not alone in this, research suggests that many, if not most countries, do not have any data as to the number of wildlife farms in their jurisdiction, the number or types of animals raised in those farms, or the locations of these facilities—leaving them uninformed as to their own risk.[425]

George Steinmetz / Phra Nakhon Si Ayutthaya, Thailand 2020

## Regulation of Farmed Wildlife

Different legal regimes govern wild animals and domestic ones. But wildlife farming blurs these lines, taking animals from one category and treating them as if they are part of the other.[426] This tension exposes weaknesses in the ability of regulatory systems to flex and adapt and ultimately confuses traditional frameworks in ways that make the wildlife farming industry more resistant to regulation. Such brittle regulatory frameworks stand in stark contrast to the way disease operates, moving freely from animals to humans and back again, jumping across industries and sowing risk across supply chains.

Andrew Skowron / We Animals Media

*As neither livestock nor free-roaming wildlife, they exist on the fault lines between regulatory agencies and are left underregulated, or in some cases unregulated altogether.*

In many countries, such as the US and South Africa, captive wildlife fall into a regulatory blindspot. As neither livestock nor free-roaming wildlife, they exist on the fault lines between regulatory agencies and are left underregulated, or in some cases unregulated altogether, as a result. And yet, these operations, which combine high-risk species of wildlife with intensive human interaction, present some of the most profound public health threats of any industry.[427]

Many regulatory levers used to reduce disease risk from livestock are not applied to captive wildlife. Typically, there are no pre- or post-slaughter health inspections and no quarantine requirements. The method of slaughter, too, is often left unregulated. There is little to no disease monitoring or testing at either the individual or population level. And still, many countries, including China, impose no public health-based restrictions as to which species of wildlife can be farmed.[428] [429] In all countries, extending the regulatory schemes that govern livestock to include all farm-raised animals, including wildlife, could substantially decrease zoonotic risk and facilitate important information gathering.

Disease surveillance and reporting requirements for farmed wildlife are far more limited than for domestic livestock in part because many of the tests available are not validated for use in wildlife species. Certain diseases must be reported to the World Organization for Animal Health ("WOAH") if they occur in livestock, but not if they are found in free or captive wildlife. For example, influenza in poultry must be immediately reported by member countries to the WOAH. However, influenza outbreaks in mink are not required to be disclosed, though the danger posed to humans from a mink outbreak is likely far greater.[430]

Jo-Anne McArthur / Djurrattsalliansen / We Animals Media

Disease indemnification programs that cover losses of traditional livestock species do not often extend to wildlife species, meaning that when outbreaks occur on wildlife farms, producers have little incentive to report them.[431] And unlike the livestock industry, which can often reliably count on governmental support, some wildlife farmers see their industry as facing an existential threat because the uses they serve are considered by many to be nonessential. For example, twice in the last 20 years, China has implemented bans on certain forms of wildlife farming following outbreaks, first in the wake of SARS and, later, during the COVID-19 pandemic. It is an open question whether regulators can rely on wildlife farmers to self-report disease outbreaks when doing so might erode support for the industry among policymakers or the public. These fears may make it less likely that producers will self-report outbreaks, even when losing substantial amounts of animals to infection.

Stefano Belacchi / Essere Animali / We Animals Media

Where farmed wildlife are regulated, human use often determines which rules apply. Wild animals raised for human consumption, for example, may be regulated differently than those raised for leather. Still,

Andrew Skowron / We Animals Media

*The regulatory systems that govern production are rarely updated and unable to account for this diversity and rapid proliferation.*

wildlife farming complicates these dichotomies as well when facilities supply several different uses. A producer might sell one quail for hunting, another to a live animal food market, a third to a restaurant, and a fourth animal for sale as an exotic pet. Further, the same individual quail might fulfill multiple uses—feathers for decoration or jewelry, eggs for consumption, and ultimately, meat rendered for dog food. While in some cases, wildlife supply chains are short and straight, in others, they are more complex and circuitous. For example, in the US a kangaroo bred on a wildlife farm might be sold to a zoo for display but later be removed for sale to a private dealer, who then sells the animal to a customer as a pet. This customer may later offer the kangaroo for sale at an exotic animal auction, where the animal could be purchased by a petting zoo for display at children's birthday parties, and finally sold to a captive hunting ranch where it is shot, skinned, stuffed, and mounted. Different laws would apply at different stages of the animal's life depending on the way the animal is used by humans. Zoonotic risk is present from beginning to end.

Additional oversight of on-farm conditions, transport, slaughter, and sale could help to account for some of the most critical existing gaps. Closely tailoring new regulations to a public health purpose, relying on scientific research and risk assessments, would best protect against zoonotic spillover and spread.[432] Perhaps more so than any other form of animal commerce discussed in this report, wildlife farming illustrates the need to break apart regulatory silos between administrative agencies for comprehensive disease control strategies.[433]

The vast array of wildlife uses, species, and forms of captive production has multiplied in every direction, but the regulatory systems that

govern production are rarely updated and are unable to account for this diversity and rapid proliferation. Prior to 2016, for example, China's Wildlife Protection Law had not been substantially updated in 30 years, before the wildlife farming industry was formally legalized.[434] Because wildlife farming operations take a seemingly endless variety of forms, any type of one-size-fits-all regulatory regime chafes against this diversity. Further, it may be that the window for better regulation is also closing. As the wildlife farming industry continues to grow in economic importance and in political power, producers have been more effective in lobbying to limit regulation.

Jo-Anne McArthur / We Animals Media

Government support for wildlife farming sometimes presents itself discreetly, through subtle definitional or administrative changes. For example, China recently reclassified 191 amphibious species, including frogs and turtles, as "aquatic animals," to exempt them from regulations that previously governed them as terrestrial wildlife (and prohibited their consumption), transferring regulatory authority instead to the Bureau of Fisheries.[435] [436] [437] [438] Still, these seemingly minor changes can have substantial effects. For example, consider the Chinese softshell turtle: China produced over 729 million lbs (364,000 tons) of turtle meat and products in 2021.[439] The 265,000 workers involved in this trade in Guangdong province alone now operate with less oversight.[440]

Seb Alex / We Animals Media

*Government support for wildlife farming sometimes presents itself discreetly, through subtle definitional or administrative changes.*

Creating "white lists" of species that can be legally farmed is another strategy to foster the growth of wildlife farming. In some cases, regulators have also changed the definition of wildlife to exclude captive animals from protections. When South Africa moved to expand human consumption of captive wildlife by allowing commercial processing of species such as giraffes, it did so under the guise of implementing "safety measures," regulations that on their face appear to improve oversight but, in practice, authorized the slaughter and consumption of species that was previously disallowed.[441] [442]

In the months and years following the onset of the COVID-19 pandemic, some countries, such as France and the Netherlands, moved to phase out certain types of wildlife

farming because of the risk they pose for future outbreaks. Others, such as South Africa, instead sought to expand commercial production and utilization of wildlife while public attention was focused on other aspects of the pandemic.[443] Many, including the US, took few, if any, affirmative steps in either direction. Denmark, the world's largest mink producer prior to COVID-19, offered farmers a deal: accept a larger buyout and stop farming mink, or accept a smaller one and continue farming. All but 13 of the country's 1,200 producers opted to end production permanently, yet policies to reduce wildlife farming, whether driven by animal welfare concerns or public health risks, have become a political lightning rod

David Chancellor / Game Farming, South Africa

*Backsliding in policies aimed to ban or reduce wildlife farming is not uncommon.*

across Europe and faced steep resistance from producers.[444] [445] [446]

Backsliding in policies aimed to ban or reduce wildlife farming is not uncommon. In the wake of SARS, the Chinese government banned the farming of civet cats, believed by experts to be the source of the epidemic.[447] But less than a year after the SARS virus emerged, China reversed course and lifted the ban on civet production.[448] This change came after pressure from the wildlife farming

industry, which lost an estimated one billion yuan in sales revenue as a result of the short-lived ban.[449] That same year, civets were included on a formal list of species selected for active farming, even as new studies found that between 78%-100% of civets sampled at wildlife markets tested positive for the SARS virus and that many vendors—40% of wild-animal traders and 20% of butchers—at the market also yielded positive samples.[450] [451] [452] [453] [454] In one county alone, officials provided 9.5 million yuan to support new investment in civet farming.[455] Financial and regulatory support for the industry continued through the advent of COVID-19.

*Civets were included on a formal list of species selected for active farming, even as new studies found that between 78%-100% of civets sampled at wildlife markets tested positive for the SARS virus and that many vendors at the market also yielded positive samples.*

Ana Norman Bermudez / We Animals Media

# Livestock Production Industry

George Steinmetz / New South Wales, Australia 2022

*The sheer scale of the livestock industry demands that we take zoonoses from livestock seriously.*

Zoonotic threats from livestock are serious and consistently overlooked. Animals kept for food production have been the source of more than a third of all emerging zoonotic diseases, most notably novel strains of influenza viruses, which were responsible for both the 2009 swine flu pandemic and the 1918 pandemic that claimed more than 50 million lives.[456] The disease risk that livestock pose is attributable in part to their close contact with humans. Eight of the 10 mammalian species who share the highest number of viruses with humans are domestic species, including pigs, cattle, horses, sheep, and goats.[457] An estimated 80% of pathogens carried by livestock can infect other species, such as ours.[458] [459] Their physical proximity to both humans and wildlife means that livestock also act as a bridge, playing a critical role as intermediate hosts who ferry viruses from wildlife to humans.[460] Still, many people are unaware that livestock harbor diseases that are transmissible to humans—and many countries' regulatory environments reflect this lack of awareness or lack of concern. In other cases, the economic importance of livestock production shelters the industry from common sense public health regulation.

Animal agriculture is large and growing. The sheer scale of the livestock industry demands that we take zoonoses from livestock seriously. Humans consume more than 85 billion land animals each

George Steinmetz / Northern Territory, Australia 2023

year, along with 179 million tons of seafood.[461] [462] [463] [464] Pigs alone, lined up nose to tail, would circle the earth 57 times; from Los Angeles to London, the chain would stretch 261 animals wide.[465] A disease event that spreads from livestock to humans could occur on a similarly vast scale.

George Steinmetz / Shandong, China 2016

*Climate change and changes in land-use patterns increase the risk of disease emergence, and animal agriculture is a key driver of both processes.*

Climate change and changes in land-use patterns increase the risk of disease emergence, and animal agriculture is a key driver of both processes.[466] Livestock production accounts for the majority of humanity's land-use footprint and 14.5% of global emissions, according to UN FAO data.[467] [468] Today, roughly 32%-45% of the Earth's ice-free land surface is used to house and feed livestock.[469] [470] To appreciate just how much space this is, note that buildings, roads, and all the other paved surfaces in the world cover less than 1% of its land.[471] [472] Forests are cleared to make way for pasture land for livestock or fields of soybeans to feed to farmed salmon.[473] [474] As wildlife habitat is turned into farmland, displaced wild species are forced to live and interact more closely

with humans and domestic livestock, sharing both space and pathogens.[475] In Brazil, cattle ranches occupy between 75%–80% of recently deforested areas of the Amazon rainforest.[476]

These numbers are not static—they are growing. The number of livestock has tripled in the last 50 years, as has the amount of land dedicated to growing crops to feed them.[477] This increase in livestock production is driven by a rising human population and rising demand for animal protein as a global middle income market expands. This change is perhaps most dramatic with respect to pig and poultry production in East and Southeast Asia.

*The number of livestock has tripled in the last 50 years, as has the amount of land dedicated to growing crops to feed them.*

National governments encourage the growth of livestock production—some in order to ensure and secure domestic supply of animal protein, others in hopes of reaching lucrative export markets. Livestock production is increasing in almost every country included in this report.[478] In 2022, the US commercially processed over 10 billion land animals for food, an increase of 204 million over 2021.[479] Expansion in the livestock industry is incentivized through a host of different regulatory measures, most often subsidies and other forms of financial support, education, and infrastructure.[480] However, environmental and public health externalities of this animal production are often overlooked. The livestock production industry, monolithic in its economic and cultural importance, may be reluctant to meet these challenges unless it can be compelled to do so through regulatory interventions or economic incentives. Until then, the zoonotic risks from livestock will likely increase as global production continues to rise.

Shatabdi Chakrabarti / FIAPO / We Animals Media

*As animal agriculture continues to grow, the way animals are raised in many parts of the world is also changing.*

## A Broad Range of Livestock Production Methods

As animal agriculture continues to grow, the way animals are raised in many parts of the world is also changing. Currently, livestock producers operate along a spectrum of production methods ranging from intensive to extensive—large-scale industrial operations and small-scale, local, and backyard operations, with many approaches in the middle combining elements from each system. As nations seek to expand production capacity, many are moving from dispersed, informal, and small-scale systems to large, highly-controlled systems. This movement is driven by a desire to minimize cost and maximize efficiency; in some cases, it is also motivated by concerns about food safety and food security. As with other critical resources, nations want to ensure a constant, steady supply of animals and animal products. This leads to exerting more control over each animal as well as over the entire production system.

Some countries such as the US have leaned heavily towards intensive industrial-scale production (98% of meat sold in the US is produced using intensive production systems).[481] In other places, animals are raised much the same as they were hundreds of years ago by pastoral herders or on smallholder farms. "Extensive" production methods are often smaller in scale, and involve greater use of land per animal, more contact with humans, and less biosecurity.[482] Today, livestock production operates on both ends of this spectrum, sometimes side by side.

Zoonotic risk is present in any system of livestock production. From pastoralist herders in Israel who travel with their animals and sleep beside them, to smallholder farmers in Vietnam who keep an assortment of animals wandering freely outside or around the house, to the industrialized animal production factories of the American Midwest that contain hundreds of thousands, even millions, of animals in vast indoor warehouses sealed from the outside, one feature is common: every existing form of livestock production involves human-animal interactions that create opportunities for disease emergence and spillover.

Sudip Maiti / FIAPO / WAe Animals Media

*Modes of production that decrease some forms of risk can amplify others.*

Each system presents significant, if differing, zoonotic risks.[483] Modes of production that decrease some forms of risk can amplify others.[484] For example, the sheer scale of intensive, industrialized operations focused on biosecurity and efficiency can amplify the scale at which an outbreak occurs if a pathogen emerges.[485] A smaller "backyard" operation that reduces the likelihood of a pathogen occurring at scale often has little biosecurity or regulatory oversight.[486] Meanwhile, the accelerating expansion of both kinds of systems is outpacing regulation.[487]

In some cases, the proximity and interplay between large intensive production facilities and smaller extensive ones can amplify risk. As diseases such as H5N1 influenza circulate and move through smallholder farms and backyard poultry operations, those flocks can serve as potential springboards and entry points for the disease to reach large-scale production facilities.[488] At the same time, large-scale industrial facilities can magnify an outbreak, generating new strains of a virus (for example, turning a low pathogenic strain into a highly pathogenic one), and infect nearby small producers. Each method of production can make the other more dangerous, as can movement from one form of production to another. Layered on top of these threats are overlapping risks that arise from wildlife trade, wildlife farming, and other forms of animal use that coincide and interact with animal agriculture.


Zuzana Mit / We Animals Media

## Zoonotic Risks from Extensive Production Methods

A smallholder farm is one type of an extensive practice that is lower-yielding, has poorer biosecurity, and involves more workers and human interfaces along the supply chain. It also requires larger amounts of space per animal and thus more land under development. Livestock such as chickens on a smallholder farm in Vietnam, for example, may be held with other types of birds—ducks, quails, and pheasants— as well as pigs or cows. This mixed species herd may move freely around the property, drinking and swimming in pools or rice paddies that they share with both wild animals and humans. These types of operations are marked by close interactions between livestock, wildlife, and humans, with thinner and hazier spatial demarcations between them.

George Steinmetz / Bor, South Sudan 2009

For extensive operations, husbandry is hands-on. In India, many producers live and eat near their animals, and sometimes, sleep next to them to protect them from theft or predators. Such proximity to humans increases risk, as pathogens from animals seep into their bedding, water buckets, food troughs, or infect their owners through airborne particles. Human exposure to livestock pathogens is more frequent and widespread.

*For extensive operations, husbandry is hands-on.*

But there are benefits that lower zoonotic disease risk. Animals raised on smallholder farms have lower stocking densities than those raised on industrial facilities. They generally have more space and better airflow, and lower levels of stress, all of which can reduce the likelihood of infection. When disease occurs in smallholder farms, outbreaks are often limited in scale, though they can spread rapidly in regions where such production is common.[489] When avian influenza began spreading through Vietnam, the virus reached 57 of the 64 provinces in just six weeks. Health officials faced difficult logistical questions: how does one contain a contagious virus in birds in a region where an estimated 200 million farmers each have on average 15 birds of all different species—ducks, quails, chickens, geese, and turkeys? [490] Exercising control measures is extremely difficult, especially without strong centralized authority, and with long distances between small farms and resources such as vet techs or diagnostic laboratories. Variation, lack of physical access, and social barriers to compliance all make coordinated disease response more challenging.

Haig / Act for Farmed Animals / We Animals Media


Deniz Tapkan Cengiz / We Animals Media

Smallholder production tends to take place on the peripheries of regulation in outskirts of cities, in rural areas, and in places that are geographically harder to reach. Sometimes producers are transient, making them more difficult to regulate. Bedouin herders in the Negev Desert have some of the highest brucellosis infection rates in Israel, and their animals, among the lowest vaccination rates.[491] Campaigns to reach these herds have been unsuccessful in part because of the lack of trust felt between smallholder producers and regulators. Smallholder farming may be less responsive to regulation in general, particularly where production is undertaken for subsistence consumption or out of economic necessity.

Sometimes lack of compliance comes from lack of trust, willingness, or resources–including health literacy and disease awareness, and the tools to promote them. But other times, it derives from a simple failure to communicate existing laws to producers. For example, research found that in Vietnam, most small scale slaughterhouses do not meet regulatory standards; however, most slaughterhouse operators were not aware that regulatory standards existed.[492] Lack of compliance (both intentional and unintentional) suggests that education and communication surrounding public health regulations can be as important as the regulation itself.[493]

The ubiquity of smallholder farming can also insulate the practice from government intervention. For example, in Vietnam, 90% of households raise backyard flocks or other food animals.[494] The political and practical realities of trying to enforce health controls across such a wide swath of the populace strongly discourage regulatory efforts. But extensive and smallholder operations are not exclusively found in emerging market economies. Sometimes, they exist side-by-side with more intensive forms of production. In the US, backyard poultry production is allowed in almost all major cities. Operators rarely use gloves or other protective equipment when handling birds; only about 3% of those raising backyard poultry provide any form of veterinary care.[495]


Havva Zorlu / We Animals Media

Small-scale producers are

rarely closely monitored or even inventoried by regulators. In cases where one-size-fits-all regulation is applied to both industrial size operations and smallholder farms, it generally is designed for the former and chaffes against the latter. Where inspection or licensing is required, many small producers simply do not comply. In Israel, 91% of chicken producers are unlicensed.[496] [497]

*Individuals raising animals for personal or local consumption are often completely exempt—functionally or factually—from sanitary regulations around slaughter.*

Further, individuals raising animals for personal or local consumption are often completely exempt—functionally or factually—from sanitary regulations around slaughter. In the US, for example, poultry slaughter for personal consumption as well as small-scale operations producing less than 20,000 birds per year are exempt from federal health inspection.[498] Yet, these de minimis regulations neglect the fact that wherever spillover happens, whether on a backyard farm where an individual slaughters one chicken or on an industrial facility processing 175 birds-per-minute, disease can radiate out, spreading human-to-human from one person to millions more.[499] Either scenario could ignite a pandemic. Regulatory exemptions given to small producers on the basis that they have little effect on the public food supply may make sense with respect to certain forms of bacterial foodborne illness, but they do not make sense with respect to viral zoonotic spillover, which is perhaps most likely to occur at the point of slaughter.[500]

In many instances and in multiple countries, slaughter happens on an as-needed basis with few sanitary precautions—one or a few animals at a time. Processing takes place at small stores, or markets,

Milos Bicanski / We Animals Media

or in and around the home in spaces that are difficult to regulate practically and politically. Slaughter of pigs is performed manually in home kitchens in Vietnam, with animals sourced from multiple backyard farms where they have been raised among other species, including poultry. In Kenya and Israel, slaughter often takes place on roadsides or on open-air, concrete slabs.

Rafael Bastante / We Animals Media

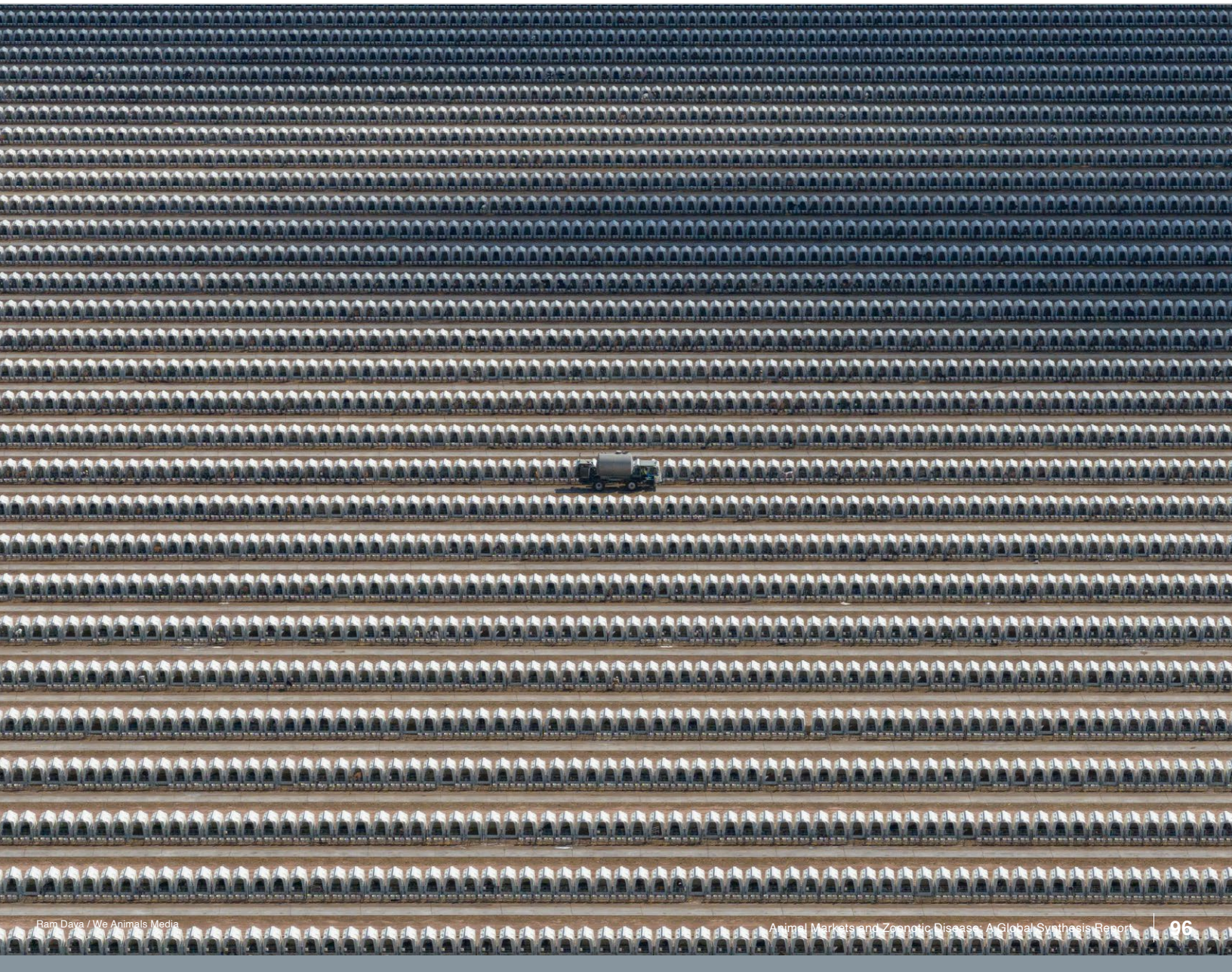
Unregulated slaughter is a significant public health problem, one that in many cases is driven by structural issues, including lack of access to regulated slaughter facilities. It is estimated that of the 1,000,000 or more sheep and goats raised by small producers in Israel, only a quarter are slaughtered in regulated slaughterhouses. The other 75% are killed, die, or are smuggled across the border to Palestine with no health or safety checks and no regulatory oversight. In Israel, just 3%-5% of sheep and goat meat is sold through supermarkets.[501] The rest is sold through butchers, restaurants, and markets where consumers are given little information about where the meat comes from and what public health measures, if any, were employed during production.

