PHASE I

SCOPING REPORT TEMPLATE

This report outlines the country's One Health context and the process followed during the scoping phase, with details of stakeholder engagement, activities identified, and lessons learnt. All gray text boxes must be completed before submission.

SUMMARY INFORMATION	
Project Title:	Nature for Health Scoping Report for Ghana *Nature for Health Ghana: Reducing Spillover Risk Through a One Health Approach*
MPTFO Fund Code:	*(MPTFO to add country and Gateway child code)*
MPTFO Project ID:	*(MPTFO to add)*
Participating Organization (PO):	Name of Participating Organization: EcoHealth Alliance Name of Partner Focal Point: Robin Breen Address: 520 Eighth Avenue, Suite 1200, New York, NY 10018, USA Telephone: +1 212 380 4460 E-mail: breen@ecohealthalliance.org Additional Point of Contact: Darya Ivanova E-mail: ivanova@ecohealthalliance.org
Project Location:	Ghana
Project Description:	Provide an executive summary of the scoping process, stakeholders engaged, and activities identified. In In Ghana, the N4H is led by a multi-sector Core Team consisting of representatives from the University of Ghana School of Veterinary Medicine (UGSVM), Veterinary Services Directorate (VSD), Public Health Directorate of Ghana Health Service (GHS), Ministry of Environment, Science, Technology and Innovation (MESTI), National Disaster Management Organisation (NADMO) and Wildlife Division of Forestry Commission (FC) and EcoHealth Alliance, the global Implementing Partner. Two facilitators also

supported the scoping process.

The scoping process uses systemic practice methods to understand zoonotic disease spillover risks and their drivers and identify context-specific solutions aligned with local and national priorities to better prevent spillover in the future. To achieve this goal, four stakeholder consultation workshops were held in the Ashanti Region, Savannah Zone, Western Region, and Greater Accra Region. Each workshop consisted of background presentations followed by small group activities (Table 1).

Table 1. Activities used in the N4H scoping process workshops.

Activity	Description
Rich Picture	Hand drawn representation of a complex situation and its relationship with the wider environment. Rich picture scenarios were based on the country's priority zoonotic diseases
Mental Model	Individual and group questions aimed to understand and extract participants beliefs, perceptions, and knowledge relating to spillover prevention
Spillover Risk Interfaces	Participants identify specific settings, or interfaces, where people come into contact with animals, both wild and domestic (and their potential diseases), factors that decrease or increase exposure, and the stakeholders with the power to make changes (to reduce risk) at each specific interface.
Risk Management Actions	Participants identify and prioritise realistic actions people and groups can take to manage and prevent zoonotic disease risk, including the stakeholders involved, expected outcomes, resources needed for it to work well, and factors to motivate or hinder its success.

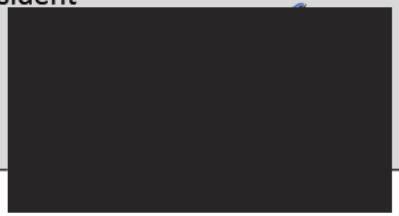
Workshops were attended by a diverse group of stakeholders including, local and regional government representatives from across the human-animal-environment spectrum, farming associations (crop, poultry, pigs), mining associations, bush meat trading associations, universities and research institutes, and several non-governmental organisations. The stakeholders made it clear that there is strong interest from government, NGOs, and communities in working together to prevent zoonotic spillover through a One Health approach.

Each workshop shed light on the regionally specific challenges and existing systems and activities already in place to prevent spillover that could be strengthened. Recurring themes that arose in multiple workshops were the need for:

	1. Community education and sensitisation 2. Funding and logistical support for local governments including veterinary extension services, park rangers, and environmental health officers 3. Training on proper biosecurity measures, including updated Standard Operating Procedures (SOPs) 4. Enforcement of existing by laws 5. Improved data sharing between sectors, especially incorporating wildlife and ecological data. Overall, the scoping process was essential in better understanding how communities interact with wildlife and the environment, what preventative measures are already in place, and where there are entry points to strengthen One Health actions to prevent spillover. Looking ahead, the information collected in this 6-month scoping phase is being used to design a 2-3-year project to reduce spillover risk that will begin in late 2024. We are extremely grateful to everyone, especially the workshop participants, who shared their knowledge and time with us throughout the scoping process.
Total Scoping Phase Cost 2023-2024:	*Up to 250,000 USD maximum* USD 249,977.00
Project Period:	*Average 6 months based on country interests and priorities.* **Actual Start Date:** 30/11/2023 **Actual End Date:** 31/08/2024

Participating Organization Official with Delegation of Authority[1]: Peter Daszak

Name and title of PO: Peter Daszak, PhD, President

Signature: Peter Daszak 

Date: 30/10/2024

[1] Signatory must have delegation of authority under the rules of the Participating Organization.