*In places like Vietnam where health regulations do not apply or are not enforced with respect to small producers, although a majority of livestock are produced through these methods, vast portions of the food system are largely exempt from regulation.*

Regulation in general has very little to say about small-scale farming. However, the idea that such operations are too small to present any real public health threat neglects the fact that viruses spread person-to-person far beyond the point of spillover. And in places like Vietnam where health regulations do not apply or are not enforced with respect to small producers, although a majority of livestock are produced through these methods, vast portions of the food system are largely exempt from regulation.[502]

## Zoonotic Risks from Intensive Production Methods

Smallholder farming maintains a special status and even reverence across cultures, but in many places, these practices are changing rapidly and giving way to larger, more intensive regimented systems of livestock production to accommodate growing demand.[503] Any effort to supplant smallholder production is politically fraught—perhaps even more so when done under the banner of zoonotic risk reduction. Many view these policy moves with suspicion, voicing an inherent mistrust of big business, globalization, and regulators alike. In such cases, public health can be undermined by political divisions.[504] When avian influenza spread through Indonesia, rumors circulated that control measures, and perhaps the virus itself, were a ploy to drive small producers out of the business. Questions about who stood to profit from the outbreak undermined the effectiveness of policy responses by sowing bitter discord between small producers and policymakers.[505]



Ram Daya / We Animals Media

In some cases, this movement from extensive to intensive production has been pushed forward through policy and financed by public funds or international development organizations including the World Bank.[506] In other cases, it is simply a reflection of the consolidation of corporate power. In the US, where chickens, cows, and pigs are the dominant forms of livestock, small independent farms have all but given way to large, consolidated production facilities. Ninety-eight percent of livestock in the US live in large-scale facilities known as CAFOs (concentrated animal feeding operations), colloquially called "factory farms." [507] [508] However, this transition from extensive to intensive systems of production, which is happening rapidly in places such as China and Vietnam, may carry additional zoonotic risks.[509]

Concentrated livestock production systems are easier to monitor and regulate than dispersed small-holder farms or home production. And the confined nature of these operations make it more likely that diseased animals can be culled before spreading infection to other farming operations. Intensive operations strive to deliver meat that is both uniform and inexpensive. Industrial producers aim to maximize efficiency in every aspect of production. Intensification of livestock increases the number of animals that are held together. But as the size and stocking density of animal production facilities increase, so too does the

*As the size and stocking density of animal production facilities increase, so too does the magnitude of a potential outbreak.*

Glass Walls / We Animals Media

magnitude of a potential outbreak.[510] [511] An outbreak at an intensive production facility may infect 10,000x more animals than an outbreak at a smallholder farm, producing 10,000x pathogens, and, in the case of food-borne pathogens, reach many more people.

In proportion to the number of animals involved, zoonotic risks from industrial production arise–and can spread–at scale. This is true whether a disease emerges in the vast indoor warehouses where animals are held together until they reach market weights or at slaughter facilities that use conveyor-belt like systems to process nearly 200 animals per minute or on the wide cargo ships that ferry livestock and livestock products to consumers across the globe.[512] [513] [514]

*The animals themselves are not the only source of disease risk.*

The animals themselves are not the only source of disease risk. In North Carolina, the state's 9 million swine produce 62 million lbs of manure each day and 10 billion gallons of manure each year.[515] [516]A single swine facility can produce more sewage than all but a small handful of the largest cities in the US.[517] Disposing of this amount of waste has generated inelegant solutions: feces and urine from hog facilities are held in large open-pit lagoons and later sprayed, untreated, onto fields.[518] [519] Disposing of the animal waste and dead animals generated by these facilities presents significant logistical challenges and zoonotic risk. For example, in the US during the early months of the COVID-19 pandemic, when meat packing facilities were closed or operating at reduced capacity, livestock producers struggled to safely dispose of the millions of carcasses of animals that were culled due to these supply-chain issues.[520] [521] [522]

*The enormity of these operations and density of animals within them make production facilities extremely conducive to disease transmission.*

The enormity of these operations and density of animals within them make production facilities extremely conducive to disease transmission among animals, as does the lack of airflow. At a small-scale farm, using less intensive forms of production, disease may impact some animals but not all of them, while in a CAFO, pathogens may infect virtually every animal (especially where animals have been bred to have uniform genetics). The inevitability of disease spread within industrial facilities mean that

Jo-Anne McArthur / We Animals Media

when a highly contagious pathogen such as H5N1 influenza is detected, producers preemptively kill every animal in the facility to contain the spread—indicating just how difficult it is to isolate and control outbreaks within these immense and overcrowded operations. Concentrating animals in numbers and in closed environments seldom seen in nature can also give pathogens opportunities to rapidly evolve and generate new forms.[523] This may be particularly true on industrial farms where disease can cycle through animals who are nearly genetically identical, infecting populations who lack the kind of genetic diversity that can be protective in the event of an outbreak. Once inside a facility, pathogens can spread with a kind of supernatural efficiency not seen in nature. If you were to design a system to spread and circulate a disease within a single, closed-door population, it may look very similar to an industrial farm, marked by vast numbers of animals held in close confinement with little genetic diversity, limited air flow, high levels of stress, and poor levels of hygiene.

*Concentrating animals in numbers and in closed environments seldom seen in nature can also give pathogens opportunities to rapidly evolve and generate new forms.*

Rebecca Cappelli Loviconi / We Animals Media

Havva Zorlu / We Animals Media

### *Influenzas: The Viruses with the Greatest Pandemic Potential*

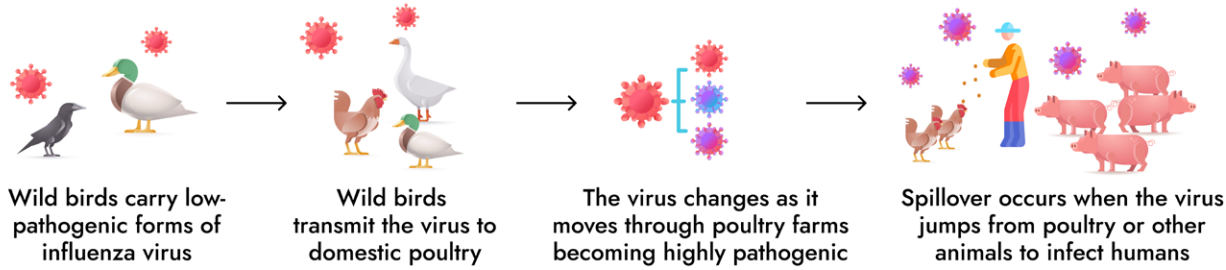
*Influenzas, above all other forms of viruses, present the greatest threat of large-scale destruction of human life.[524] [525] Experts predict that a pandemic strain influenza virus could infect roughly 30% of the people on earth in a matter of months.[526] If mortality rates are similar to past pandemic strains, roughly 200 million people could die during this first wave—more than 25x COVID-19's recorded death toll to date.[527] [528] A spreadable strain with higher mortality rates could lead to deaths on a scale, not yet seen.[529] [530] Too often, these nightmare scenarios are only a few mutations away—closer than many policymakers or the public realize.[531]*

*Influenza viruses are infamous for their ability to change rapidly and spread person-to-person. However, what makes influenzas so dangerous is not simply a reflection of the viruses' behavior, but also our own. Livestock production is the primary driver of influenza risk to humans and is believed to have ignited the 2009 "swine flu' epidemic and the 1918 influenza pandemic which took 50 million lives.[532]*

*Two of the primary carriers of influenza are pigs and poultry, which are produced across the globe by the billions annually. Their production is expected to double in the next decade in low and middle-income countries.[533] While wild aquatic birds such as ducks and geese serve as the natural reservoirs of influenza, the strains they carry are not easily spread to humans. But, when they infect domestic poultry, that can rapidly change as the virus takes on new and sometimes increasingly-dangerous forms.*

*Large-scale production facilities where chickens are held together in high densities provide the influenza viruses an opportunity to evolve rapidly as they move through a captive, closed-door, and closely-confined population of animals. In the process, the virus can be transformed from the low-pathogenic version carried by wild birds to a highly-pathogenic form that can cause mass mortality in poultry and, potentially, in people. Pigs amplify this risk and serve as ideal mixing vessels, who can combine existing strains of influenzas from birds or other animals, and transmit them to humans.[534] This route of disease emergence is well-established—it presents one of the greatest known risks to human health worldwide. Because both pork and poultry are staples on plates across much of the globe, the potential for emergence of novel pandemic strains of influenza is ever-present and particularly acute in areas where these systems of production overlap.[535]*

### *Transmission of Influenza Viruses*



Animals in these intensive operations tend to have low standards of welfare and high levels of stress, which reduces an animal's ability to fight infection.[536] Due to stress caused by their environment, they may engage in behaviors such as self-mutilation or cannibalism, which increase the risk of transmission by creating open wounds that are susceptible to infection and dispersing blood and other bodily fluids.[537] With thousands of animals on site, these types of injuries, as well as disease itself, can frequently go unnoticed.

Animals are quickly cycled through production facilities and are sometimes fed hormones or antibiotics to promote rapid growth and prevent or treat illness despite living in poor conditions. The vast majority of medically significant antibiotics are fed to livestock—upwards of 80% in some countries and 70% worldwide.[538] Overuse of antibiotics drives the creation of new antibiotic-resistant strains of bacteria. In this way, livestock production can both expose humans to disease and handicap our ability to treat some of those same pathogens.

*The vast majority of medically significant antibiotics are fed to livestock—upwards of 80% in some countries and 70% worldwide.*


George Steinmetz / Berbera, Somaliland 2023

The risk of spillover is greatest to those who work within these operations. Each day they share the ammonia-rich air with thousands of animals, removing dead ones and other waste.[539] These are not the kind of casual interspecies contacts that happen by chance in nature, but more intensive and dangerous forms of human-animal interactions that may expose humans to higher levels of pathogens. Studies have found that farm workers have higher rates of H1N1 influenza infection from pigs, avian influenza, hepatitis E, and a host of other zoonotic pathogens compared to the general public.[540] [541] Yet, once a disease spills over, it can spread far beyond a handful of livestock workers. Studies suggest that the communities surrounding industrial animal production facilities may themselves act as a springboard for zoonotic outbreaks.[542] [543]

*Once a disease spills over, it can spread far beyond a handful of livestock workers.*

## AT A LOCAL LEVEL, LIVESTOCK PRODUCTION INCREASES SPILLOVER RISK BY:

I. Increasing contact between humans and livestock
   - A. (e.g., cattle and the humans who raise, transport, slaughter, and consume them)

II. Increasing contact between livestock and wildlife
   - A. (e.g., cattle living on razed pasture land abutting diminished habitat for native fauna)

III. Increasing contact between humans and wildlife
   - A. (e.g., cattle ranchers, who live more closely with native fauna, including, for example, bats, wild birds, or other animals, who have been displaced when their habitat was converted to agricultural land)

## ON A GLOBAL LEVEL, LIVESTOCK PRODUCTION INCREASES SPILLOVER RISK BY:

IV. Destroying wildlife habitat
   - A. As a larger share of the Earth's land is dedicated to livestock production and the production of crops to feed livestock, less of it is available for native wild animals.

V. Decreasing biodiversity
   - A. The number and types of native species of wildlife and plants is reduced as livestock production eliminates habitat and undermines ecosystem health through pollution, production of monocultures, etc.

VI. Accelerating climate change through direct emissions and deforestation
   - A. Conditions emerging from climate change increase spillover risk by driving species to move and interact with new species (including humans), exposing themselves to new diseases in the process. Climate change also leads to resource scarcity, which can drive human-animal conflict.

## Livestock Distribution and Disease Risk

Both extensive and intensive systems of food animal production have profound environmental impacts, driving greenhouse gas emissions and reshaping ecosystems. Livestock production drives zoonotic risk in direct and indirect ways as it affects both local and global environmental systems. Many of these effects are characterized by more frequent interactions among humans, livestock, and wildlife, and increasing overlap across these three spheres.

Haig / We Animals Media

Risk from livestock production is determined not simply by the number of animals and how they are raised, but also where they are raised. While zoonotic risk is baked into any form of existing livestock production, factors such as geographic location can amplify or reduce the likelihood of an outbreak.

Livestock farming in and around human settlements raises the risk of spillover.[544] The more closely and frequently humans and livestock interact, the greater the risk of disease transmission between them. In many places, this risk is expanding. For example, as Ghana strives to increase animal protein production, livestock are brought into urban and peri-urban areas where they were not found before.[545] Residents have more regular contact with the animals—sharing space, resources (both food and water), and pathogens, as well. The same is true in Kenya. Bacteria from animal waste seeps into the soil to contaminate drinking water in peri-urban communities around Kisumu, where goats, sheep, and chickens wander through informal housing settlements.[546]

*Risk from livestock production is determined not simply by the number of animals and how they are raised, but also where they are raised.*

George Steinmetz / Bor, South Sudan 2009

Home production of livestock, whether animals are kept as food or as pets, increases the risk of spillover.[547] In the US, more than 90% of major cities allow for backyard poultry production, but few regulate how birds are slaughtered; just 10% impose regulations governing disposal of dead birds.[548] [549] Chickens and other birds move around the coop or through the yard where they interact with other domestic animals, wild birds, as well as children who touch and play with them.[550] Close, persistent contact between humans and livestock lends more chances for disease to spread between the two. By contrast, distancing livestock production centers from human settlements would decrease the risk of spillover, and perhaps also reduce the likelihood spillover events will mature into pandemics if they occur in more geographically isolated areas and populations.[551]

*Close, persistent contact between humans and livestock lends more chances for disease to spread between the two.*

Similarly, livestock farming in areas of rich biodiversity, such as tropical rainforests, where higher

numbers of wildlife and wildlife species are present, is more dangerous than farming in areas with lower concentrations of wildlife. Pathogens can move from wild animals to domestic animals and vice versa. This is especially true in areas of tropical and subtropical forests where the land use changes required to turn forested areas into pasture land destroy wildlife habitat—fragmenting forestscapes, accelerating climate change, and undermining ecosystem health.[552] These changes in land use displace wildlife, forcing them into closer contact with domestic animals and humans.[553]

Fenceline contact between wildlife and livestock allows the sharing of pathogens from one to the other and presents serious biosecurity concerns. Though domestic animals may be fenced in, wild ones are not easily fenced out. Deer casually hop over cattle fencing, while wild hogs burrow under it, spreading African swine fever to domestic pigs.[554] Feral and free-roaming cats and dogs slip easily between barns and livestock pens, ferrying pathogens from the outside in, as rodents and other small mammals move along the ground collecting feed and leftover grain. Some wild animals are even harder to keep out. Insects, too, can ferry disease between species of livestock and wildlife. A tick or mosquito, after feeding on one animal, carries their pathogens and mixes them with the blood of another animal or human. Birds and bats move freely through the airspace above agricultural animals, dropping pathogens down in their saliva, feces, and urine. These patterns have given rise to deadly outbreaks like Hendra virus in Australia and Nipah virus in Malaysia.[555]

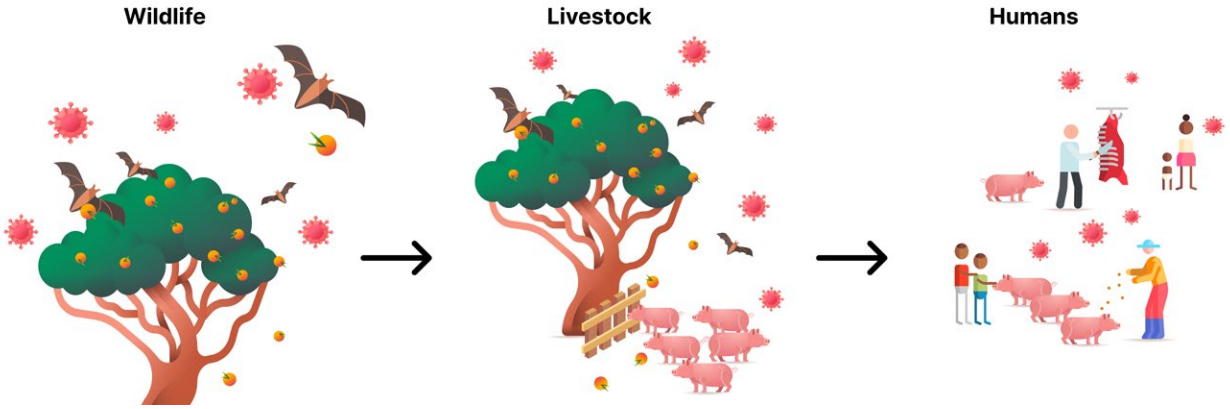
*Though domestic animals may be fenced in, wild ones are not easily fenced out.*

Jo-Anne McArthur / Sibanye Trust / We Animals Media

### *Nipah Virus: How Livestock Transmit Diseases from Wildlife to Humans*

*The origins of Nipah virus demonstrate how livestock can act as a bridge—taking pathogens circulating in wildlife and delivering them to humans.[556] In the rural region at the center of Malaysia's pig industry, animals started coughing, panting, and trembling. Pigs soon began dying, so quickly and in such large numbers that towns were scattered with piles of dead piglets. People soon began dying too. Many of those infected fell into a coma and were dead within the week.[557] Down the coast in Singapore, pig exporters and slaughterhouse workers also became infected as the outbreak spread.*

*The Malaysian army was called into the village of Sungai Nipah to carry out mass cullings of pigs in the region.[558] [559] At the same time, scientists in hazmat suits searched the region to find out how the novel virus, with no known cure, had spread to pigs.[560] Their answer came from a half-eaten piece of fruit found on the floor of a pig pen.[561] Scientists believed that these fruits from nearby mango and javan apple trees had been inoculated with Nipah virus by fruit bats, who fed on these fruits and are believed to be the natural reservoirs of the virus. Pigs became infected by feeding on the remains of the fruit bats' meals which had fallen from tree branches overhanging the pig pen.[562] More than 100 people died from this chance encounter between pigs and fruit bats.[563] The Nipah pigs demonstrate how domestic animals can act as a conduit for viruses bringing them from wildlife to humans and how interactions between animal species can lead to new outbreaks of human disease.*




Much of the risk of spillover could be mitigated through reorganization and reallocation of global livestock production. Placing livestock production away from human settlements in areas of low biodiversity, where there is little known crossover with the endemic diseases of native wildlife could mitigate much of the risk, as could protecting existing forestland from the march of agricultural expansion. But current trend lines point in the opposite direction: many of the countries expanding livestock production the fastest are those where the environmental impact of expansion will be greatest. Production may move away from tightly-regulated areas and towards locations where it can be done cheaply with less regulation, particularly as demand for meat rises in those areas and across the world.[564] These problems may become particularly acute in the Global South where incomes are lowest and biodiversity is highest.[565] There is an urgent need to consider environmental impacts of livestock production and the implications of those effects on zoonotic disease emergence.

*Much of the risk of spillover could be mitigated through reorganization and reallocation of global livestock production.*

## Regulation and Promotion of Livestock Industry

Meat has a coveted cultural status in most parts of the world, and efforts to increase meat production are generally supported by policymakers. Consumption of meat has long been tied to social position, and in developing economies, meat consumption signifies arrival to the middle class.[566] Poorer communities across the globe subsist on beans, grains, and potatoes while meat is often more expensive. The exponential growth of demand for meat in Southeast Asia, for example, has coincided with a substantial increase in wealth. The price of meat, in many cases, is used as a yardstick to measure purchasing power. In many countries, particularly in the US, there is a strong expectation that meat will be affordable and widely available. As a result, today, the US meat industry is heavily and increasingly subsidized, allowing Americans to consume larger quantities.[567] [568]

*Corporate meat giants such as Tyson and J.B.S. wield enormous financial and political power, increasing the likelihood of regulatory capture.*

Jo-Anne McArthur / We Animals Media

Movement towards intensive systems of production is often accompanied by consolidation in the livestock industry, as a few companies control larger and larger market shares. In the US, the four largest producers control 82% of the US beef market, 66% of the US pork market, and 54% of the US chicken market.[569] [570] Corporate meat giants such as Tyson and J.B.S. wield enormous financial and political power, increasing the likelihood of regulatory capture.

This threat of regulatory capture manifests in legal ways—such as campaign donations and sophisticated lobbying efforts aimed at decreasing regulation of the livestock industry—as well as illegal ones. For example, the world's largest meat packer, JBS, pled guilty in 2020 to bribery charges in a sprawling corporate corruption campaign, after paying hundreds of millions of dollars in bribes to more than 1,900 Brazilian politicians and officials to secure favorable treatment and low-cost financing from state-run banks.[571] [572]

Jo-Anne McArthur / Born Free Foundation / We Animals Media

Lines between the livestock industry and those governing it can become blurred, as a state has a strong interest in the success of the domestic industry. In some places, this relationship is explicit: 20% of JBS is owned by the Brazilian Development Bank through taxpayer funding.[573] However, more often, these connections are advanced through policy, including regulatory decisions, subsidies, structural supports, and other methods—often with little regard for disease risk.[574] In the US, the Department of Agriculture serves the twin goals of regulating and promoting agribusiness. This dual purpose leads to a constant balancing in which public health concerns are measured against the economic interests of industry. It also forecloses the type of traditional regulatory relationship that is common across many other sectors.

Livestock production maintains a special status in many nations because of its monolithic economic and cultural importance. In light of this, there is an almost-universal reluctance to regulate animal agriculture. Widespread funding and interest is dedicated to examining disease threats *to* livestock, but there is less financing and interest focused on zoonotic risks posed *by* livestock production.[575] [576] Where livestock is regulated for human health, much of the regulatory focus is on food safety, paying particular attention to a handful of well-known bacterial pathogens—*salmonella*, *listeria*, *E. coli* and the like— while overlooking other risks from live animals. Public health education has done much the same—instructing people on how to handle meat to avoid food-borne illness, but saying very little about how to interact safely with live animals. Many countries, such as the US, regulate livestock primarily from the point of slaughter forward, while in some cases, particularly with viruses, transmission risk may be greatest while the animal is still alive.

*Widespread funding and interest is dedicated to examining disease threats to livestock, but there is less financing and interest focused on zoonotic risks posed by livestock production.*

Livestock production is expanding globally and in almost every nation, but there are rare exceptions. The largest meat exporter in the EU, the Netherlands, has taken steps to curb livestock

production after a 2019 court ruling found the country's climate policy noncompliant with European environmental accords.[577] The Dutch government's plan aims to reduce the number of livestock held in the country's dense animal husbandry sector by 35 million before 2030, using a series of buyouts and relocation efforts along with a strategy to help some producers transition away from intensive production methods to a more extensive production system.[578] This decision to moderate levels of livestock production has little to do with disease concerns, perhaps even less to do with animal welfare, but everything to do with the environmental consequences of animal agriculture.

Vince Penn / We Animals Media

Nick Schafer Media / We Animals Media

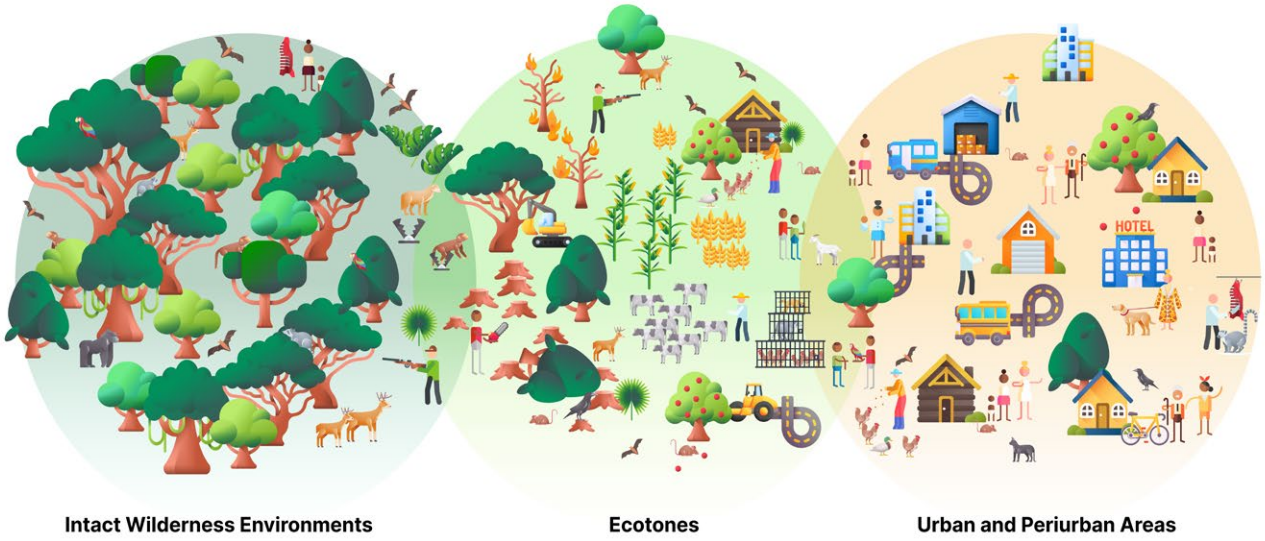
# ENVIRONMENTAL DRIVERS OF ZOONOTIC EMERGENCE AND THEIR RELATIONSHIP TO ANIMAL INDUSTRIES

Some environmental drivers of disease emergence are closely connected to animal industries. These industries act as proximate drivers of disease emergence, and they also initiate cycles of environmental harms that can increase the risk of spillover in a variety of direct and indirect ways. Habitat loss driven by agricultural and urban expansion necessitated by increases in human population amplifies the risk of zoonotic disease, displacing wild animals and forcing them into closer contact with farmed animals and humans.[579] Other large-scale environmental patterns also contribute significantly to the risk of zoonotic disease emergence. Chief among these are biodiversity loss and climate change.[580]

*These industries act as proximate drivers of disease emergence, and they also initiate cycles of environmental harms which can increase the risk of spillover.*

## Agricultural Expansion, Habitat Loss, and Disease Emergence

The global food system is the largest single user of land and the primary driver of land-use change, accounting for nearly 90% of deforestation and causing steep declines in biodiversity as natural land is razed and converted for food production.[581] [582] [583] [584] Consumption of large amounts of animal-based foods, even where efficiency is maximized through industrial systems of production, is a key driver of land transformation and human encroachment into natural areas.[585] [586] Encroachment into natural ecosystems expands transition zones—border areas where different habitats mix—and provides new and




additional opportunities for pathogens to adapt, diversify, and move between species, increasing the risk of spillover.[587] [588] [589]This pattern of disease emergence has been associated with hantavirus pulmonary syndrome, Lyme disease, yellow fever, Nipah virus infection, influenza, rabies, and others.[590] [591] This danger is particularly acute in areas of high biodiversity undergoing rapid land-use change driven by livestock production.[592] [593]

*Encroachment into natural ecosystems expands transition zones—border areas where different habitats mix—and provides new and additional opportunities for pathogens to adapt, diversify, and move between species.*

Justin Mott / Kindred Guardians Project / We Animals Media

Brazil, which boasts more biodiversity than any other country, also has one of the largest populations of livestock. The coincidence and conflict between wildlife and animal agriculture heightens the risk of new outbreaks, making Brazil a potential hotspot for disease emergence. At the same time, the landscape of Brazil is undergoing rapid changes as hectares of forestland are burned or cut to make way for agricultural production.[594] Roughly 75%–80% of recently cleared land that once belonged to the Brazilian Amazon rainforest is now cattle pasture.[595] Though efforts to curb deforestation in the Amazon prohibit raising cattle on illegally cleared forestland, these regulations are nearly impossible to enforce without an effective system in place to track a herd's origins.[596] [597] Cattle sometimes are moved from illegal pastureland into the legal supply chain, and consumers lack effective

mechanisms to distinguish between legally produced and illegally produced meat.[598] [599] [600] [601] Environmental harms concealed by opaque supply chains undermine global health security.

*As ecosystems are broken apart, the risk of outbreak grows.*

As ecosystems are broken apart, the risk of outbreak grows. Rabies rates are higher in regions of Brazil where bats have lost greater amounts of forest habitat because the displaced animals are forced to interact more closely with livestock and humans.[602] [603] Such changes also are predictive of higher rates of yellow fever—a disease spread from primates to people through mosquitoes, one which becomes more common when primates lose forest habitat.[604] [605] The same is true in China, where areas with more profound forest loss driven by livestock production were found to be at higher risk for

George Steinmetz / Mato Grosso, Brazil 2022

coronaviruses transmitted by horseshoe bats than other areas where forest remained largely intact.[606] In India, outbreaks of Kyasanur Forest disease were associated with the encroachment of agriculture and cattle production into forest land.[607] [608] Similarly, studies have found that protecting lakes and wetlands in China reduced the probability of spillover of avian influenza from wild birds to poultry, as intact wetlands acted as a buffer, separating wildlife and livestock.[609]

Habitat destruction drives behavioral changes in wildlife that augment the risk of spillover. It pushes different kinds of animals into closer contact and changes the ways in which, and the places in which, they live and interact with humans. In Australia, bats experiencing environmental stress, who lack habitat and proper nutrition, carry higher rates of the Hendra virus, which can be spread to horses.[610]

Havva Zorlu / We Animals Media

The risk of Hendra virus rises when populations of flying foxes struggle to find enough nectar to survive, as many flowering trees in Australia have been lost to land-clearing and bushfires.[611] This species of bat, once migratory, has changed its behavior in response to this shifting environmental landscape. Today, many colonies instead live year-round near agricultural areas in order to find enough food to survive. In these areas, bat colonies overlap with livestock pasture, allowing for viruses to spread from bats to other animals, like horses, who become infected when they come into contact with bat saliva or urine as they graze in the paddocks below them.[612] Horses can then transmit Hendra virus to humans, for whom it is 50% fatal.[613]

Feedback loops initiated by land-clearing for livestock and agriculture amplify the risk of zoonotic spillover through a range of underexplored ways.[614] Rarely are these possibilities factored into risk assessments of animal agriculture, though there is a clear causal line between the two and the cascading impacts on human, animal, and environmental health are becoming increasingly clear.

There is a need for policymakers to take a more active role in facilitating and incentivizing sustainable agricultural practices to minimize habitat destruction and reduce livestock–wildlife interfaces.[615] Some estimates suggest that direct forest protection payments and other such prevention measures could reduce the risk of pandemics by 40% by protecting intact habitats and reducing the stress on wildlife populations.[616] These challenges will become even more urgent as climate change drives new interactions between animal species and destroys existing habitat—reshaping settlement patterns of both humans and animals.

*Feedback loops initiated by land-clearing for livestock and agriculture amplify the risk of zoonotic spillover through a range of underexplored ways. Rarely are these possibilities factored into risk assessments.*

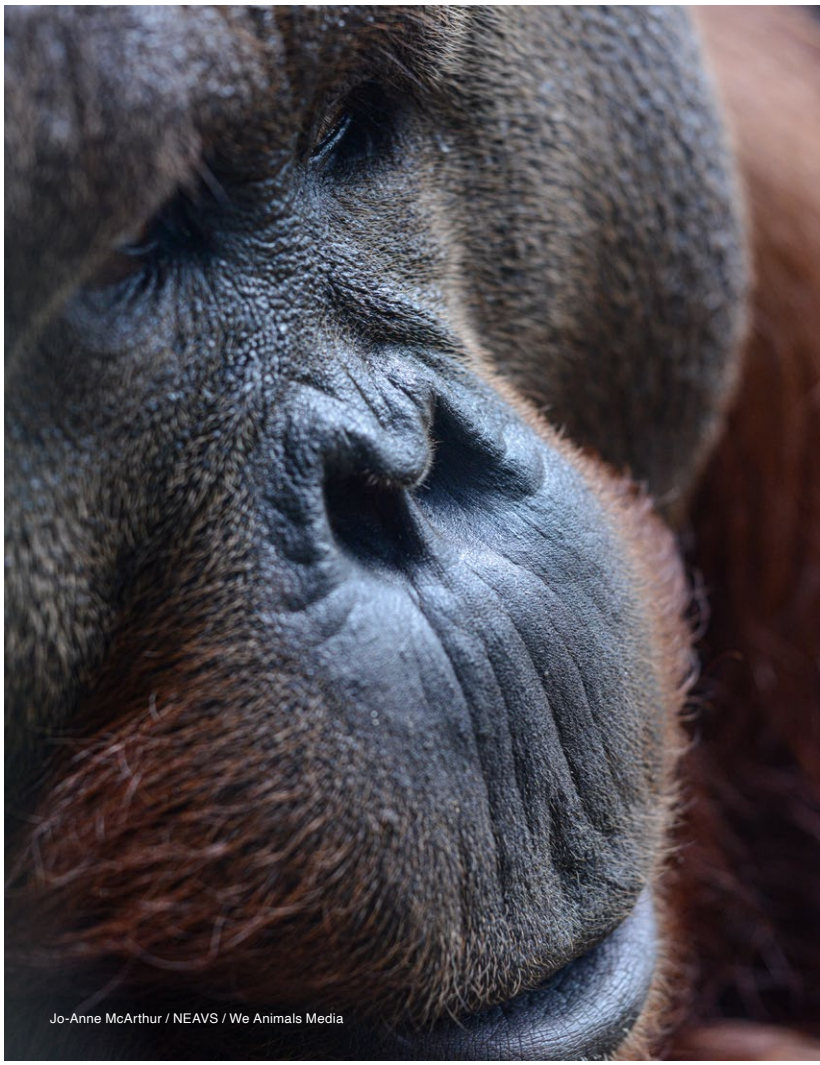
Jo-Anne McArthur / We Animals Media

## Biodiversity and Disease Emergence

There is a faulty perception that the risk of zoonotic disease comes from nature, when, often, the risk comes from dismantling it. Livestock production and overexploitation of wildlife can drive environmental change, reshaping and destabilizing ecosystems, and catalyzing new risks of disease emergence. Just as healthy individuals expel fewer germs than sick ones, healthy intact ecosystems spawn fewer disease outbreaks than degraded ones.[617] When broken apart and fit to our needs, they become fragile.[618] The risk of an outbreak grows.[619] The animals who remain and thrive in these types of degraded landscapes tend to be those most capable of spreading disease to humans.[620] [621] Diseases such as Lyme, Chagas, Langya virus infection, and hantavirus pulmonary syndrome are carried by deer mice, shrews, and cotton rats, who flourish in human-altered areas devoid of native plants and predators.[622] [623] [624] In low diversity areas, pathogens can become more prevalent, as vectors, such as ticks and mosquitos, feed more frequently on reservoir species, who carry the virus, as opposed to in high diversity areas where they feed on a wider range of species, some of which are poor or dead-end hosts for the virus, reducing and diluting the level of pathogens present in the area overall. [625] [626] [627]

Biodiversity loss and agricultural expansion are closely entwined, as land clearing activities can also facilitate the hunting and trade of wildlife, further increasing zoonotic risk. For example, in Angola, human-set fires are used to clear forested land for crop or cattle production. As the fire burns the forest, hunters stand by—waiting to shoot and capture wild animals forced to flee from the flames.[628] Expanding human and agricultural development allows

hunters new inroads into once-wild areas and facilitates hunting in areas that were previously hard to reach.[629] In many cases, logging or other land clearing activities and the wild meat trade go hand-in-hand, with loggers themselves subsisting off of wild animals while working in the area and sometimes opportunistically harvesting wild animals to sell or trade.[630] In addition to spillover risks associated with the killing, trade, or consumption of wild animals for food, overhunting and land use change can lead to increased contact between domestic animals and wild animals carrying pathogens or vector species, such as ticks and mosquitos. For example, vampire bats may more frequently feed on cattle in areas where wild mammals are rare due to habitat loss or overhunting; they may also come into more frequent contact with humans, increasing the risk of rabies spillover.[631] [632]



Jo-Anne McArthur / NEAVS / We Animals Media

*Expanding human and agricultural development allows hunters new inroads into once-wild areas and facilitates hunting in areas that were previously hard to reach.*

Systems of modern industrial farming often promote the use of monocultures, both in crop and livestock production. These systems, which create high-densities of a single plant or animal species (often to the exclusion of all others), are adverse to biodiversity, and they also carry implications for disease risk.[633] Homogeneous populations are more susceptible to significant disease outbreaks, and infection is more easily transmitted between genetically similar hosts.[634]

Dense, homogeneous concentrations of livestock can make large-scale disease events more likely. Chickens, for example, are produced worldwide, in numbers and densities rarely seen in nature. An estimated 85 billion chickens were produced and processed in 2023, and this species now dramatically outnumbers all other species of birds.[635] [636] Within most chicken flocks, birds have very low rates of genetic diversity.[637] This is increasingly true as traditional breeds of livestock and poultry are phased out and producers move to a select handful of hyper-efficient breeds, further reducing genetic variation among livestock populations globally.[638] These conditions can increase the ability of pathogens to transmit widely within flocks and the likelihood that a pathogen may obtain new adaptations during that process.[639] For instance, large, single-breed poultry

*Improving biodiversity and restoring native ecosystems can reduce the risk of disease.*

facilities have played a crucial role in the spread of avian influenza by facilitating the development of highly pathogenic versions of influenza viruses.[640]

In addition, plant monocultures, for example, in corn or soy production for livestock feed, can have harmful effects on the soil, drive deforestation, contribute to increased use of pesticides, and further degrade biodiversity.[641] The presence of plant monocultures can also increase the risk of infection among humans. This has been observed, for example, with respect to palm oil monocultures in Indonesia.[642] Still, many of the ways in which crop monocultures impact the risk of infectious diseases are not well understood by scientists.[643]

Conversely, improving biodiversity and restoring native ecosystems can reduce the risk of disease. For example, studies suggest that forest restoration efforts required by current environmental legislation in Brazil could decrease the risk of hantavirus by 45%.[644] [645] These virtuous cycles offer an opportunity to protect public health and prevent future outbreaks by bringing ecosystems into greater balance: improving genetic diversity within species and biodiversity among them, providing more abundant and consistent habitat and resources, and distributing animals over a wider area to avoid congregating them in small corridors that may facilitate disease transmission.[646]

Alix Livingstone / Farm Transparency Project / We Animals Media

## Climate Impacts on Disease Risk

Conditions emerging from climate change pose serious threats to habitat, biodiversity, and ecosystem health. Today, climate change and extreme weather events drive zoonotic risk in concrete, visible ways. For example, anthrax released from a frozen animal carcass due to melting permafrost led to dozens of hospitalizations and the death of a child in Siberia, where the outbreak also killed 2,000 reindeer.[647] [648] Or, for example, when Hurricane Floyd hit animal production facilities in North Carolina. The storm left millions of pounds of manure, pathogens, and tens of thousands of dead pigs scattered across the coastal region. A photograph taken in the wake of the storm shows a shark feeding on a pig carcass three miles off the North Carolina coast.[649] [650] Climate change is already significantly altering the dynamics of disease transmission by insect vectors.[651]

And over time, climate will continue to drive disease risk in dynamic and unpredictable ways. It will move and displace populations of people and animals, altering habitat and changing where and how species live as well as the ways in which they interact with one another. These changes and migrations will bring more opportunities for disease transmission. A study published in *Nature* suggests that, looking

only at a subset of 3,100 mammal species, climate driven changes mean that the coming decades will see 300,000 first encounters between species, and with these encounters, 15,000 spillover events where viruses move into new hosts.[652]

While animal agriculture poses direct risks of zoonotic transmission, it also contributes heavily to risks associated with a changing climate. The climate impact of animal agriculture has been largely overlooked by policymakers to date, who have more-often aimed interventions at industries like transportation or energy. However, the climate effects of livestock production are vast and frequently underrecognized, particularly when taking into account the impacts of livestock-driven deforestation.

*The climate effects of livestock production are vast and frequently underrecognized, particularly when taking into account the impacts of livestock-driven deforestation.*

Stefano Belacchi / Essere Animali / We Animals Media

According to data from the Food and Agriculture Organization of the United Nations, livestock production accounts for 14.5% of global greenhouse gas emissions, an amount on par with the entire global transportation sector.[653] [654] Unlike plants, which capture carbon, animals produce it. And unlike growing crops, livestock require food, in addition to land and water, and that food requires more land and more water, amplifying the environmental impacts of production.[655] Cows, for example, consume 15-25 calories for every 1 calorie of meat they produce.[656] At present, two-thirds of the crop calories produced in the US are used to feed livestock instead of humans, more than 40% of US land is dedicated to livestock feed and production, and the livestock industry accounts for a substantial portion of US water usage as well— irrigating crops to feed to cattle accounts for 23% of all water used nationally, making the cattle

feed industry the single largest consumptive user.[657] [658] [659]

In addition to carbon dioxide, livestock production generates other, more potent, pollutants like methane. Agriculture generates more methane emissions than any other industry, including oil and gas.[660] Globally, animal agriculture, particularly cattle production, is the dominant source of all agricultural methane emissions.[661] [662] Climate acts as a dynamic threat multiplier of zoonotic disease risks; at the same time, climate change is driven, in significant part, by the animal agriculture industry. The broader impacts of animal industries on the environment should be better accounted for when assessing the zoonotic risks that these industries pose.

Jo-Anne McArthur / We Animals Media

Lukas Vincour / Zvířata Nejíme / We Animals Media

# MITIGATION OF AND RESPONSE TO OUTBREAKS ACROSS ANIMAL INDUSTRIES

Zoonotic diseases, driven both by direct contact with animals and larger patterns of environmental change, will continue to move from animals to humans in the near future. What happens when diseases make this jump and how well are current systems prepared to handle these events? Better preparedness and faster response may help mitigate the damage caused by disease, but neither is it a solution. While these post-spillover factors can affect the trajectory of an outbreak after it occurs, each is limited in its effectiveness.

## The Limits of Preparedness

Some pathogens are incredibly difficult to contain. A single gram of manure from infected chickens can carry enough influenza virus to infect 1,000,000 birds, while the virus can persist in wet manure for weeks.[663] [664] Influenzas can be transported on the shoes of workers, carried on the wind from neighboring facilities, or can be introduced when new birds are added to a flock or when birds return, unsold, from market. Given the difficulties of trying to disinfect a single facility, let alone hundreds of thousands of smallholder farms, it is no surprise how far and how fast these viruses spread.[665]

When a strain of avian influenza, H5N1 virus, spread across the world in the spring of 2022, advanced warning and strict biosecurity measures were not enough to stop it. Even in the industrial livestock operations of the American Midwest, where production takes place in sealed indoor warehouses with no exposure to outside

*When a strain of avian influenza, H5N1 virus, spread across the world in the spring of 2022, advanced warning and strict biosecurity measures were not enough to stop it.*

air, and workers shower, step in disinfectant before entering, and cover their clothes in tyvek suits, the virus swept across the region, infecting millions of animals in the process, many dying before they ever showed symptoms. The virus breached these defenses not once, but over and over again, hundreds of times, as each facility was infected. The virus hopscotched from one production operation to the next, reaching 37 of the 50 states and leading to the death of more than 40 million birds in just four months after arriving in the US.[666]

Even with advanced warning and the strictest biosecurity measures the industry could muster, producers appeared powerless to stop the disease that they knew was coming. How much more can realistically be done? Many of these animals never see the light of day, yet they continue to be infected. There are limits to biosecurity, and there is no such thing as perfect preparedness.[667]

Glass Walls / We Animals Media

Disease modeling suggests that rapid response is not enough to contain the spread of many known contagious pathogens, let alone novel ones. Consider a disease like rinderpest, for which a vaccine exists and is readily available. Simulations suggest that even with a "nearly optimal response," including a large-scale and

*There are limits to biosecurity, and there is no such thing as perfect preparedness.*

effective vaccination campaign undertaken within a week of the first observed cases, an outbreak of rinderpest in cows would spread and lead to the death of hundreds of thousands of cattle.[668] These models often make assumptions that may present an overly-rosy picture—that we are dealing with a known disease, that the pathogen spreads the same way as it has in previous outbreaks, that the disease does not spillover to new species, and that institutions and producers will respond as they should.

*After a disease outbreak occurs, its trajectory is determined, in part, by how soon it is reported and how the regulatory system responds.*

## Barriers to Communication

After a disease outbreak occurs, its trajectory is determined, in part, by how soon it is reported and how the regulatory system responds. Whether and when producers report outbreaks are affected by the regulatory systems in place, and how producers are incentivized or discouraged from reporting. How quickly and deftly the regulatory system responds depends on communication and planning as officials seek to contain the current outbreak and identify how and to where it is spreading.

Andrew Skowron / We Animals Media

## Reporting

Compensation schemes, which offer payouts to producers who lose their animals to infectious disease, are a common policy tool used to incentivize early and honest reporting of zoonotic disease. If a pig producer in Germany begins losing animals at their facility, it is in their economic interest to contact public health officials as soon as possible, who will then work to contain the outbreak and indemnify producers against resulting losses.[669] But these systems are not in place everywhere, nor do they cover everyone.

Where no such safety nets exist, where they do not compensate producers fully, or where they require long months of waiting on paperwork and approvals, reporting is rare and unintended consequences are common. A smallholder farmer in Vietnam, whose flock contracts an infectious disease, may respond by selling the birds immediately, dispersing the animals along with the disease in an attempt to cash in before it is too late.[670] When H5N1 avian influenza arrived in Vietnam, the virus spread to 57 of the 64 provinces in just six weeks, in part driven by the fears of producers who did not want to lose their flocks without compensation.[671] The same was true in Egypt, where the government's failure to indemnify producers against disease losses only accelerated the virus's spread.[672] Fire sales of infected animals drive outbreaks, allowing pathogens to spread rapidly, as producers move sick animals as quickly as they can from their farm to the next, exacerbating the danger and sowing disease broadly across the region. Without trust in the system and buy-in to its larger purpose of disease containment, small producers' rational economic response to disease often makes outbreaks worse.

Jo-Anne McArthur / We Animals Media for The Guardian

*Fire sales of infected animals drive outbreaks, allowing pathogens to spread rapidly, as producers move sick animals as quickly as they can from their farm to the next, exacerbating the danger sowing disease broadly across the region.*

George Steinmetz / Northern Territory, Australia 2022

## Lack of Transparency

Reporting outbreaks to officials does not always ensure that information will be shared openly with the public, with other officials, with the WHO and WOAH, or with other outside nations. There are strong short-term incentives to downplay risk. Economic motivations to dismiss risk can be especially powerful in areas heavily dependent on animal exports. Disease outbreaks in the food supply lead to embargos on live animal and meat exports, some of which can last years and gut domestic production. Even when embargos end, reputational damage often remains, driving down the value of animal exports long after the outbreak is over.

Disease outbreaks can hurt other industries as well, including tourism. In the wake of Ebola, travel to and from West and Central Africa ground to a virtual stand-still. Even countries in the region with no Ebola cases saw tourism revenue cut in half overnight.[673] During the SARS outbreak, tourism to Hong Kong and Singapore dropped roughly 70% in 60 days. Airline carriers lost $7 billion in revenue during the outbreak, forcing them to lay off thousands of employees.[674] [675]

With respect to disease reporting, it is hard to overstate the stakes and sensitivities at play.[676] [677] No country wants to be labeled unsafe or unsanitary. Augmenting these concerns is the outdated practice of naming diseases after the places where they were first documented or discovered. These labels have staying power and can wound the place for which they are named, at the same time inflaming cultural stereotypes.

Wherever public health becomes political, the results can be dangerous. Censorship, driven by nationalistic interests, can increase risk and dampen response. Where information seeps out slowly, valuable containment time is lost.[678] This culture

*Wherever public health becomes political, the results can be dangerous.*

Havva Zorlu / We Animals Media

of silence deepens mistrust between countries and within them. It can create informational silos and firewalls that separate samples from the scientists who need them, separate people from public health information, and separate whole nations from the rest of the world.[679] [680] [681] However, risk is globalized as pathogens do not respect human-set boundaries.

## Siloing

Regulatory silos, entrenched by poor communication among different branches or levels of government, can further undermine disease reporting and response. While disease can jump from wildlife to livestock to humans and back again, many regulatory systems struggle to exercise this same kind of flexibility. Important findings and relevant data are not shared across agencies.

*While disease can jump from wildlife to livestock to humans and back again, many regulatory systems struggle to exercise this same kind of flexibility.*

Deniz Tapkan Cengiz / We Animals Media

The gulf between animal and human health authorities can be vast, despite the deep connectedness and consequences of each area on the other. When chickens began dying in large numbers on farms outside of Hong Kong, investigators reported the new disease, H5N1 influenza, to veterinary health authorities, but not to human health officials, believing the outbreak had little relevance to public health.[682] [683] Two months later, a three-year old boy died from the same disease, his diagnosis delayed without critical information.[684]

Years later, as H5N1 ravages wild bird and poultry populations across the globe, killing hundreds of millions of animals, and as it continues to spread to new species of mammals, including cattle, the CDC and others maintain that the risk to human health is "low."[685] Such an assessment perhaps speaks to a larger inability to account for risks that are both catastrophic and rare but also to the half-hearted way in which policymakers have taken up the One Health framework across much of the world. In some cases, particularly in developing nations, public health officials are singularly focused on combating disease in humans, while concern about disease in animals is regarded as a luxury they cannot afford. As one veterinary epidemiologist explained, the reception to such work is often, "People are dying of malaria, and you're coming and telling us about a chicken disease?"[686] But malaria is itself a zoonosis, and such a response overlooks the founding principle of One Health—namely that human health, animal health, and environmental health are interconnected and interdependent.[687] One Health approaches, interdisciplinary and collaborative by nature,

*Such an assessment perhaps speaks to a larger inability to account for risks that are both catastrophic and rare.*

provide an antidote to the kinds of siloing that can undermine efforts to combat zoonotic disease at every level of government; however, operationalizing One Health principles through policy has often proved challenging.

Along these lines, while in many countries livestock health authorities recognize the significant potential impacts of disease occurrence in wildlife, they often consider these threats as outside the scope of their mission and rarely work cooperatively with scientists or experts from the wildlife field.[688] Diseases are shared between wild animals and domestic ones, but too often, information about them is not. Different agencies within the US that govern livestock and wildlife each have their own pathology labs, but few, if any, protocols or mechanisms to share scientific findings between them. These divides permeate across different levels of government, both vertically and horizontally, and occur within agencies as well. In some cases, informational silos within a regulatory agency separate science and scientists from policymakers, leading to policy that is shaped largely by other factors. There are hopeful signs that things might be changing, in particular where there are strong financial incentives to stay abreast of disease events in wildlife. The US Department of Agriculture, for example, has begun some monitoring of avian influenza rates in hunter-harvested wild birds to better track the diseases.[689] And, in Ghana and in Peru, new initiatives have aimed to increase information sharing between human and animal health authorities.[690]

*These divides permeate across different levels of government, both vertically and horizontally, and occur within agencies as well.*

David Chancellor / Anesthetized Cheetah, Samburu National Park, Northern Kenya

Where there is no single coordinating entity responsible for zoonotic disease, fiefdoms persist, agencies become politicized, and their effectiveness is marginalized. Some of these problems could be remedied by realigning incentives to encourage or require information sharing. Yet, this is unlikely to occur without mandates and infrastructure in place to do so.

## Containment

When officials become aware of an outbreak, a culling of infected or exposed animals is carried out to contain it. Such a process presents both logistical and public health challenges. How does one safely kill and dispose of 100,000 or 1,000,000 infected chickens or pigs? Should the animals be buried, at the risk that pathogens may seep into the groundwater and infect neighboring communities, or should they be incinerated, at risk of aerosolizing the pathogens? The cranes and other forms of heavy equipment needed to move the carcasses provide a sense of the enormous scale of such operations when these outbreaks occur.[691] Plans and processes for safe disposal of infected animals is one aspect of disease control that policymakers from all countries seem to chronically overlook, and few are prepared to deal with these outbreaks at scale as the number of livestock and the size of operations continue to rise.

*The cranes and other forms of heavy equipment needed to move the carcasses provide a sense of the enormous scale of outbreaks.*

Selene Magnolia / Essere Animali / We Animals Media

In 2021, Danish officials exhumed 29 million pounds (13,000 tonnes) of mink carcasses from poorly-dug graves where they had been hastily buried after the animals were found to be infected with and transmitting SARS-CoV-2.[692] After some of the buried carcasses resurfaced, officials feared that they may be contaminating nearby water sources and putting human health at further risk.[693]

Oikeutta Eläimille / We Animals Media

In Southeast Asia, in places where $CO_2$ or other culling methods are not available, birds infected with H5N1 were stuffed into sacks to be suffocated as a means of controlling the outbreak. But without proper equipment or training, many of the birds escaped from the bags and were picked up and eaten by children in the neighborhood, or even by the individuals carrying out the depopulation efforts who had not been briefed on *why* they were being asked to undertake this work.[694]

*Danish officials exhumed 29 million pounds of mink carcasses from poorly-dug graves where they had been hastily buried after the animals were found to be infected with and transmitting SARS-CoV-2.*

## Traceability

Traceability remains an issue throughout much of the global livestock trade for large and small producers alike. While small producers tend to sell through shorter supply chains, they move through more informal networks, which often operate with less documentation. Animals from different sources are mixed—middlemen in Vietnam may collect chickens from several different homes, loading them into the same cage on the back of a motorbike before selling them to restaurants or vendors. Transactions occur without paper trails, and sellers are often unsure of where their animals come from. Meanwhile, large producers sell through longer supply chains, some of which are vertically integrated. However, as animals are aggregated in great numbers and dispersed through a wide range of channels to supermarkets and manufacturers and export markets, they too are rarely tracked sufficiently. Pork from a pig raised in Mexico might be consumed at a dinner table in South Korea. A single infected shipment might be spread across multiple countries or dozens of states halfway across the world.[695]

Though technology is available to track livestock animals throughout the value chain, in most parts of the world, it has not been adopted.[696] Consumers operate with limited information as to where

the animals they eat came from and what sorts of health and safety checks were present throughout production. From a regulatory standpoint, when an outbreak occurs, these information gaps mean valuable containment time is lost. At present, even wealthy nations like the US lack a rigorous system to link shipments, or an item within a shipment, back to its point of origin, while the EU and others impose stricter standards on traceability and consumer protections.[697] China has made significant strides in this respect following the melamine crisis in 2008. The UAE, in part motivated by the importance of religious restrictions upon consuming certain kinds of animal products, is also employing traceability technology with increasing efficiency and accuracy.

Jo-Anne McArthur / Djurrattsalliansen / We Animals Media

*Though technology is available to track livestock animals throughout the value chain, in most parts of the world, it has not been adopted.*

All these regions are working to develop a regulatory framework around the application of blockchain technology, which promises the ability to track and gather important food safety data as an animal moves from producer to plate.[698] Supermarket corporations such as Walmart may use their economic power to deliver these changes even sooner voluntarily. However, it is less clear whether these technological gains will be applied in developing market economies or to more localized production systems.

## Need for Preventative Measures

As livestock production continues to grow and intensify, as more land covered with forests and wildlife is cleared and developed in support of this expansion, and as the effects of these changes on climate become increasingly apparent, the risk of zoonotic disease outbreaks will continue to rise. These trendlines point in dire directions. Even with best-case-scenario reporting and response, many pathogens will have already spread beyond the point of easy containment.[699] After-the-fact approaches are limited in effectiveness and often more expensive than preventative measures.[700] Too often, policymakers regard spillover events as random occurrences—lightning strikes that cannot be predicted or prevented, but in fact they often follow familiar patterns.[701] And while the specifics of each instance may vary, these general contours largely remain the same, creating opportunities for preventative policy measures that limit the frequency of spillover events.

*Too often, policymakers regard spillover events as random occurrences—lightning strikes that can't be predicted or prevented, but in fact they often follow familiar patterns.*

George Steinmetz / Jiangsu, China 2016

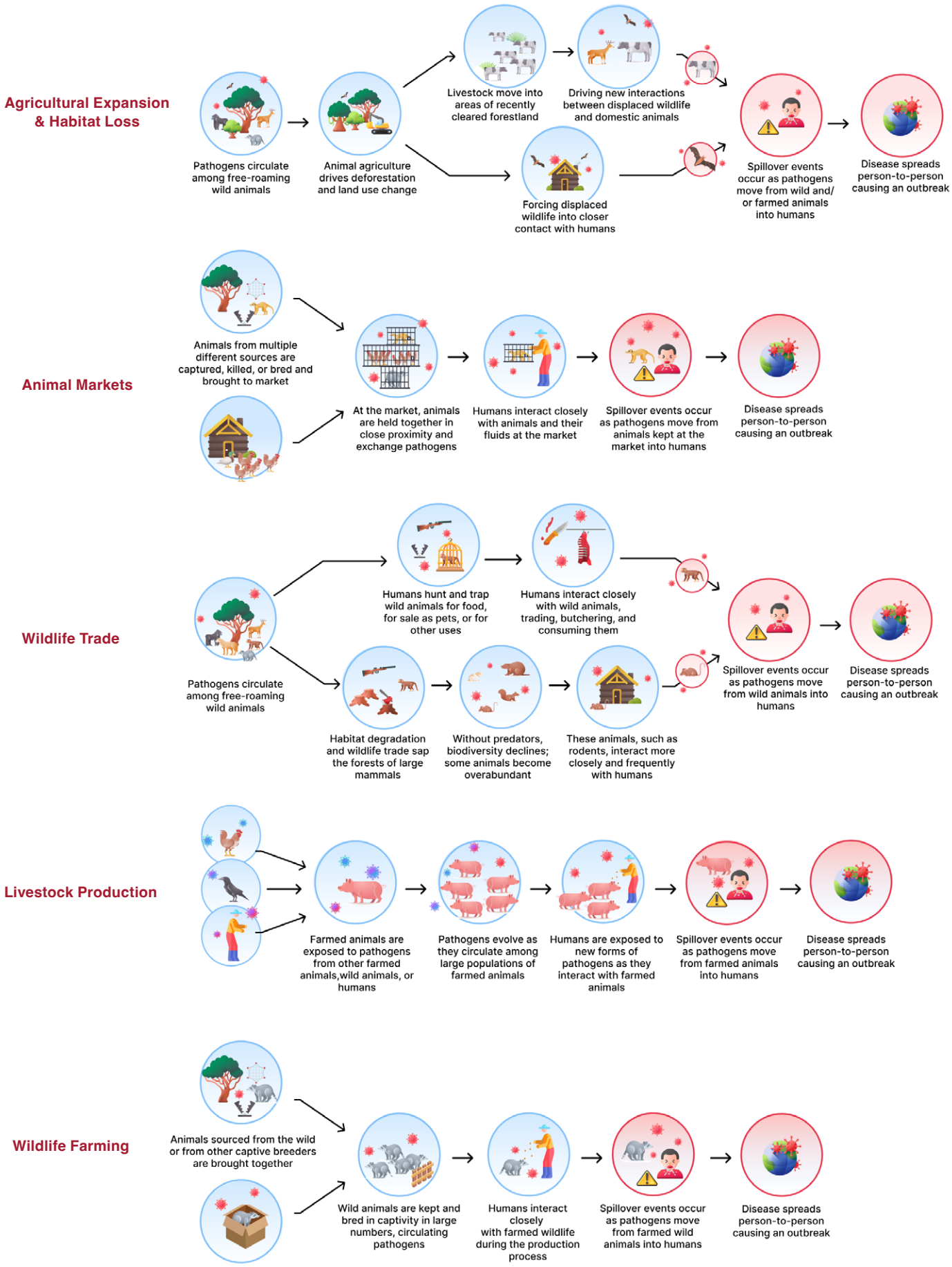
David Chancellor / Elephant Hunting for Wild Meat and Trophy, Namibia

# PATTERNS OF ZOONOTIC SPILLOVER

While human-animal interactions do not account for every instance of zoonotic spillover, they are a hallmark, defining many of the most common patterns of disease emergence. Across continents and countries, these patterns remain surprisingly consistent. Often the same forces shape and dictate the ways in which humans, animals, and ecosystems interact, paving the way for new outbreaks. Each of the following paradigms illustrates a common pathway of disease emergence—a familiar archetype that describes the ways in which and the routes through which pathogens move from animals into humans. Reduced to their most basic forms—actor, action, consequence—they outline and sketch much of humanity's risk from emerging infectious disease. While they do not capture every circumstance of spillover, many of the most serious zoonotic viruses, from SARS to Ebola to influenza to HIV-1, have moved through one of these channels to reach humans. Future outbreaks will occur through these same pathways and many of those outbreaks can be prevented through better policy. Interventions at any point along these "spillover supply chains" may be effective at disrupting these cycles of disease emergence.

*Future outbreaks will occur through these same pathways and many of those outbreaks can be prevented through better policy.*

# POTENTIAL PATHWAYS FOR ZOONOTIC SPILLOVER



David Chancellor / Zoonotic Disease Surveillance, Mpala Research Centre, Northern Kenya

# POLICY GOALS AND IMPLEMENTATION OF BETTER PRACTICES

In what follows, we describe policy goals that aim to reduce the risk of zoonotic disease and some promising attempts to implement them. Strategies that have been adopted or have been shown to be effective in one jurisdiction provide examples that others can model and adapt for their own. While approaches to addressing zoonotic disease threats are heavily context-dependent, the following principles inform policy improvements across many jurisdictions: 1) information gathering and development, 2) communication and information sharing, 3) aligning incentives, and 4) evidence-based policymaking.

These four principles are developed into four graphic trees below, which describe these ideas in more detail and provide specific examples of how each has been applied in practice. These examples are drawn from the 15 country case studies upon which this report was built, as well as from countries outside this cohort. In some instances, these examples illustrate policies that have not yet been applied but are needed (those hypothetical examples are distinguished in italics). From left to right, these trees move from the general to the specific and describe the kinds of efforts that are required to address the zoonotic risks posed by animal industries. Many of the examples that apply these principles are not comprehensive but demonstrate progress and movement in a positive direction. These should be part of an iterative effort to continue to refine and apply strategies that reduce risk.

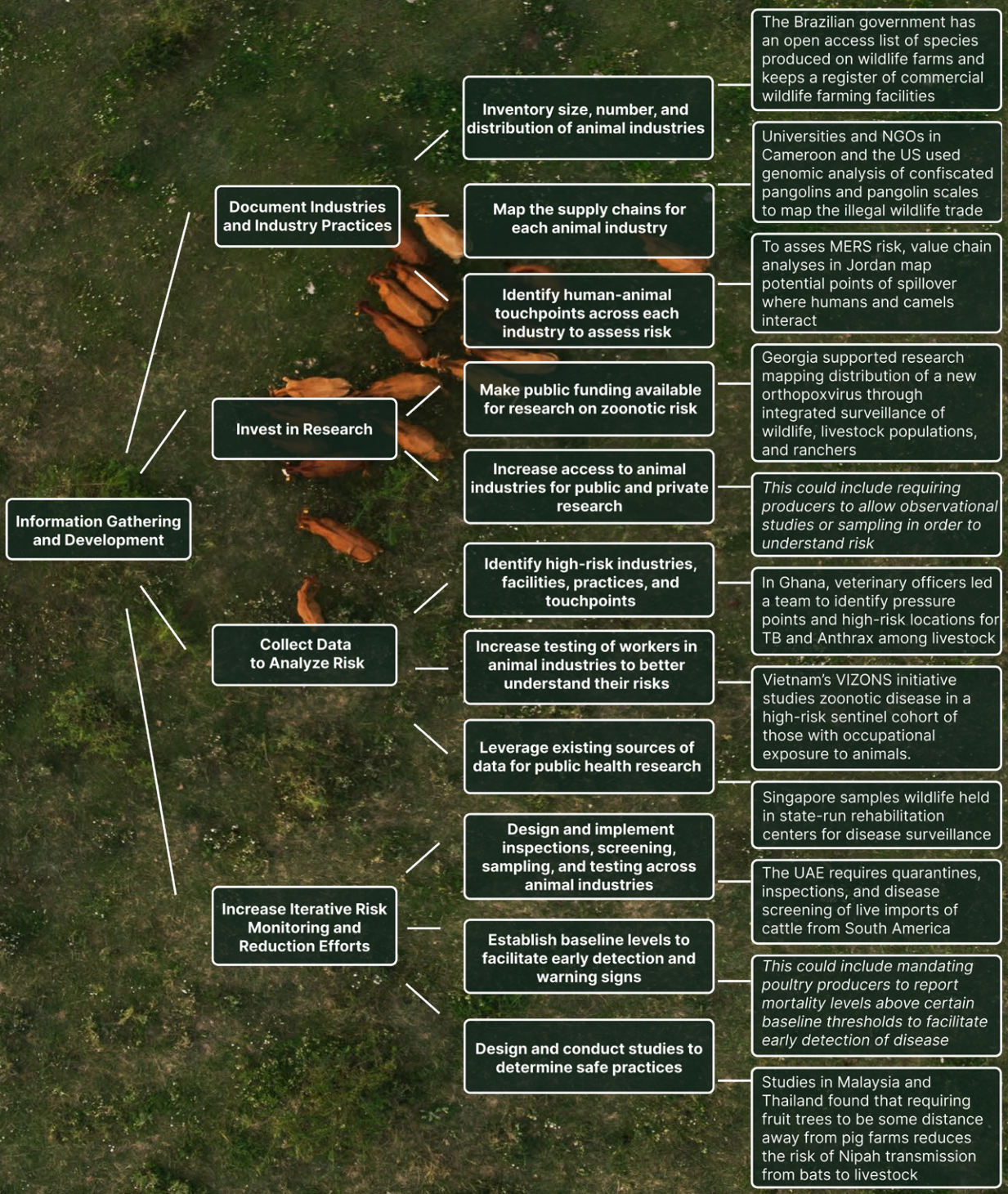
1. **Information Gathering and Development** includes efforts aimed at creating systems and processes for gathering information such as mapping high-risk touchpoints along animal supply chains, disease screening and monitoring, data collection, and investment in research. Obtaining more information about various forms of human-animal interactions, animal industries, and other sources of risk is critical to better understand current practices and the zoonotic risks that those practices pose. Filling in existing gaps in knowledge is critical both for preventing future spillover events and also for informing response when outbreaks occur. Information gathering and development efforts establish an essential foundation for everything that follows: communication and information sharing, aligning incentives, and evidence-based policymaking.[702]

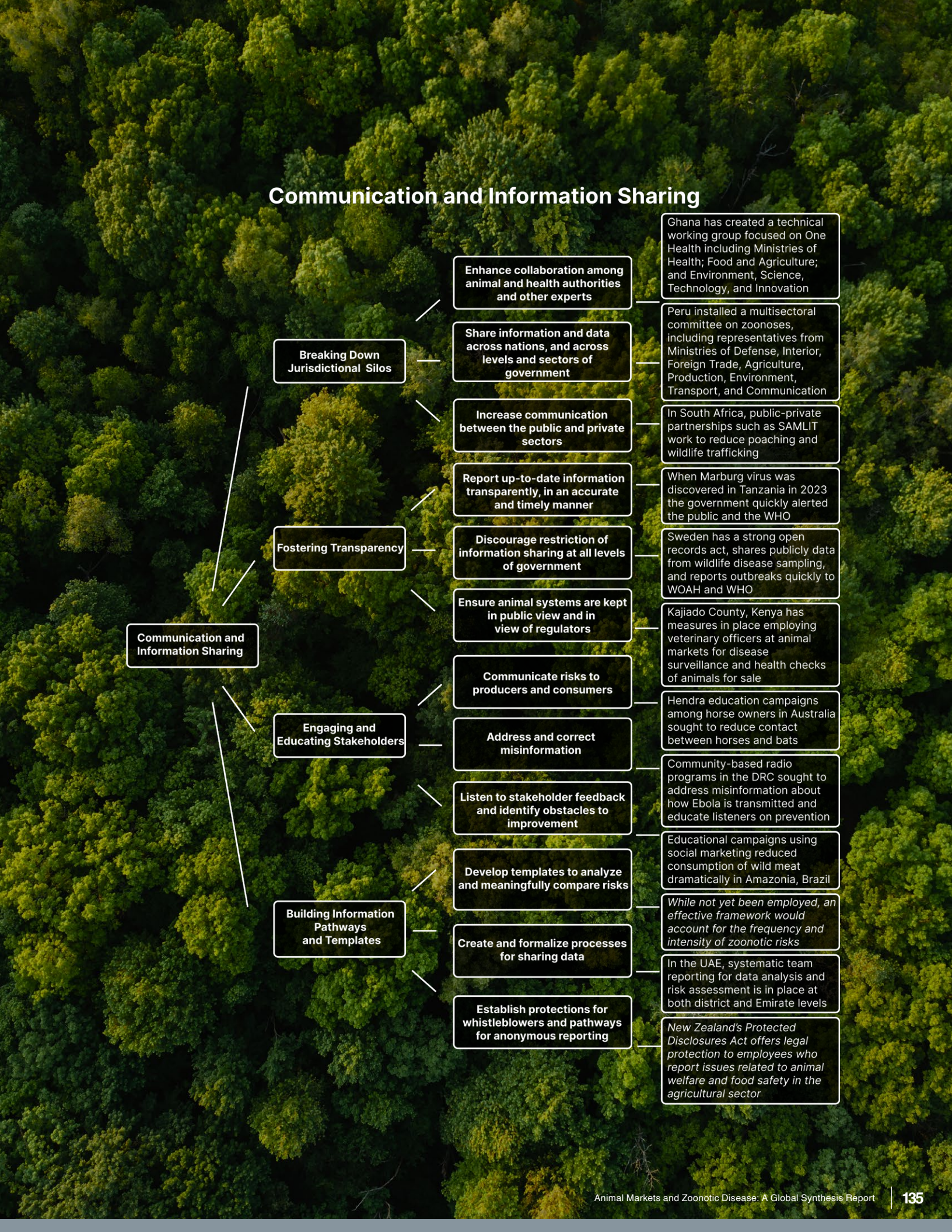
2. **Communication and Information Sharing** describes efforts that aim to disseminate information and increase collaboration and coordination to reduce risk. Timely, accurate, and open sharing of information across local, regional, and national boundaries is essential to assess and address the risk of zoonotic disease. Producers and public officials from across regulatory agencies and between different levels of government must communicate efficiently. Effectively communicating requires breaking down regulatory silos across levels of government and public and private entities within countries and across national borders. Transparency helps educate the public, builds trust, reduces misinformation, and promotes compliance with existing regulation. These efforts can be advanced through formalizing pathways for information sharing. Communication and information sharing takes information that has been gathered and disseminates it to relevant stakeholders, so that it can be operationalized through aligning incentive structures and evidence-based policymaking.[703]

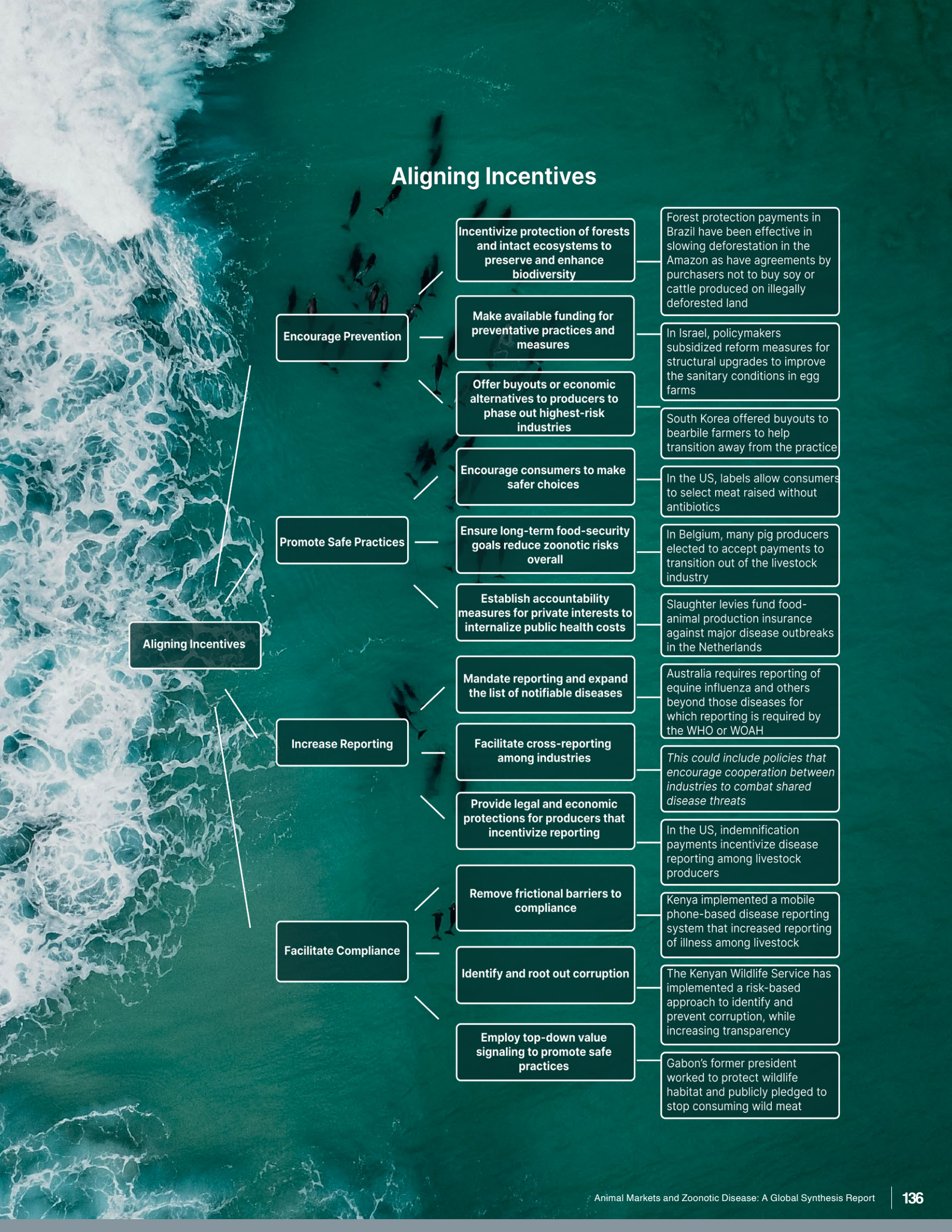
3. **Aligning Incentives** involves understanding key stakeholders' interests and relationships with animal industries, including cultural practices, economic drivers, and food security concerns and ensuring that these interests are aligned with goals of protecting public health. Stakeholders include not only producers but also consumers, NGOs, and governmental bodies themselves. Understanding the motivations and goals of these stakeholders allows regulators to provide incentives to act in ways that reduce zoonotic risk and that comply with regulations—regionally, nationally, and globally. Taking a more active role in areas where current incentive structures are misaligned could help prevent future outbreaks. Aligning incentives requires information gathering and sharing. Where incentives structures cannot be aligned with public health, evidence-based policy making may be needed to further manage risk or ensure compliance.[704]

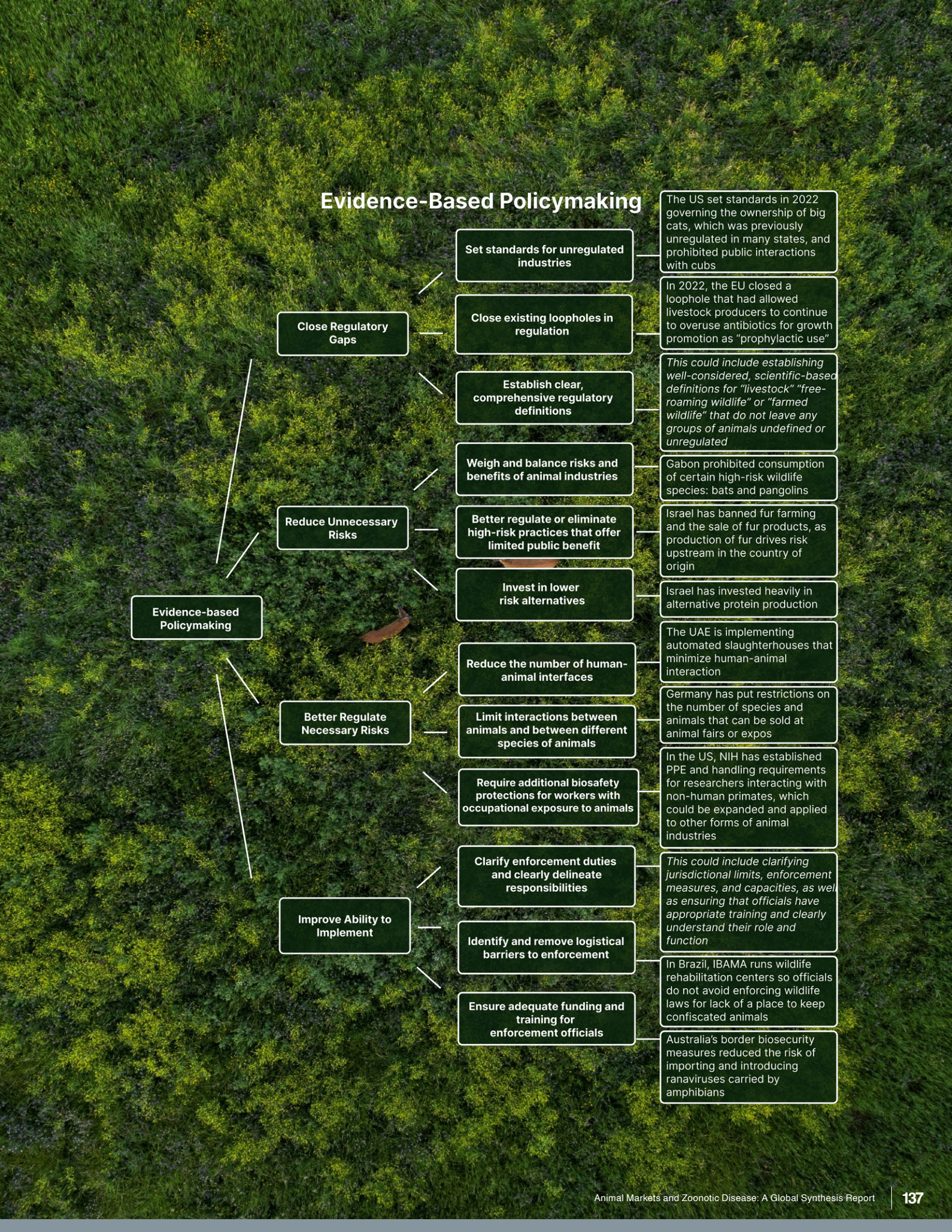
4. **Evidence-based Policymaking** describes the law, regulation, and policy that reflects awareness of existing risk and is informed by the best available scientific evidence. In addition, these efforts integrate an understanding of cultural and economic drivers that are reflected in stakeholders' interests. At the same time, evidence-based policymaking must account for cultural values, practical needs, and food security. Evidence-based policymaking is made possible by information gathering and development, communication and information sharing, and through aligning incentives to ensure cohesive goals and compliance.[705]

# Information Gathering




Communication and Information Sharing
Communication and Information Sharing
Breaking Down Jurisdictional Silos
Enhance collaboration among animal and health authorities and other experts
Ghana has created a technical working group focused on One Health including Ministries of Health; Food and Agriculture; and Environment, Science, Technology, and Innovation
Share information and data across nations, and across levels and sectors of government
Peru installed a multisectoral committee on zoonoses, including representatives from Ministries of Defense, Interior, Foreign Trade, Agriculture, Production, Environment, Transport, and Communication
Fostering Transparency
Increase communication between the public and private sectors
In South Africa, public-private partnerships such as SAMLIT work to reduce poaching and wildlife trafficking
Report up-to-date information transparently, in an accurate and timely manner
When Marburg virus was discovered in Tanzania in 2023 the government quickly alerted the public and the WHO
Discourage restriction of information sharing at all levels of government
Sweden has a strong open records act, shares publicly data from wildlife disease sampling, and reports outbreaks quickly to WOAH and WHO
Ensure animal systems are kept in public view and in view of regulators
Kajiado County, Kenya has measures in place employing veterinary officers at animal markets for disease surveillance and health checks of animals for sale
Engaging and Educating Stakeholders
Communicate risks to producers and consumers
Hendra education campaigns among horse owners in Australia sought to reduce contact between horses and bats
Address and correct misinformation
Community-based radio programs in the DRC sought to address misinformation about how Ebola is transmitted and educate listeners on prevention
Listen to stakeholder feedback and identify obstacles to improvement
Educational campaigns using social marketing reduced consumption of wild meat dramatically in Amazonia, Brazil
Building Information Pathways and Templates
Develop templates to analyze and meaningfully compare risks
While not yet been employed, an effective framework would account for the frequency and intensity of zoonotic risks
Create and formalize processes for sharing data
In the UAE, systematic team reporting for data analysis and risk assessment is in place at both district and Emirate levels
Establish protections for whistleblowers and pathways for anonymous reporting
New Zealand's Protected Disclosures Act offers legal protection to employees who report issues related to animal welfare and food safety in the agricultural sector


Aligning Incentives
Aligning Incentives
Encourage Prevention
Incentivize protection of forests and intact ecosystems to preserve and enhance biodiversity
Forest protection payments in Brazil have been effective in slowing deforestation in the Amazon as have agreements by purchasers not to buy soy or cattle produced on illegally deforested land
Make available funding for preventative practices and measures
In Israel, policymakers subsidized reform measures for structural upgrades to improve the sanitary conditions in egg farms
Offer buyouts or economic alternatives to producers to phase out highest-risk industries
South Korea offered buyouts to bearbile farmers to help transition away from the practice
Promote Safe Practices
Encourage consumers to make safer choices
In the US, labels allow consumers to select meat raised without antibiotics
Ensure long-term food-security goals reduce zoonotic risks overall
In Belgium, many pig producers elected to accept payments to transition out of the livestock industry
Establish accountability measures for private interests to internalize public health costs
Slaughter levies fund food-animal production insurance against major disease outbreaks in the Netherlands
Increase Reporting
Mandate reporting and expand the list of notifiable diseases
Australia requires reporting of equine influenza and others beyond those diseases for which reporting is required by the WHO or WOAH
Facilitate cross-reporting among industries
This could include policies that encourage cooperation between industries to combat shared disease threats
Provide legal and economic protections for producers that incentivize reporting
In the US, indemnification payments incentivize disease reporting among livestock producers
Facilitate Compliance
Remove frictional barriers to compliance
Kenya implemented a mobile phone-based disease reporting system that increased reporting of illness among livestock
Identify and root out corruption
The Kenyan Wildlife Service has implemented a risk-based approach to identify and prevent corruption, while increasing transparency
Employ top-down value signaling to promote safe practices
Gabon's former president worked to protect wildlife habitat and publicly pledged to stop consuming wild meat


Evidence-Based Policymaking
Evidence-based Policymaking
Close Regulatory Gaps
Set standards for unregulated industries
The US set standards in 2022 governing the ownership of big cats, which was previously unregulated in many states, and prohibited public interactions with cubs
Close existing loopholes in regulation
In 2022, the EU closed a loophole that had allowed livestock producers to continue to overuse antibiotics for growth promotion as "prophylactic use"
Establish clear, comprehensive regulatory definitions
This could include establishing well-considered, scientific-based definitions for "livestock" "free-roaming wildlife" or "farmed wildlife" that do not leave any groups of animals undefined or unregulated
Reduce Unnecessary Risks
Weigh and balance risks and benefits of animal industries
Gabon prohibited consumption of certain high-risk wildlife species: bats and pangolins
Better regulate or eliminate high-risk practices that offer limited public benefit
Israel has banned fur farming and the sale of fur products, as production of fur drives risk upstream in the country of origin
Invest in lower risk alternatives
Israel has invested heavily in alternative protein production
Better Regulate Necessary Risks
Reduce the number of human-animal interfaces
The UAE is implementing automated slaughterhouses that minimize human-animal interaction
Limit interactions between animals and between different species of animals
Germany has put restrictions on the number of species and animals that can be sold at animal fairs or expos
Require additional biosafety protections for workers with occupational exposure to animals
In the US, NIH has established PPE and handling requirements for researchers interacting with non-human primates, which could be expanded and applied to other forms of animal industries
Improve Ability to Implement
Clarify enforcement duties and clearly delineate responsibilities
This could include clarifying jurisdictional limits, enforcement measures, and capacities, as well as ensuring that officials have appropriate training and clearly understand their role and function
Identify and remove logistical barriers to enforcement
In Brazil, IBAMA runs wildlife rehabilitation centers so officials do not avoid enforcing wildlife laws for lack of a place to keep confiscated animals
Ensure adequate funding and training for enforcement officials
Australia's border biosecurity measures reduced the risk of importing and introducing ranaviruses carried by amphibians

David Chancellor / Trophy Hunting and Taxidermy, South Africa

# TAKEAWAYS

Human-animal interactions are as diverse as they are ubiquitous. In looking longitudinally across countries, examining both risk and regulatory response, patterns and themes emerge that echo across multiple jurisdictions. A selection of these global takeaways are further distilled below. Chief among them is the idea that although many zoonotic outbreaks are preventable, current regulation is not proportional to risk. Taken together, they tell a story of a serious and pressing threat to global health security—one that has too often been overlooked and underappreciated. This is particularly true in the Global North, where many consider zoonotic disease to be a threat that belongs more in the last century than the current one. However, human-animal interactions in every country across the globe contribute to zoonotic risk. Supply chains span different continents and demand from wealthy consumer nations such as the US, which itself processes more than 10 billion animals each year, also drives high-risk practices in much of the developing world. In this globalized economy, risk, too, is globalized, and no amount of us-versus-them thinking can overcome this fundamental truth.

*In this globalized economy, risk, too, is globalized, and no amount of us-versus-them thinking can overcome this fundamental truth.*

These takeaways for the global community highlight some of the most important points that may inform strategies for how to better guard against future outbreaks and better manage our current risk:

1. ***Just as human-animal interactions occur everywhere, zoonotic disease risk is everywhere. Many (but not all) of these interactions and spillover events are driven by human use of animals.***

2. ***Animal production and human-animal interactions are growing in magnitude and diversifying in form and structure, outpacing regulation.***

3. ***There is no agreed-upon template or framework for zoonotic risk analysis.***

4. ***While risk cannot be eliminated, it can be reduced. Many zoonotic outbreaks are preventable and driven by non-subsistence animal usage.***

5. ***Current regulation is not proportional to risk, nor is the amount of funding dedicated to addressing these risks adequate.***

6. ***Siloing between human and animal health authorities (as well as among wildlife and livestock officials and across different industries and levels of government) undermines zoonotic disease mitigation and response.***

7. ***Policy that supports animal industries can increase zoonotic risk, and, in many countries, there is a reluctance among policymakers to regulate animal industries.***

8. ***The risks (including zoonotic risks) and rewards of animal industries are not distributed evenly.***

9. ***Policy that facilitates and incentivizes sustainable agricultural practices to minimize habitat destruction and domestic–wild animal interfaces would reduce the risk of zoonotic outbreaks.***

10. ***Animal use should be regulated more effectively and decreased overall to reduce zoonotic risk.***

Shatabdi Chakrabarti / FIAPO / We Animals Media

Molly Condit / Sinergia Animal / We Animals Media

# CONCLUSION

Zoonotic disease is a global threat. Human-animal interactions occur in every country on Earth, and each of those interactions carries zoonotic risk. These risks are not random. Across diverse countries and cultural contexts, the patterns of human behavior that give rise to zoonotic spillover remain surprisingly similar from one country to the next, though the details and conditions of each vary. The hallmark of most is a moment of close contact between humans and animals.

Zoonotic spillover events occur in predictable patterns, making them ripe for better regulation. Many interactions through which spillover occurs are driven by human use of animals for fur, food, fiber, entertainment, decoration, research, companionship, cosmetics, traditional medicine, religious use, and other purposes. Supply chains that move animals allow for the aggregation and distribution of the pathogens that they carry. And along these supply chains are opportunities for pathogens to move between animals and human hosts.

The problem, however, is not simply that the ways in which humans employ animals drive zoonotic risk, but that too often policymakers are acting indifferently or recklessly with respect to those risks—casually writing off serious threats without thinking about them or perhaps even recognizing them as threats at all. Palm civets, the suspected animal source of the SARS epidemic, are farmed to produce expensive specialty coffee made from their droppings. Raccoon dogs, who may have first spread COVID-19 to humans, are kept and killed in large numbers to make fur coats from their pelts. Are these risks justified? There might be some risks worth taking, but many others where this cost–benefit tilts grossly out of balance.

*The problem is not simply that the ways in which humans employ animals drive zoonotic risk, but that too often policymakers are acting indifferently or recklessly with respect to those risks.*

Collectively, policymakers must work to right these scales and act more deliberately with respect to the risks they take, to replace indiscriminate animal use with thoughtful use, and to analyze and appreciate the dangers posed by different forms of animal industry in order to make informed appraisals about when such risk is justified and when it is not. And they must move to reduce and manage risk wherever possible. These challenges demand humility and cultural sensitivity. Yet, much of this work could be done in ways that would scarcely be felt by the public at large.

Because zoonotic outbreaks are not random and instead follow predictable patterns, because zoonotic disease emergence is often driven by human actions, and because so often the activities and industries driving zoonotic disease risk operate with few safeguards in place, law and policy are essential tools to address zoonotic threats. Patterns of disease emergence can be disrupted through more effective regulation, and the high-risk human activities that generate risk can be reduced, reformed, and better monitored. Not only do law and policy have the potential to affect zoonotic threats, they are sorely needed in circumstances such as these where private interests can operate contrary to public health—often with little oversight and large externalized costs.

While it is widely accepted that outbreaks can be better contained through effective policy, what is equally true, and more seldom recognized, is the fact that, through better law and policy, many outbreaks can be prevented. When used to their potential, these are powerful guardrails to protect global health security.

Balvik C. / We Animals Media

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231. *See* UAE case study.
232. Alisa Davies et al., "Live Wild Birds Exports from West Africa: Insights into Recent Trade from Monitoring Social Media," *Bird Conservation International* 32, no. 4 (2022): 559–72, https://ora.ox.ac.uk/objects/uuid:1487bbf0-0997-4f14-8f84-55b5e00654cd.
233. There, the legal and illegal exotic pet trade were until recently quite visibly connected, even at the point of sale, but now the illegal exotic pet trade has retreated somewhat into shadow, in part due to the 2017 law.
234. Particularly when demand for wildlife cannot be met with legal sources, increased illegal trade may result. Derek P. Tittensor et al., "Evaluating the Relationships Between the Legal and Illegal International Wildlife Trades," *Conservation Letters* 13, no. 5 (2020): e12724, https://conbio.onlinelibrary.wiley.com/doi/full/10.1111/conl.12724.
235. The number of actual documented seizures of illegally traded wildlife represent "an absolute lower bound" of the true level of illegal trade activity. Derek P. Tittensor et al., "Evaluating the Relationships Between the Legal and Illegal International Wildlife Trades," *Conservation Letters* 13, no. 5 (2020): e12724, https://conbio.onlinelibrary.wiley.com/doi/full/10.1111/conl.12724.
236. For example, in the wild bird trade, researchers have found: 1) Misdeclaration of parrot species as non-CITES species on paper work; 2) Mammals mixed with bird species and shipped or transported together; 3) People responsible for inspecting imports of wildlife are unable to differentiate species to determine if paperwork matches birds in containers; 4) Traffickers may seek to disguise CITES Appendix I listed parrots as other species, for example by using a fine green mesh netting on containers of gray parrots to make them appear as "green parrots"; 5) Permits for species that are extinct—so the species will be flagged when someone types the species' name into the CITES database. *See* UAE Case Study.
237. Sometimes legal status depends on what purpose the animal will be used for. In other cases, the line between legal and illegal trade may be fainter still; for example, some nations allow the sale of ivory that was collected from elephants prior to a certain historical date. Distinctions such as these can make it extremely difficult for enforcement authorities to distinguish between legal and illegal shipments.
238. In countries such as Vietnam and Brazil, the practices of the captive-bred wildlife industry underscore the close connection to the illegal wildlife trade. For example, a 2020 report by the NGO TRAFFIC documented "widespread fraud and malpractice" on the part of amateur and commercial breeders who mislabel species declarations, forge permits, and tamper with government identifications in order to sell illegally obtained wild animals. Sandra Charity and Juliana Machado Ferreira, "Wildlife Trafficking in Brazil," *TRAFFIC*, July 2020, https://www.traffic.org/site/assets/files/13031/brazil_wildlife_trafficking_assessment.pdf.
239. Özgün Emre Can, Neil D'Cruze, and David W. Macdonald, "Dealing in Deadly Pathogens: Taking Stock of the Legal Trade in Live Wildlife and Potential Risks to Human Health," *Global Ecology and Conservation* 17 (2019): e00515, https://www.sciencedirect.com/science/article/pii/S2351989418302312.
240. Marcos A. Bezerra-Santos et al., "Illegal Wildlife Trade: A Gateway to Zoonotic Infectious Diseases," *Trends in Parasitology* 37, no. 3 (2021): 181–4, https://pubmed.ncbi.nlm.nih.gov/33454218/.
241. Marcos A. Bezerra-Santos et al., "Illegal Wildlife Trade: A Gateway to Zoonotic Infectious Diseases," *Trends in Parasitology* 37, no. 3 (2021): 181–4, https://pubmed.ncbi.nlm.nih.gov/33454218/.
242. Some rare birds are purchased for tens of thousands of dollars, with middlemen selling each for thirty times their purchase price, allowing the practice to remain profitable even when the majority of animals die in transit. Denise Hruby, "Bird Smuggler Turned Gamekeeper: The Man Shining a Light on Illegal Wildlife Trade," *The Guardian,* Aug. 21, 2022, https://www.theguardian.com/environment/2022/aug/01/it-is-the-best-business-the-man-who-smuggled-birds-across-europe.
243. In light of new connections made between wildlife trafficking and other illegal trades or the financing of corrupt regimes or terrorism, many countries have sought to strengthen penalties for wildlife trafficking, but few have taken serious steps to reduce the legal trade.
244. Elizabeth R. Rush, Erin Dale, and A. Alonso Aguirre, "Illegal Wildlife Trade and Emerging Infectious Diseases: Pervasive Impacts to Species, Ecosystems and Human Health," *Animals: An Open Access Journal from MDPI* 11, no. 6 (2021): 1821. https://doi.org/10.3390/ani11061821.
245. For example, simian foamy virus has been detected in shipments of wild meat entering the US illegally. "Wildlife Trade, COVID-19, and Other Zoonotic Diseases," *Congressional Research Service,* February 19, 2021, https://crsreports.congress.gov/product/pdf/IF/IF11494.
246. Steven Van Borm et al., "Highly Pathogenic H5N1 Influenza Virus in Smuggled Thai Eagles, Belgium," *Emerging Infectious Diseases* 11, no. 5 (2005): 702–705. https://doi.org/10.3201/eid1105.050211.
247. "Taiwan Finds 3rd Case of Deadly H5N1 Virus in Birds Smuggled From China," *Medical Daily,* July 17, 2012, https://www.medicaldaily.com/taiwan-finds-3rd-case-deadly-h5n1-virus-birds-smuggled-china-241383.
248. Elizabeth R. Rush, Erin Dale, and A. Alonso Aguirre, "Illegal Wildlife Trade and Emerging Infectious Diseases: Pervasive Impacts to Species, Ecosystems and Human Health," *Animals : An Open Access Journal from MDPI* 11, no. 6 (2021): 1821. https://doi.org/10.3390/ani11061821.
249. Bruno M. Ghersi et al., "Wide Distribution and Ancient Evolutionary History of Simian Foamy Viruses in New World Primates," *Retrovirology* 12, no. 89 (2015): https://doi.org/10.1186/s12977-015-0214-0.
250. Vincent Nijman, "Illegal and Legal Wildlife Trade Spreads Zoonotic Diseases," *Trends in Parasitology* 37, no. 5 (May 2021): https://doi.org/10.1016/j.pt.2021.02.001.
251. William S. Symes et al., "The Gravity of Wildlife Trade," *Biological Conservation* 28 (Feb. 2018): 268-276, https://doi.org/10.1016/j.biocon.2017.11.007.
252. "Illegal Wildlife Trade Has Become One of the 'World's Largest Criminal Activities," *Interpol*, Nov. 6, 2023, https://www.interpol.int/en/News-and-Events/News/2023/Illegal-wildlife-trade-has-become-one-of-the-world-s-largest-criminal-activities.
253. For example, mpox was introduced to the US through legal wildlife imports, and some customers who purchased infected animals and later tested positive for the virus themselves expressed surprise that animals purchased legally were not "safe." B. Lee Ligon, "Monkeypox: A Review of the History and Emergence in the Western Hemisphere," *Seminars in Pediatric Infectious Disease* 15, No. 4 (2004): 280–287, doi: 10.1053/j.spid.2004.09.001.
254. Peter Jahrling et al., "Preliminary Report: Isolation of Ebola Virus from Monkeys Imported to USA," *The Lancet* 335, no. 8688 (March 1990): 502-505, https://doi.org/10.1016/0140-6736(90)90737-P.
255. Nguyen Quynh Huong et al., "Coronavirus Testing Indicates Transmission Risk Increases Along Wildlife Supply Chains for Human Consumption in Viet Nam, 2013–2014," *PLoS ONE* 15, no. 8 (2020): e0237129, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0237129.
256. John Scanlon, " Wildlife Must be Protected from Crime and Trade for the Sake of Public and Planetary Health," *PLoS Biology* 19, no.10 (2021): e3001422, https://doi.org/10.1371/journal.pbio.3001422.
257. CITES is a global policy tool with 184 participating member parties meant to ensure that wildlife are captured, hunted, traded, and consumed in a sustainable way that will not drive species into extinction. Derek P. Tittensor et al., "Evaluating the Relationships Between the Legal and Illegal International Wildlife Trades," *Conservation Letters* 13, no. 5 (2020): e12724, https://conbio.onlinelibrary.wiley.com/doi/full/10.1111/conl.12724.
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259. Anne-Lise Chaber et al., "Bat E-Commerce: Insights Into the Extent and Potential Implications of This Dark Trade," *Frontiers in Veterinary Science* 8 (2021):651304, https://doi.org/10.3389/fvets.2021.651304.
260. Convention on International Trade in Endangered Species Appendices I, II, and III, https://cites.org/sites/default/files/eng/app/2023/E-Appendices-2023-11-25.pdf.
261. This is true so long as the exporting and importing countries are permissive of the transaction.
262. Freyja Watters et al., "The US Market for Imported Wildlife Not Listed in the CITES Multilateral Treaty," *Conservation Biology: The Journal of the Society for Conservation Biology* 36, no. 6 (2022):e13978, https://doi.org/10.1111/cobi.13978.

263. CITES requirements and enforcement mechanisms have limitations and are often circumvented.
264. However, the same screening systems put in place by nations for conservation purposes could be leveraged to enforce public health restrictions and improve disease surveillance if applied to different ends.
265. Stefan Borsky et al., "CITES and the Zoonotic Disease Content in International Wildlife Trade," *Environmental and Resource Economics* 76 (2020): 1001–17, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7399621/pdf/10640_2020_Article_456.pdf.
266. CITES lists over 38,000 species for whom trade is to be regulated or banned; each species is placed into one of three categories of protection. Species belonging to "Appendix I" require an export permit from the country of origin as well as an import permit from the destination country; species in "Appendix II" require an export permit from the country of origin; species in "Appendix III" require export permits from some countries, but generally only a certificate of origin is required. All signatory countries must enact and enforce national legislation implementing CITES.
267. While incomplete, CITES data are important and useful; the data available can give us a sense of the species, countries, and destinations involved in the trade, as well as changes over time.For example, figures extracted from the CITES database show a marked reduction in some taxa around 2020, when COVID-19 began to spread, affecting not only global markets and trade, but the movement of animals particularly. It is important to note that CITES requires export permits for the species it tracks, but import permits are only needed by countries that nationally require them. Because of this, there is some disparity across participating nations between the number of exports reported and where they are being imported. "CITES Trade Database," *Convention on the International Trade in Flora and Fauna*, accessed January 24, 2023, https://trade.cites.org/.
268. The trade in both CITES-listed and non-listed species continues, largely undeterred— sometimes underground, sometimes in plain sight. In the UAE Case Study, sources reported that wealthy travelers can sometimes print their own CITES passes, sight unseen, in private airport terminals.
269. This includes the affluent countries driving the demand as well as the source countries where socioeconomic realities seem to depend upon supplying that demand.
270. The term "foreign pathogen" refers to a pathogen causing disease that is not endemic or otherwise found in a region but that may be found elsewhere in different parts of the world and introduced, for example, through the global wildlife trade.
271. In 2019, the US legally imported more than 224 million live wild animals and 883 million wildlife products worth over $4.3 billion. K. M. Smith et al., "Summarizing US Wildlife Trade with an Eye towards Assessing the Risk of Infectious Disease Introduction," *Ecohealth* 14, No. 1 (2017): 29-39, doi: 10.1007/s10393-017-1211-7; "Law Enforcement at a Glance," *U.S. Fish and Wildlife Service*, last modified March 28, 2020, https://www.documentcloud.org/documents/6843670-U-S-Fish-and-Wildlife-Service-Law-Enforcement-at.
272. According to previous research, between 2012 and 2016, the US was the largest importer of live wildlife species listed under CITES, alongside France, Spain, the UAE, and Qatar. Among the rest of the top 10 importers during this time period were Japan, Thailand, South Africa, and Malaysia. Overall, China exported the most animals, followed by Cambodia, Vietnam, South Africa, Ghana, the US, Indonesia, Togo, the UAE, and the Czech Republic. Özgün Emre Can, Neil D'Cruze, and David W. Macdonald, "Dealing in Deadly Pathogens: Taking Stock of the Legal Trade in Live Wildlife and Potential Risks to Human Health," *Global Ecology and Conservation* 17 (2019): e00515, https://www.sciencedirect.com/science/article/pii/S2351989418302312.
273. "China's Role in Wildlife Trafficking and the Chinese Government's Response," U.S.-China Economic and Security Review Commission Staff Research Report, Dec. 6, 2018, https://www.uscc.gov/sites/default/files/Research/2018.12.06%20-%20Wildlife%20Trafficking%20-%20Final%20Version.pdf.
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275. *See* US Case Study.
276. Rachel Nuwer, "Many Exotic Pets Suffer or Die in Transit, and Beyond—and the US Government is Failing to Act," *National Geographic,* March 2, 2021, https://www.nationalgeographic.com/animals/article/exotic-pets-suffer-wildlife-trade,
277. "Update: Multistate Outbreak of Monkeypox—Illinois, Indiana, Kansas, Missouri, Ohio, and Wisconsin, 2003," *CDC MMWR Weekly*, July 11, 2003, 52(27): 642-646, https://www.cdc.gov/mmwr/preview/mmwrhtml/mm5227a5.htm.
278. B. Lee Ligon, "Monkeypox: A Review of the History and Emergence in the Western Hemisphere," *Seminars in Pediatric Infectious Disease* 15, No. 4 (2004): 280–287, doi: 10.1053/j.spid.2004.09.001.
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280. Sandra Charity and Juliana Machado Ferreira, "Wildlife Trafficking in Brazil," TRAFFIC, July 2020, https://www.traffic.org/site/assets/files/13031/brazil_wildlife_trafficking_assessment.pdf.
281. Dimas Marques, "In Brazil's Wildlife Care Centers, Struggles and Successes Go Unseen," *Mongabay.org*, Nov. 25, 2021, https://news.mongabay.com/2021/11/in-brazils-wildlife-care-centers-struggles-and-successes-go-unseen/.
282. For example, one study found that 88% of wildlife officials surveyed in Vietnam believe that the country has an insufficient number of wildlife rescue centers and resources needed for them to operate and enforce the laws effectively. Thu Thuy Pham et al., "Policymaker Perceptions of COVID-19 Impacts, Opportunities and Challenges for Sustainable Wildlife Farm Management in Vietnam," *Environmental Science & Policy* 136 (2022): 497-509, doi:10.1016/j.envsci.2022.07.017.
283. Freyja Watters and Phill Cassey, "'Astonishing': Global Demand for Exotic Pets is Driving a Massive Trade in Unprotected Wildlife," *Phys.org*, October 7, 2022, https://phys.org/news/2022-10-astonishing-global-demand-exotic-pets.html.
284. Nguyen Quynh Huong et al., "Coronavirus Testing Indicates Transmission Risk Increases Along Wildlife Supply Chains for Human Consumption in Viet Nam, 2013–2014," *PLoS ONE* 15, no. 8 (2020): e0237129, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0237129.
285. Giulia I. Wegner et al., "Averting Wildlife-Borne Infectious Disease Epidemics Requires a Fon Socio-Ecological Drivers and a Redesign of the Global Food System," *The Lancet* 47 (2022): 101386, https://doi.org/10.1016/j.eclinm.2022.101386.
286. Raina K. Plowright et al., "Ecological Countermeasures to Prevent Pathogen Spillover and Subsequent Pandemics," *Nature Communications* 15 (2024): 2577, https://doi.org/10.1038/s41467-024-46151-9.
287. "Wildlife farming," as the term is used in this discussion, includes removing eggs or young animals from the wild and raising them in captivity— a practice that is sometimes referred to as "wildlife ranching."
288. In each of these cases, a form of coronavirus is believed to have spilled over to humans from contact with captive wildlife. While the first connection is well established, the second remains speculative.
289. Jessica Bell Rizzolo, "Wildlife Farms, Stigma and Harm," *Animals* 10, no. 10 (2020): 1783, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7601737/.
290. Wildlife farming is a form of captive breeding that encompasses a wide range of practices in which wild animals are raised commercially for human use; however, it does not include all forms of captive breeding. In particular, captive breeding for non-commercial purposes, such as the breeding of an endangered species as part of a species survival plan would not be considered wildlife farming.
291. Though the term "wildlife farming" has been used most frequently to describe commercial captive-breeding operations in developing nations, wildlife farming occurs in high-income countries as well, particularly, in the US, where a wide range of wild species are bred for eating, hunting, research, or for sale as exotic pets. However, though these practices fall within the definition of wildlife farming, they are often described by different languages. For example, facilities breeding various exotic species of birds for hunting or for sale to animal markets in the US are known as "commercial upland game bird producers," though these operations fall squarely within the definition of wildlife farm and would be referred to as such if they existed in China, for instance.
292. Jennah Green, Jan Schmidt-Burbach, and Angie Elwin, "Taking Stock of Wildlife Farming: A Global Perspective," *Global Ecology and Conservation* 43 (2023): e02452, https://doi.org/10.1016/j.gecco.2023.e02452.
293. This statistic is drawn from a number of different sources, but is supported here where 42% of more than 3000 species of reptiles in the trade in LEMIS data are captive bred: Benjamin M. Marshall, Colin Strine, and Alice C. Hughes, "Thousands of Reptile Species Threatened by Under-Regulated Global Trade," *Nature Communications* 11 (2020): 4738, https://www.nature.com/articles/s41467-020-18523-4.
294. In addition, most veterinarians or other animal health professionals have little formal training involving wildlife and may be unfamiliar with many wildlife diseases.
295. Jennah Green, Jan Schmidt-Burbach, and Angie Elwin, "Taking Stock of Wildlife Farming: A Global Perspective," *Global Ecology and Conservation* 43 (2023): e02452, https://doi.org/10.1016/j.gecco.2023.e02452.
296. Some estimates place the total number of animals raised on wildlife farms each year closer to 5.5 billion. "Bred for Profit: The Truth about Global Wildlife Farming," *World Animal Protection*, March 4, 2024, https://www.worldanimalprotection.org/globalassets/pdfs/reports/english/bred-for-profit-report-on-global-wildlife-farming.pdf.

297. In fact, few countries even define what constitutes "wildlife farming." In a twelve-country survey researchers found that only one provided any definition for the term. Jennah Green, Jan Schmidt-Burbach, and Angie Elwin, "Taking Stock of Wildlife Farming: A Global Perspective," *Global Ecology and Conservation* 43 (2023): e02452, https://doi.org/10.1016/j.gecco.2023.e02452.
298. Jennah Green, Jan Schmidt-Burbach, and Angie Elwin, "Taking Stock of Wildlife Farming: A Global Perspective," *Global Ecology and Conservation* 43 (2023): e02452, https://doi.org/10.1016/j.gecco.2023.e02452.
299. In addition, the types of zoonotic pathogens circulating among wildlife vary with geographic location, species type, and other environmental factors.
300. The human–animal interactions that occur on wildlife farms include many of the same close contacts that occur during the course of livestock production: handling, feeding, cleaning, transporting, killing, and processing.
301. Najmul Haider et al., "COVID-19: Zoonosis or Emerging Infectious Disease?" *Frontiers in Public Health* 8 (2020): 596944, https://doi.org/10.3389/fpubh.2020.596944.
302. Xiaowei Jiang and Ruoqi Wang, "Wildlife Trade is Likely the Source of SARS-CoV-2," *Science* 377, no. 6609 (2022): 925–6, https://www.science.org/doi/full/10.1126/science.add8384.
303. Civet cats produce an estimated 50 tons of digested coffee beans each year. A single cup of kopi luwak coffee can cost thirty dollars or more at restaurants in the US or Europe, where they are sipped far away from the thin wire cages where the animals are held and fed an unhealthy diet of almost exclusively coffee cherries. Yenni Kwok, "The World's Most Expensive Coffee is a Cruel Cynical Scam," *Time*, October 2, 2013, https://world.time.com/2013/10/02/the-worlds-most-expensive-coffee-is-a-cruel-cynical-scam/.
304. Yunbo Jiao and Tien Ming Lee, "China's Conservation Strategy Must Reconcile Its Contemporary Wildlife Use and Trade Practices," *Frontiers in Ecology and Evolution* 9 (2021): 675400, https://www.frontiersin.org/articles/10.3389/fevo.2021.675400/full.
305. Notably, this view is endorsed by the Convention on International Trade in Endangered Species of Wild Fauna and Flora.
306. Jennah Green, Jan Schmidt-Burbach, and Angie Elwin, "Taking Stock of Wildlife Farming: A Global Perspective," *Global Ecology and Conservation* 43 (2023): e02452, https://doi.org/10.1016/j.gecco.2023.e02452.
307. However, countries that are reliant on animal-based tourism may be more susceptible to public pressure to curb the USe of certain wildlife. When South Africa's captive lion breeding industry came under international scrutiny for poor conditions and possible disease risks, the government changed course and decided to shutter the industry on the basis that it "was doing damage to South Africa's conservation and tourism reputation." For the full statement by Barbara Creecy, the minister of South Africa's Department of Forestry, Fisheries and the Environment, see: https://www.gov.za/news/speeches/minister-barbara-creecy-release-high-level-panel-report-reviewing-policies-and ; "South Africa to Clamp Down on Captive Lion Breeding," *Reuters*, May 2, 2021, https://www.reuters.com/world/africa/south-africa-clamp-down-captive-lion-breeding-minister-says-2021-05-02/; Rachel Fobar, "South Africa Plans to End Controversial Captive Lion Industry," *National Geographic*, May 3, 2021, https://www.nationalgeographic.com/animals/article/south-africa-bans-lion-farming.
308. Peter Li, "Reopening the Trade After SARS: China's Wildlife Industry and the Fateful Policy Reversal," *Environmental Policy and Law* 50, no. 3 (2020): 251–67, https://content.iospress.com/articles/environmental-policy-and-law/epl201008.
309. Jane Parry, "WHO queries culling of civet cats," *British Medical Journal* 328, no. 7432 (2004):128, doi: 10.1136/bmj.328.7432.128-b.
310. Margaret Harris Cheng, "SARS Source Back on the Menu," *The Lancet Infectious Diseases* 7, no.1 (2007): 14, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7130012/.
311. In China, the practice began as early as the 1950's, grew in the 1980's, but was not formally legalized until 2003.
312. Yunbo Jiao and Tien Ming Lee, "China's Conservation Strategy Must Reconcile Its Contemporary Wildlife Use and Trade Practices," *Frontiers in Ecology and Evolution* 9 (2021): 675400, https://www.frontiersin.org/articles/10.3389/fevo.2021.675400/full.
313. In 2016, the annual production value of wildlife farming was estimated at USD 80 billion. Wei Xia et al., "How One Pandemic Led to Another: Was African Swine Fever Virus (ASFV) the Disruption Contributing to Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) Emergence?" *Preprints* (2021): 2021020590, https://www.preprints.org/manuscript/202102.0590/v2.
314. Peter J. Li, "Enforcing Wildlife Protection in China: The Legislative and Political Solutions," *China Information* 21, no. 1 (2007): 71–107, https://journals.sagepub.com/doi/10.1177/0920203X07075082; see also footnote 69 here: Li Yuming, "Tantan fazhan woguo yesheng dongwu yangzhiye de jige wenti" (On a number of questions regarding China's wildlife farming industry), Chinese Wildlife 19, no. 6 (1998): 26–8, https://animallawconference.org/wp-content/uploads/2015/09/Enforcing-Wildlife-Protection-in-China.pdf.
315. Jian Zhang Ma, Research Report on the Sustainable Development Strategy of China's Wildlife Farming Industry (Chinese Academy of Engineering, 2017) 130 <http://106.3.149.172/ZKbaogao/ZkbgDetail?sysid=2089> accessed November 19, 2020 (in Chinese); Yunbo Jiao and Tien Ming Lee, "China's Conservation Strategy Must Reconcile Its Contemporary Wildlife Use and Trade Practices," *Frontiers in Ecology and Evolution* 9 (2021): 675400, https://doi.org/10.3389/fevo.2021.675400.
316. The growth has not been linear nor uniform across different countries or species. Within the wildlife farming industry, some uses, like fur, have declined in recent years. In China, for example, the number of mink and raccoon dogs raised for fur has dropped since 2015, from 60.6 million to 25.3 million in 2019. Wei Xia et al., "How One Pandemic Led to Another: Was African Swine Fever Virus (ASFV) the Disruption Contributing to Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) Emergence?" *Preprints* (2021): 2021020590, https://www.preprints.org/manuscript/202102.0590/v2.
317. Quyen Vu et al, *An Analysis of Wildlife Farming in Vietnam* (Hanoi: Education for Nature–Vietnam (ENV), 2017), https://env4wildlife.org/wp-content/uploads/2021/03/Farming-Report-Oct-23-2017.pdf.
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320. "Wildlife Farming in Viet Nam: Southern Viet Nam's Wildlife Farm Survey Report in a Glance," Food and Agriculture Organization of the United Nations, accessed October 21, 2023, https://www.fao.org/3/az118e/az118e.pdf.
321. "SA Reclassifies Wild Species as Farm Animals," *Getaway,* October 17, 2019, https://www.getaway.co.za/travel-news/sa-reclassifies-wild-species-as-farm-animals/#:~:text=The%20South%20African%20government%20have,categorised%20by%20this%20new%20status.
322. It is sometimes difficult to determine whether change in regulation drives change in practice or the other way around. Often, it's both. In this case, the Department of Environment Forestry and Fisheries (DEFF) said that the change was made "due to changing farming systems in South Africa," suggesting that, "game animals are included as these are already part of farm animal production systems in the country."
323. Ioannis Magouras et al., "Emerging Zoonotic Diseases: Should We Rethink the Animal–Human Interface?" *Frontiers in Veterinary Science* 7 (2020): 582743, https://www.frontiersin.org/articles/10.3389/fvets.2020.582743/full.
324. Jennah Green, Jan Schmidt-Burbach, and Angie Elwin, "Taking Stock of Wildlife Farming: A Global Perspective," *Global Ecology and Conservation* 43 (2023): e02452, https://doi.org/10.1016/j.gecco.2023.e02452.
325. *See* Vietnam Case Study.
326. *See also* Mai Trinh Thi et al., "Commercial Civet Farming Practices and Conservation Impacts on Wild Civet Populations in Central Vietnam," *Research Square*, Preprint (2022), https://assets.researchsquare.com/files/rs-1806075/v1/0d558491-d773-48ae-9ae5-602b2d258753.pdf?c=16582274.
327. Some states, like China, give producers license to "seed" these operations by capturing animals from the wild. But this can be far from a one-time thing. In many cases, especially with species that are difficult to breed in captivity, producers are constantly resupplying their farms with animals from the wild, introducing existing animals to new diseases— and creating a revolving door of risk.
328. This risk cuts both ways, as keeping a captive wildlife population may allow human diseases to spillover and establish themselves in animal populations, and potential spill-back to humans.
329. It is contested as to whether creating a parallel legal market for wildlife, especially one fed and continually replenished from the wild, is a net positive or a net negative for conservation of wild populations.
330. Miranda H. Mockrin, Elizabeth L. Bennett, and Danielle T. LaBruna, *Wildlife Farming: A Viable Alternative to Hunting in Tropical Forests?* WCS Working Paper No. 23 (Bronx: Wildlife Conservation Society, 2005), https://www.researchgate.net/publication/265424621_Wildlife_farming_A_viable_alternative_to_hunting_in_tropical_forests; Emma G. E. Brooks, Scott I. Roberton, and Diana J. Bell, "The Conservation Impact of Commercial Wildlife

Farming of Porcupines in Vietnam," *Biological Conservation* 143, no. 11 (2010): 2808–14, https://doi.org/10.1016/j.biocon.2010.07.030; Jessica A. Lyons and Daniel J. D. Natusch, "Wildlife Laundering Through Breeding Farms: Illegal Harvest, Population Declines and a Means of Regulating the Trade of Green Pythons (*Morelia viridis*) from Indonesia," *Biological Conservation* 144, no. 12 (2011): 3073–81, https://doi.org/10.1016/j.biocon.2011.10.002; Lauren Coad et al., *towardss a Sustainable, Participatory and Inclusive Wild Meat Sector* (Bogor Barat: Center for International Forestry Research, 2019), 176, https://www.cifor.org/publications/pdf_files/Books/BCoad1901.pdf.

331. Close to 100% of civet producers in Vietnam have reported taking animals from the wild. *See* Vietnam case study.
332. Mai Trinh Thi et al., "Commercial Civet Farming Practices and Conservation Impacts on Wild Civet Populations in Central Vietnam," *Research Square*, Preprint (2022), https://assets.researchsquare.com/files/rs-1806075/v1/0d558491-d773-48ae-9ae5-602b2d258753.pdf?c=16582274.
333. Xiaowei Jiang and Ruoqi Wang, "Wildlife Trade is Likely the Source of SARS-CoV-2," *Science* 377, no. 6609 (2022): 925–6, https://www.science.org/doi/full/10.1126/science.add8384.
334. Xiaowei Jiang and Ruoqi Wang, "Wildlife Trade is Likely the Source of SARS-CoV-2," *Science* 377, no. 6609 (2022): 925–6, https://www.science.org/doi/full/10.1126/science.add8384.
335. The price of meat from domestic animals can also affect demand for meat from wildlife. This is sometimes the case in the wake of disease outbreaks in livestock. For example, when the price of pork increased substantially due to large-scale losses from African Swine Fever Virus (ASFV), consumer demand increased in Thailand for certain forms of inexpensive wild meat like crocodile. There is some evidence to indicate that China might have experienced a similar spike in demand for wild meat driven by ASFV.
336. *See* China Case Study.
337. Lingyun Xiao, "Why Do We Need a Wildlife Consumption Ban in China?" *Current Biology* 31, no. 4 (2021): R168–72, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8860476/#!po=95.0000.
338. The range of species farmed in Vietnam is similarly diverse. In 2017, there were 9,280 legally registered farms containing a total of roughly 2,100,000 animals representing 263 species.Two years prior, in 2015,, a FAO pilot study found that 185 wildlife species were commercially farmed. These species included macaque monkeys, flying foxes, Asian palm civets, and many species of rodents, all of which are considered high-risk species for zoonoses. Trang Nghiem et al., "Understanding Wildlife Farming and Zoonotic Disease Management in Viet Nam," *Oxford University Clinical Research Unit, EcoHealth Alliance*, accessed April 11, 2024, https://www.ecohealthalliance.org/wp-content/uploads/2023/10/Full-Report-Final_v02.pdf; "Wildlife Farm Census to Ensure Safe and Healthy Wild Animal Products in Viet Nam," *Food and Agriculture Organization of the United Nations*, accessed November 20, 2023, https://www.fao.org/vietnam/news/detail-events/en/c/276998/. (https://docs.google.com/document/d/1GQz-wIRF3XKaCvIEIX3-iRTnoSANdyyPSRsfgNr7BLA/edit
339. Mink can take human viruses and give them an opportunity to reassort and develop new strains that can then be passed back to humans. In this way, mink and other species function like a fun house mirror— taking human viruses, changing and transforming them, and then reflecting them back to humans.
340. In many cases, raising wild animals has low barriers to entry, and little downside if the animals die. Relatively little capital is needed to start a wildlife farming enterprise—capturing and gathering wild animals, and feeding them household scraps or other types of low-value forage.
341. The many human–animal touchpoints across these supply chains provide multiple opportunities for spillover. In some cases these interfaces are more numerous than those presented by the hunting or capture of free-roaming wildlife. Because producers interact with animals from birth to death, disease exposure may be more significant and prolonged in wildlife farming compared to the wildlife trade.
342. Disease risk is present throughout supply chains that move wild animals and animal parts, but wildlife farms themselves are a critical node on this value chain and one that can (and perhaps should) be more heavily regulated.
343. All of these processes have potential to promote disease transmission.
344. Food and Agriculture Organization of the United Nations, *Wildlife Farming in Viet Nam* (Rome: FAO, 2014), https://www.fao.org/3/az118e/az118e.pdf.
345. Nguyen Quynh Huong et al., "Coronavirus Testing Indicates Transmission Risk Increases Along Wildlife Supply Chains for Human Consumption in Viet Nam, 2013–2014," *PLoS ONE* 15, no. 8 (2020): e0237129, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0237129.
346. Nguyen Quynh Huong et al., "Coronavirus Testing Indicates Transmission Risk Increases Along Wildlife Supply Chains for Human Consumption in Viet Nam, 2013–2014," *PLoS ONE* 15, no. 8 (2020): e0237129, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0237129.
347. Nguyen Quynh Huong et al., "Coronavirus Testing Indicates Transmission Risk Increases Along Wildlife Supply Chains for Human Consumption in Viet Nam, 2013–2014," *PLoS ONE* 15, no. 8 (2020): e0237129, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0237129.
348. Co-infection with multiple viruses or viral strains allows for recombination and may lead to the creation of new forms of viruses.
349. Typically, these are made of four wooden posts supporting a thin ceiling with palm fronds hanging underneath. Often domestic animals or crops are raised underneath these roost sites, which can also be used as a place for children to play. Nguyen Quynh Huong et al., "Coronavirus Testing Indicates Transmission Risk Increases Along Wildlife Supply Chains for Human Consumption in Viet Nam, 2013–2014," *PLoS ONE* 15, no. 8 (2020): e0237129, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0237129.
350. Nguyen Quynh Huong et al., "Coronavirus Testing Indicates Transmission Risk Increases Along Wildlife Supply Chains for Human Consumption in Viet Nam, 2013–2014," *PLoS ONE* 15, no. 8 (2020): e0237129, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0237129.
351. Another study of farmed civets across four provinces of Southern China found that more than 53% of fecal samples taken from the cages of captive civets carried parasitic pathogens that could infect humans, including those that cause Giardia. Zhengjie Yu et al., "Molecular Characterization and Zoonotic Potential of *Enterocytozoon bieneusi*, *Giardia duodenalis* and *Cryptosporidium* sp. In Farmed Masked Palm Civets (*Paguma larvata*) in Southern China," *Parasites & Vectors* 13 (2020): 403, https://parasitesandvectors.biomedcentral.com/articles/10.1186/s13071-020-04274-0.
352. Nguyen Quynh Huong et al., "Coronavirus Testing Indicates Transmission Risk Increases Along Wildlife Supply Chains for Human Consumption in Viet Nam, 2013–2014," *PLoS ONE* 15, no. 8 (2020): e0237129, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0237129.
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358. Wei Xia et al., "How One Pandemic Led to Another: Was African Swine Fever Virus (ASFV) the Disruption Contributing to Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) Emergence?" *Preprints* (2021): 2021020590, https://www.preprints.org/manuscript/202102.0590/v2.
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360. Lucy O. Keatts et al., "Implications of Zoonoses from Hunting and Use of Wildlife in North American Arctic and Boreal Biomes: Pandemic Potential, Monitoring, and Mitigation," *Frontiers in Public Health* 9 (2021): 627654, https://www.frontiersin.org/articles/10.3389/fpubh.2021.627654/full; Najmul Haider et al., "COVID-19: Zoonosis or Emerging Infectious Disease?" *Frontiers in Public Health* 8 (2020): 596944, https://doi.org/10.3389/fpubh.2020.596944; Nguyen Quynh Huong et al., "Coronavirus Testing Indicates Transmission Risk Increases Along Wildlife Supply Chains for Human Consumption in Viet Nam, 2013–2014," *PLoS ONE* 15, no. 8 (2020): e0237129, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0237129; Christine K. Johnson et al., "Global Shifts in Mammalian Population Trends Reveal Key Predictors of Virus Spillover Risk," *Proceedings of the Royal Society B* 287, no. 1924 (2020): 20192736, doi: 10.1098/rspb.2019.2736.
361. Jennah Green, Jan Schmidt-Burbach, and Angie Elwin, "Taking Stock of Wildlife Farming: A Global Perspective," *Global Ecology and Conservation* 43 (2023): e02452, https://doi.org/10.1016/j.gecco.2023.e02452.

362. The density of animals needed to sustain the spread of a particular pathogen is known as the host-density threshold. Populations below this threshold will not be affected by the diseases in the long term; populations above it will be. For example, imagine a pathogen requires a host density of 10 animals per square kilometer to sustain its spread within a particular species. If wild foxes are present in the area with an average of 3 animals per square kilometer, the pathogen will not be able to circulate in the long term among fox populations. But on a wildlife farm, where 2,000 foxes are held within one square kilometer, foxes are susceptible to this same pathogen that does not otherwise affect them in the wild, where animals are too spread out to sustain its spread.
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377. Angela Symons, "Could Fur Farming Be Banned in the EU? Here's Which Countries Still Support the Industry," *euronews.green*, June 16, 2023, https://www.euronews.com/green/2023/02/08/fur-import-ban-could-be-dropped-in-the-uk-heres-which-eu-countries-still-support-the-indus.
378. Much of the demand for fur now resides in Asia. In much of the rest of the world, demand for fur is declining. Annual production in the EU fell from 45 million mink in 2014 to 12 million in 2021 after Denmark's decision to cull 17 million mink in response to COVID-19 outbreaks on fur farms.
379. Prior to the mass cullings of mink carried out during the COVID-19 outbreak, Denmark had roughly three times more captive mink than people (17 million farmed mink, with a total human population of 5.792 million).
380. Fourteen of the EU member states have banned fur farming, and Great Britain and Israel have recently sought to eliminate the trade altogether by banning the sale of fur products.
381. Adolfo Arranz and Han Huang, "China's Wildlife Trade," *South China Morning Post*, March 4, 2020, https://multimedia.scmp.com/infographics/news/china/article/3064927/wildlife-ban/index.html.
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383. Mink in China are not vaccinated against influenza viruses.
384. A COVID-positive wild mink, caught outside of a Utah fur farm, sparked fears that the virus would begin circulating freely in wildlife, allowing it a permanent reservoir in nature. Hon S. Ip et al., "An Opportunistic Survey Reveals an Unexpected Coronavirus Diversity Hotspot in North America," *Viruses* 13, no. 10 (2021): 2016, https://www.mdpi.com/1999-4915/13/10/2016/htm#app1-viruses-13-02016. COVID has also spread to white-tailed deer and other species of native wildlife. "Latest Covid Twist: Coronavirus is Spreading in Deer, Study Finds—and Many are Getting It from Humans," *Global Center for Health Security,* August 29, 2023, https://www.unmc.edu/healthsecurity/transmission/2023/08/29/latest-covid-twist-coronavirus-is-spreading-in-deer-study-finds-and-many-are-getting-it-from-humans/#:~:text=The%20researchers%20said%20their%20findings,largely%20replaced%20by%20the%20omicron.
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386. Ten percent of the animals sampled were co-infected with more than one coronavirus, increasing the risk that a new form of coronavirus might develop.
387. Hon S. Ip et al., "An Opportunistic Survey Reveals an Unexpected Coronavirus Diversity Hotspot in North America," *Viruses* 13, no. 10 (2021): 2016, https://www.mdpi.com/1999-4915/13/10/2016/htm#app1-viruses-13-02016.
388. "We raise pheasants because people like to hunt them." Simply put, this statement from the Pennsylvania Game Commission distills the position of many states that support wildlife stocking programs across the US. Pheasant Management Program," *Pennsylvania Game Commission*, accessed January 16, 2023, https://www.pgc.pa.gov/Wildlife/WildlifeSpecies/Ring-NeckedPheasant/Pages/PheasantManagement.aspx.
389. Pheasant Management Program," *Pennsylvania Game Commission*, accessed January 16, 2023, https://www.pgc.pa.gov/Wildlife/WildlifeSpecies/Ring-NeckedPheasant/Pages/PheasantManagement.aspx.
390. In the US, hunters are free to butcher and eat the animals they kill, and states do not require health screening of animals bred and sold for this purpose. If a game bird producer raised and sold a bobwhite quail to a live bird market for butchering, the quail would be required to undergo health and safety checks before it could be sold and eaten by customers. But if that same quail were sold to a hunting preserve, the animal could be released, shot, and eaten, and no regulations would apply. In the latter case, public exposure to zoonotic pathogens may be higher as hunters often prepare animals without the same sanitary measures in place at retail establishments. For example, only 16% of duck hunters wear gloves when handling and defeathering dead birds. Hope O. Dishman, David E. Stallknecht, and Dana Cole, "Duck Hunters' Perceptions of Risk for Avian Influenza, Georgia, USA," *Emerging Infectious Diseases* 16, no 8 (2010): 1279–81, https://doi.org/10.3201/eid1608.100032.
391. The risk from influenza may be greatest where commercial game bird facilities operate in proximity to poultry or swine production facilities. North Carolina, which produces more hogs than any other state, also produces four million game birds annually on wildlife farms. "Interested into Getting into the Upland Gamebird Business?" *South Eastern Gamebird Breeders & Hunting Preserve Association*, accessed November 9, 2023, https://segamebirds.us/interested-into-getting-into-the-upland-gamebird-business/.
392. Roy Graber, "Track 2022–23 Avian Influenza Outbreaks in North American Poultry," *WATTPoultry*, accessed November 9, 2023, https://www.wattagnet.com/egg/article/15535341/track-2022-avian-influenza-outbreaks-in-north-american-poultry.
393. Many of these outbreaks coincide with wild bird migrations. After a spate of outbreaks in the spring, in October 2022, as wild populations traveled south through the Central Flyway, H5N1 influenza returned, infecting a production facility in Nebraska that contained 159,000 game birds, all of whom were culled to contain the virus's spread. Roy Graber, "159,500 Nebraska Commercial Gamebirds Lost to Avian Flu," *WATTPoultry*, October 5, 2022, https://www.wattagnet.com/articles/45921-159-500-nebraska-commercial-gamebirds-lost-to-avian-flu.

394. Ring-necked pheasants are not native to the US and were originally imported from China and East Asia for hunting. "Common Pheasant," *National Geographic*, accessed November 10, 2023, https://www.nationalgeographic.com/animals/birds/facts/common-pheasant?loggedin=true&rnd=1673972893090.
395. While this practice of stocking public lands with farm-raised wildlife might come as a surprise to many Americans, it speaks to the cultural value placed on hunting, and perhaps to the financial structure of the regulatory agencies governing it who are largely dependent on the individuals they regulate for funding. Left out of these agency mandates is any discussion of public health. While the birds cost about $13 each, the true cost in terms of human health and ecosystem health might be much higher.
396. Douglas Main, "A Behind-the-Scenes Look at Texas' Exotic Animal Ranches," *National Geographic*, July 7, 2020, https://www.nationalgeographic.com/animals/article/inside-texas-exotic-animal-ranching-industry.
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398. Wes Ferguson, "How Texas Hunting Went Exotic," *Texas Monthly*, February 2021, https://www.texasmonthly.com/travel/how-texas-hunting-went-exotic/.
399. "Texas Administrative Code," Title 4, Part 2, Chapter 36, *Office of the Secretary of State*, accessed November 10, 2023, https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=4&ti=4&pt=2&ch=36&rl=Y.
400. "Exotic and Fur-bearing Species," *Texas Parks & Wildlife*, accessed November 10, 2023, https://tpwd.texas.gov/education/hunter-education/online-course/wildlife-conservation/exotic-species.
401. In addition, some farms may operate outside the law by raising unsanctioned species or by failing to obtain proper licensing where such requirements exist.
402. In some cases, species can be either farmed legally or legally hunted and sourced from the wild. Often though, wildlife farming a species is legal while taking the same species from the wild through hunting or trapping is not.
403. Corruption is particularly likely in places like Vietnam, where enforcement officials are paid low salaries but are tasked with regulating a lucrative industry such as the wildlife trade.
404. Quyen Vu et al., *An Analysis of Wildlife Farming in Vietnam* (Hanoi: Education for Nature–Vietnam (ENV), 2017), https://env4wildlife.org/wp-content/uploads/2021/03/Farming-Report-Oct-23-2017.pdf.
405. Animals themselves are not easily traceable; they carry no barcodes to distinguish their source or origin.
406. Sandra Charity and Juliana Machado Ferreira, *Wildlife Trafficking in Brazil* (Cambridge: TRAFFIC, 2020), https://www.traffic.org/site/assets/files/13031/brazil_wildlife_trafficking_assessment.pdf.
407. Rodrigo R. Mayrink, *Expert Examination to Detect Fraud in Official Passerine Bands: A Tool to Combat Wildlife Trafficking*, MA dissertation (Florianópolis: Federal University of Santa Catarina, 2016), https://1library-co.translate.goog/document/q5rje5jz-pericial-deteccao-oficiais-passeriformes-ferramenta-combate-trafico-silvestres.html?_x_tr_sl=pt&_x_tr_tl=en&_x_tr_hl=en&_x_tr_pto=sc/.
408. Similar problems plague the livestock sector as well, where authorities are not easily able to distinguish between animals who were raised on illegally cleared forestland and those who were not. Marin Elisabeth Skidmore et al., "Cattle Ranchers and Deforestation in the Brazilian Amazon: Production, Location, and Policies," *Global Environmental Change* 68 (2021): 102280, https://doi.org/10.1016/j.gloenvcha.2021.102280; Ritaumaria Pereira et al., "Extensive Production Practices and Incomplete Implementation Hinder Brazil's Zero-Deforestation Cattle Agreements in Pará," *Tropical Conservation Science* 13, no. 1 (2020), https://doi.org/10.1177/1940082920942014.
409. In these cases, legal distinctions of which species may be used or how those animals may be sourced might carry less force and meaning to individuals who are driven by hunger or necessity.
410. Gemma Conroy, "How Wild Monkeys 'Laundered' for Science Could Undermine Research," *Nature* 623, (2023): 672-673, https://doi.org/10.1038/d41586-023-03533-1.
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412. Several hundred of the animals died due to poor conditions, while they waited to be sold into the pet or wild meat trades.
413. While there have been a handful of successful hatches of big-head turtles in recent years in controlled zoological research settings, extremely specific conditions were necessary to achieve this, as researchers worked for close to a decade to accomplish a successful captive birth.
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420. An estimated three million mink in the US are typically kept in long rows of wire cages where their waste falls through the bottom onto the floor or onto other animals below. Though on-site slaughter and processing occur at such facilities, few states require licensing. No state requires disease testing or veterinary care, and no federal laws directly apply to fur farms. Florence Fenollar et al., "Mink, SARS-CoV-2, and the Human–Animal Interface," *Frontiers in Microbiology* 12 (2021): 663815, https://www.frontiersin.org/articles/10.3389/fmicb.2021.663815/full; Sonia Shah, "Animals That Infect Humans Are Scary. It's Worse When We Infect Them Back," *The New York Times Magazine*, updated June 15, 2023, https://www.nytimes.com/2022/01/19/magazine/spillback-animal-disease.html; Dina Fine Maron, "What the Mink COVID-19 Outbreaks Have Taught Us About Pandemics," *National Geographic*, February 24, 2021, https://www.nationalgeographic.com/animals/article/what-the-mink-coronavirus-pandemic-has-taught-us.
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431. As CDC officials responded to outbreaks of COVID-19 outbreaks on fur farms, some worried privately about this policy and the how it might affect an already tenuous dynamic: "This is a unique situation where large numbers of animals are dying from infection with this virus, farmers are at risk for losing their livelihoods, and farmers/family members also have COVID-19. This is all complicated by the fact that USDA does not consider mink to be livestock and there is no indemnity payment for [losses]." FOIA Request by Dina Maron, Email Correspondence Among the CDC (Re: Suicide Prevention), October 8 and 9, 2020, 1893–1901, https://www.documentcloud.org/documents/21562819-cdc_foia_pg_1893-1901suicide-prevention?responsive=1&title=1.
432. Where regulation of wildlife farms does occur, it is often grounded in conservation rather than biosafety.
433. For example, in the first attempt to summarize the wildlife farming industry on a global scale in the literature in 2023, researchers were forced to exclude the United States from their study, which included submitting data requests to regulatory authorities, because the country "lack[ed]... [a] relevant agency that has oversight of commercial wildlife farming." Of the twelve other countries surveyed, only four were able to provide any data on the number of farms or the number of animals, and only one country made this information available to the public. Jennah Green, Jan Schmidt-Burbach, and Angie Elwin, "Taking Stock of Wildlife Farming: A Global Perspective," *Global Ecology and Conservation* 43 (2023): e02452, https://doi.org/10.1016/j.gecco.2023.e02452.
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M.M. Mekonnen and A.Y. Hoekstra, "A Global Assessment of the Water Footprint of Farm Animal Products," *Ecosystems* 15(2012): 401–415, https://doi.org/10.1007/s10021-011-9517-8; José Graziano Da Silva, "Feeding the World Sustainably," *United Nations Chronicle*, accessed February 16, 2024, https://www.un.org/en/chronicle/article/feeding-world-sustainably#:~:text=We%20cannot%20have%20nine%20billion,produce%20one%20kilogramme%20of%20meat; Alon Shepon et al., "The Opportunity Cost of Animal Based Diets Exceeds All Food Losses," *Proceedings of the National Academy of Sciences of the United States of America* 115, no. 15 (2018): 3804–9, https://www.pnas.org/doi/10.1073/pnas.1713820115; Peter Alexander et al., "Human Appropriation of Land for Food: The Role of Diet," *Global Environmental Change* 41(2016): 88–98, https://www.sciencedirect.com/science/article/abs/pii/S0959378016302370.
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481. Calculations are based on USDA Census of Agriculture Data. Jacy Reese Anthis, "U.S. Factory Farming Estimates," *Sentience Institute*, April 11, 2019, https://www.sentienceinstitute.org/us-factory-farming-estimates; CAFOs are regulated under the National Pollutant Discharge Elimination System (NPDES) of the EPA. "Animal Feeding Operations (AFOs)," *United States Environmental Protection Agency*, last updated February 16, 2023, https://www.epa.gov/npdes/animal-feeding-operations-afos.
482. There is a small movement of change from intensive to extensive practices, globally, in the interest of animal welfare motivated by the idea that intensive production methods that emphasize efficiency are often in tension with the welfare of animals.
483. The many production systems examined in this report employ diverse supply chains. They vary in ways including the environment in which animals are raised, methods and modes of animal transportation, regulation and oversight (of activities such as slaughter and processing), and enforcement. These diverse supply chains have features that amplify zoonotic spillover risk in some ways while reducing risk in other ways.
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486. Given these uncertainties, at this point it is not possible to determine whether highly efficient, intensive livestock production (such as CAFOs) better mitigates or rather exacerbates risks of zoonotic spillover as compared with extensive livestock production, which results in lower yield but with poorer biosecurity, more workers interacting with animals, and more land under development and in use.
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492. Sinh Dang-Xuan et al., "Food Safety Perceptions and Practices Among Smallholder Pork Value Chain Actors in Hung Yen Province, Vietnam," *Journal of Food Protection* 79, no. 9 (2016): 1490–7, https://doi.org/10.4315/0362-028X.JFP-15-402.
493. In the US, for example, while ignorance of the law is not a legal defense, it can be a functional one, as authorities are reluctant to enforce rules against producers who appear uninformed about regulatory requirements. *See* US Case Study.
494. *See* Vietnam Case Study.
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497. Aaron Reich, "Israel's Chicken Coops Riddled with Health and Safety Concerns: Comptroller Report," *The Jerusalem Post*, May 10, 2022, https://www.jpost.com/health-and-wellness/article-706296.
498. Some states, like California, have moved to fill these gaps left by federal law. Small producers are also exempt from licensing requirements in some states. See: United States Department of Agriculture, *Guidance for Determining Whether a Poultry Slaughter or Processing Operation is Exempt from Inspection Requirements of the Poultry Products Inspection Act* (Washington DC: USDA Food and Inspection Service, revised 2006), https://www.farmtoconsumer.org/wp-content/uploads/2016/12/USDA-FSIS-Guide-Poultry_Slaughter_Exemption_0406.pdf.
499. Once a pathogen jumps the species boundary to infect humans, human–animal interactions are no longer necessary to ensure its spread. Still, additional human–animal interactions can allow opportunities for additional spillover events that could accelerate the spread of the pathogen among humans or potentially introduce new and different forms of the pathogen to humans.

500. This is true, assuming the number of animals is constant. For example, if two thousand animals are processed at an industrial plant by the same worker, or if those two thousand animals are slaughtered by two thousand different small-scale producers who each raise and kill one animal, the risk of spillover from those two sets of interactions would likely be similar, and disease could potentially spread from one infected person to others in either scenario.
501. *See* Israel Case Study.
502. Roughly 80%-90% of households in Vietnam raise backyard poultry. See Stéphanie Desvaux, et al., *A General Review and a Description of the Poultry Production in Vietnam*, (Hanoi: Agricultural Publishing House, January 2008), https://agritrop.cirad.fr/562460/1/document_562460.pdf. and Indranil Samanta, Siddhartha N. Joardar, and Pradip K. Das, "Biosecurity Strategies for Backyard Poultry: A Controlled Way for Safe Food Production," *Food Control and Biosecurity* (2018): 481–517, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7149579/.
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512. In industrial animal production systems, slaughter is performed at designated processing plants specific to each species of livestock.
513. Current line speeds in the US allow for up to 175 chickens to be slaughtered per minute. "FSIS Announces Study of Effect of Increased Poultry Line Speeds on Worker Safety," USDA Food Inspection and Safety Services, Constituent Update, July 29, 2022, https://www.fsis.usda.gov/news-events/news-press-releases/constituent-update-july-29-2022.
514. While some countries visually inspect animals prior to slaughter—for example, to ensure that cows are able to walk to reduce the risk of mad cow disease—others do not. While the most extreme clinical signs of some diseases can be observed by visual inspection alone, many others cannot.
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        - a. Jen C. Tinsman et al., "Genomic Analyses Reveal Poaching Hotspots and Illegal Trade in Pangolins from Africa to Asia" *Science* 382, no. 6676 (2023): doi:10.1126/science.adi5066.
    - C. To assess MERS risk, value chain analysis in Jordan maps potential points of spillover where humans and camels interact.
        - a. FAO-OIE-WHO MERS Technical Working Group, "MERS: Progress on the Global Response, Remaining Challenges and the Way Forward," *Antiviral Research* 159 (2018): 35-44 https://doi.org/10.1016/j.antiviral.2018.09.002.
    - D. Georgia supported research mapping distribution of a new orthopoxvirus through integrated surveillance of wildlife, livestock populations, and ranchers
        - a. Miram Shiferaw, "Frameworks for Preventing, Detecting, and Controlling Zoonotic Diseases" *Emerging Infectious Diseases* 23 (2017): S71–S76, https://wwwnc.cdc.gov/eid/article/23/13/17-0601_article.
    - E. This could include requiring producers to allow observational studies or sampling in order to understand risk
        - a. No citation, hypothetical example
    - F. In Ghana, veterinary officers led a team to identify pressure points and high-risk locations for TB and Anthrax among livestock
        - a. *See* Ghana Case Study.
    - G. Vietnam's VIZONS initiative studies zoonotic disease in a high-risk sentinel cohort of those with occupational exposure to animals.
        - a. Juan J. Carrique-Mas, "The Baseline Characteristics and Interim Analyses of the High-Risk Sentinel Cohort of the Vietnam Initiative on Zoonotic Infections (VIZIONS)," *Scientific Reports* 5 (2015): 17965, https://www.nature.com/articles/srep17965.
    - H. Singapore samples wildlife held in state-run rehabilitation centers for disease surveillance

a. Xie Renhui, "One Health in Singapore," *CITES Database*, published April 21, 2023, https://cites.org/sites/default/files/projects/zoonotic/Singapore.pdf.

I. The UAE requires quarantines, inspections, and disease screening of live imports of cattle from South America
*a. See* UAE Case Study.

J. This could include mandating poultry producers to report mortality levels above certain baseline thresholds to facilitate early detection of disease.
a. No citation, hypothetical example

K. Studies in Bangladesh found that simple interventions could reduce contact between bats and date palm sap consumed by humans to reduce Nipah risk
a. Neil Vora et al., "Interventions to Reduce Risk for Pathogen Spillover and Early Disease Spread to Prevent Outbreaks, Epidemics, and Pandemics,"*Emerging Infectious Diseases* 2, no.3 (2023): e221079, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9973692/.

703. Citations for "Communication and Information Sharing" examples:

A. Ghana has created a technical working group focused on One Health including Ministries of Health, Food and Agriculture, and Science, Technology and Environment
*a. See* Ghana Case Study.

B. Peru installed a multisectorial committee on zoonoses, including representatives from Ministries of Defense, Interior, Foreign Trade, Agriculture, Production, Environment, Transport, and Communication
*a. See* Peru Case Study.

C. In South Africa, public-private partnerships such as SAMLIT work to reduce poaching and wildlife trafficking
a. "United States-South Africa Task Force to Focus on Disrupting Financial Flows Related to Illegal Wildlife Trade," *Department of National Treasury: Republic of South Africa*, published January 26, 2023, https://www.treasury.gov.za/comm_media/press/2023/2023012602%20SAMLIT%20%20NT%20Media%20Statement%20-%20US-SA%20Task%20Force.pdf

D. When Marburg virus was discovered in Tanzania in 2023, the government quickly alerted the public and the WHO
a. "Tanzania's Victory Over Marburg Virus: A Breath of Relief and a Path of Hope," *The World Health Organization*, published June 12, 2023, https://www.afro.who.int/countries/united-republic-of-tanzania/news/tanzanias-victory-over-marburg-virus-breath-relief-and-path-hope#:~:text=This%20feat%20was%20achieved%20through,Bakuba%20is%20safe!.

E. Sweden has a strong open records act, shares publicly data from wildlife disease sampling, and reports outbreaks quickly to WOAH and WHO
a. "Public Access to Information and Secrecy: The Legislation in Brief," *Government Offices of Sweden, Ministry of Justice*, updated 2020, https://www.government.se/contentassets/2ca7601373824c8395fc1f38516e6e03/public-access-to-information-and-secrecy.pdf.
b. Gustav Averhed et al., "Wildlife Disease Surveillance in Sweden in 2021," Staten Veterinarmedicinska Anstalt, updated April 22, 2022, https://www.sva.se/media/8da538f72493952/wildlife-disease-surveillance-in-sweden-2021.pdf.

F. Kajiado County, Kenya has measures in place employing veterinary officers at animal markets for disease surveillance and health checks of animals for sale
*a. See* Kenya Casse Study.

G. Hendra education campaigns among horse owners in Australia sought to reduce contact between horses and bats
a. Nina Kung et al., "Hendra Virus and Horse Owners – Risk Perception and Management," *PLoS ONE 8, no. 11(2013): e80897,* https://doi.org/10.1371/journal.pone.0080897.

H. Community-based radio programs in the DRC sought to address misinformation about how Ebola is transmitted and to educate listeners on prevention
a. Kasereka Masumbuko Claude and Michael T. Hawkesb,"Ebola Crisis in Eastern Democratic Republic of Congo: Student Led Community Engagement," *Pathogens and Global Health* 114, no.4 (2020): 218–223, doi: 10.1080/20477724.2020.1754654.

I. Educational campaigns using social marketing reduced consumption of wild meat dramatically in Amazonia, Brazil
a. Wilandia Chaves et al., "Changing Wild Meat Consumption: An Experiment in the Central Amazon, Brazil," *Conservation Letters* 11, no.2 (2018): e12391, https://doi.org/10.1111/conl.1239.

J. While not yet been employed, an effective framework would account for the frequency and intensity of zoonotic risks
a. No citation, hypothetical example

K. In the UAE, systematic team reporting for data analysis and risk assessment is in place at both district and Emirate levels
*a. See* U.A.E. Case Study

L. New Zealand's Protected Disclosures Act offers legal protection to employees who report issues related to animal welfare and food safety in the agricultural sector
a. "Protected Disclosures (Protection of Whistleblowers) Act 2022," *Government of New Zealand*, published 2022, https://www.publicservice.govt.nz/publications/protected-disclosures-act-2022.

704. Citations for "Aligning Incentives" examples:

A. Forest protection payments in Brazil have been effective in slowing deforestation in the Amazon as have agreements by purchasers not to buy soy or cattle produced on illegally deforested land
a. Neil Vora et al., "Interventions to Reduce Risk for Pathogen Spillover and Early Disease Spread to Prevent Outbreaks, Epidemics, and Pandemics," *Emerging Infectious Diseases* 29, no.3 (2023): e221079, doi: 10.3201/eid2903.221079.
b. Sarah Shanks, May CI van Schalkwyk, and Andrew A. Cunningham, "A Call to Prioritise Prevention: Action is Needed to Reduce the Risk of Zoonotic Disease Emergence," *The Lancet Regional Health* 23 (2022): 100506, https://doi.org/10.1016/j.lanepe.2022.100506.

B. In Israel, policymakers subsidized reform measures for structural upgrades to improve the sanitary conditions in egg farms
*a. See* Israel Case Study.

C. South Korea offered buyouts to bearbile farmers to help transition away from the practice
a. "Bred for Profit: The Truth about Global Wildlife Farming," *World Animal Protection*, published March 4, 2024, https://www.worldanimalprotection.org/globalassets/pdfs/reports/english/bred-for-profit-report-on-global-wildlife-farming.pdf.

D. In the US, labels allow consumers to purchase meat raised without antibiotics
a. "USDA Launches Effort to Strengthen Substantiation of Animal-Raising Claims," *United States Department of Agriculture*, published June 14, 2023, https://www.usda.gov/media/press-releases/2023/06/14/usda-launches-effort-strengthen-substantiation-animal-raising.

E. In Belgium, many pig producers elected to accept payments to transition out of the industry
a. Daan Boezeman et al., "Less Livestock in North-western Europe? Discourses and Drivers Behind Livestock Buyout Policies," *EuroChoices* 22, no.2 (2023):4-12, https://doi.org/10.1111/1746-692X.12399.

F. Slaughter levies fund food-animal production insurance against major disease outbreaks in the Netherlands
a. National Research Council (US) Committee on Achieving Sustainable Global Capacity for Surveillance and Response to Emerging Diseases of Zoonotic Origin, "Sustainable Financing for Global Disease Surveillance and Response," Sustaining Global Surveillance and Response to Emerging Zoonotic Diseases: Chapter 6, *The National Academy of Sciences*, published 2009, ISBN-13: 978-0-309-13734-8.

G. Australia requires reporting of equine influenza and other diseases beyond those for which reporting is not required by the WHO or WOAH
a. "Notice to Industry 17: Sampling Requirements for Equine Influenza Testing," *Australian Government: Department of Agriculture, Fisheries and Forestry*, updated April 11, 2024, https://www.agriculture.gov.au/biosecurity-trade/import/goods/live-animals/importing-live-horses/notice-industry-17.

H. This could include policies that encourage cooperation between industries to combat shared disease threats

a. NA Hypothetical

I. In the US, indemnification payments incentivize disease reporting among livestock producers
   a. *See* The Animal Health Protection Act (7 U.S.C. 8301–8317) and implementing regulations.

J. Kenya implemented a mobile phone-based disease reporting system that increased reporting of illness among livestock
   a. Yewande Alimi et al., *Report of the Scientific Task Force on Preventing Pandemics* (Cambridge: Harvard Global Health Institute, 2021), https://www.hsph.harvard.edu/c-change/wp-content/uploads/sites/2343/2021/08/PreventingPandemicsAug2021.pdf.

K. The Kenyan Wildlife Service has implemented a risk-based approach to identify and prevent corruption, while increasing transparency
   a. "Scaling Back Corruption: A Guide on Addressing Corruption For Wildlife Management Authorities," *United Nations Office on Drugs and Crime*, published 2019, https://www.unodc.org/documents/corruption/Publications/2019/19-08373_Scaling_Back_Corruption_ebook.pdf.

L. Gabon's former president worked to protect wildlife habitat and publicly pledged to stop consuming wild meat
   a. "Gabon Announces Creation of 13 National Parks," *The World Wildlife Fund*, published September 9, 2002, https://wwf.panda.org/wwf_news/?2674/Gabon-announces-creation-of-13-National-Parks.

705. Citations for "Evidence-Based Policymaking" examples:

A. In 2022, the US set standards governing the ownership of big cats, which was previously unregulated in many states, and prohibiting public interactions with cubs

B. In 2022, the EU closed a loophole that had allowed livestock producers to continue to overuse antibiotics for growth promotion as "prophylactic use"
   a. Shabbir Simjee and Gabriella Ippolito, "European Regulations on Prevention Use of Antimicrobials from January 2022," *Brazilian Journal of Veterinary Medicine*, 44 (2022): e000822, https://doi.org/10.29374/2527-2179.bjvm000822.

C. This could include establishing well-considered, scientific-based definitions for "livestock" "free-roaming wildlife" or "farmed wildlife" that do not leave any groups of animals undefined or unregulated
   a. NA Hypothetical Example

D. Gabon prohibited consumption of certain high-risk wildlife species: bats and pangolins
   a. Neil M. Vora et al, "Interventions to Reduce Risk for Pathogen Spillover and Early Disease Spread to Prevent Outbreaks, Epidemics, and Pandemics," *Emerging Infectious Diseases* 29, no.3 (2023): e221079, doi:10.3201/eid2903.221079.

E. Israel has banned fur farming and sale of fur products, asproduction drives risk upstream in the country of origin
   a. "Israel, First Country in the World to Ban by Law Fur Sales," *International Organization for Animal Protection*, accessed May 2, 2024, https://www.oipa.org/international/israel-ban-fur-fashion/; *see also,* Israel's Wildlife Protection Law.

F. Israel has invested heavily in alternative protein production
   a. Rafi Grosglik et al., "Considering the Alternatives: Lessons from Israel's Meat Substitutes Initiatives," *Frontiers in Sustainable Food Systems* 7 (2023): https://doi.org/10.3389/fsufs.2023.1342774.

G. The UAE is implementing automated slaughterhouses that minimize human-animal interaction
   a. See U.A.E. Case Study

H. Germany has put restrictions on the number of species and animals that can be sold at animal fairs/expos
   a. See Germany Case Study

I. In the US, NIH has established PPE and handling requirements for researchers interacting with non-human primates, which could be expanded and applied to other forms of animal industries
   a. "3044-2- Protection of NIH Personnel Who Work with Nonhuman Primates," *National Institute of Health*, *Policy Manual*, published October 19, 2022, https://policymanual.nih.gov/3044-2.

J. This could include clarifying jurisdictional limits, enforcement measures, and capacities, as well as ensuring that officials have appropriate training and clearly understand their role and function
   a. NA Hypothetical example

K. In Brazil, IBAMA runs wildlife rehabilitation centers so officials don't avoid enforcing wildlife laws for lack of place to keep confiscated animals
   a. Sandra Charity and Juliana Machado Ferreira, "Wildlife Trafficking in Brazil," *Cambridge, UK: TRAFFIC International*, published July 2020, https://www.traffic.org/publications/reports/brazils-widespread-wildlife-trafficking/.

L. Australia's border biosecurity measures reduced the risk of importing and introducing ranaviruses carried by amphibians
   a. Pablo García-Díaz et al., "Managing the Risk of Wildlife Disease Introduction: Pathway-Level Biosecurity for Preventing the Introduction of Alien Ranaviruses," *Journal of Applied Ecology* 54, no.1 (2017): 234-41, https://doi.org/10.1111/1365-2664.12749.