	2. Funding and logistical support for local governments including veterinary extension services, park rangers, and environmental health officers 3. Training on proper biosecurity measures, including updated Standard Operating Procedures (SOPs) 4. Enforcement of existing by laws 5. Improved data sharing between sectors, especially incorporating wildlife and ecological data. Overall, the scoping process was essential in better understanding how communities interact with wildlife and the environment, what preventative measures are already in place, and where there are entry points to strengthen One Health actions to prevent spillover. Looking ahead, the information collected in this 6-month scoping phase is being used to design a 2-3-year project to reduce spillover risk that will begin in late 2024. We are extremely grateful to everyone, especially the workshop participants, who shared their knowledge and time with us throughout the scoping process.
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Report Reviewed and endorsed by Country Partner:
Name and title of lead Ministry:

Anna Sekyibea Bekai
Ministry of Environment, Science, Technology and Innovation

Signature: [redacted]

Date: 22-10-2024

SCOPING REPORT NARRATIVE

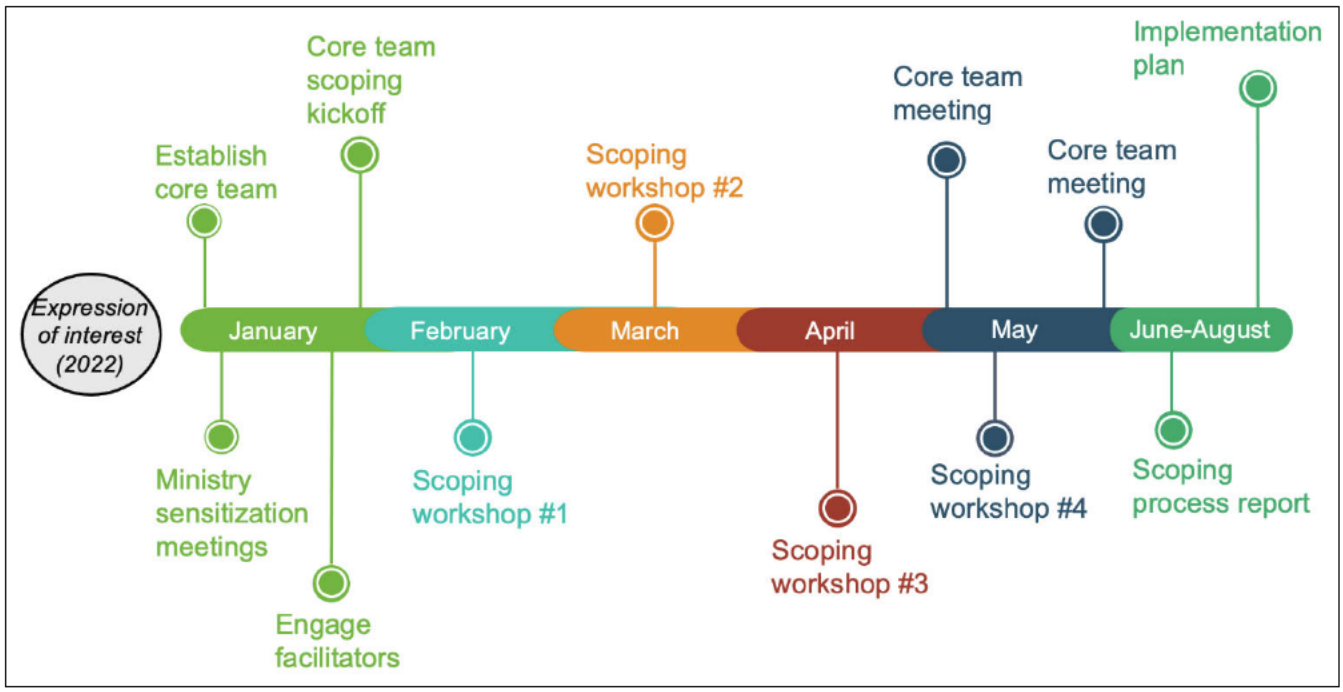
1. Systemic Approach

Describe the scoping process and methodology, with details of how the scoping process ensured a systemic approach. The section should include:

- The approaches used to understand the preventative One Health inter-relationships and their implications.
- How were boundary decisions made around purpose, control, knowledge and legitimacy?
- How did you ensure that the systemic participatory approach will be continued through the project implementation and beyond?

The N4H Ghana Scoping process took place between December 2023 - August 2024 (Figure 1).

Figure 1. Timeline of scoping process activities



Before the official start, the country coordinator liaised with colleagues involved in the expression of interest to ensure everyone was updated on the anticipated timeline. The process began by identifying and establishing a 'Core Team' and set of facilitators. The Core Team was made up of representatives from the government agencies that developed and submitted the initial N4H expression of interest plus additional representatives (e.g., Ministry of Environment, Science, Technology and Innovation; Ghana Health Service) to ensure representation from across the human, animal, and environment spectrum in line with a One Health scope (Table 2). In addition, two facilitators were brought on board in December 2023 as consultants to help support the Core Team through the scoping process. The first facilitator, Dr. Kwamina Banson (Ghana Atomic Energy Commission), is an expert in systems thinking

methods and has led analyses of agricultural production systems, while the second facilitator Prof. Juliana Enos (School of Public Health, University of Ghana) is a public health expert and experienced facilitator having led workshops across West Africa.

Table 2. Core Team members leading the scoping process in Ghana.

Person	Organization	Role
Prof. Richard Suu-Ire	School of Veterinary Medicine, University of Ghana	Country coordinator, Core Team member
Dr. Meyir Ziekah	Wildlife Division of Forestry Commission (FC)	Core Team member
Dr. Theophilus Odoom	Veterinary Services Directorate (VSD)	Core Team member
Ms. Ruth Arthur Nana Friba	National Disaster Management Organisation (NADMO)	Core Team member
Ms. Anna Bekai	Ministry of Environment, Science, Technology and Innovation (MESTI)	Core Team member
Dr. Horlali Gudjinu	Ghana Health Service (GHS)	Core Team member
Dr. Sherry Johnson	School of Veterinary Medicine, University of Ghana	Core Team member
Dr. Amos Agyei	School of Veterinary Medicine, University of Ghana	Core Team member
Dr. Catherine Machalaba	EcoHealth Alliance	Global partner support
Mr. Robin Breen	EcoHealth Alliance	Global partner support
Dr. Juliana Enos	School of Public Health, University of Ghana	Facilitator
Dr. Kwamina Banson	Ghana Atomic Energy Commission	Facilitator

In January 2024, country coordinator, Dr. Richard Suu-Ire (School of Veterinary Medicine University of Ghana), supported by colleagues from N4H global partner EcoHealth Alliance, conducted partner sensitization meetings in Accra with key government agencies and N4H partners (WHO and UNDP) to garner support for N4H and better understand how N4H can support their institutional mandates and priorities. Following these meetings, the Core Team met on 30 January to plan out the scoping process and further familiarize the Core Team with the Scoping Guide. At this meeting, the Core Team made several critical boundary decisions, including the decision to host scoping workshops in several regions of the country with different stakeholders, rather than holding workshops in one location with the same participants (Figure 2). In making this decision the Core Team chose to prioritize gathering a wider diversity of inputs from stakeholders with intimate knowledge of human-animal-ecosystem interactions at the community level. This strategy also targeted regional differences in human-animal interfaces (e.g., bushmeat trading in the Ashanti region, vs. livestock rearing among fringe communities around protected areas in the Savannah Zone, vs. mining and cocoa farming in the Western region). Although each regional workshop was slightly different, the activities were consistent across the workshops which allows for regional comparisons in understanding common human-animal-environment interfaces. Legitimacy was also a serious consideration in deciding where to hold workshops.

The Core Team recognized that it is the people and communities at the district level whose interests need to be considered most for this project to achieve its ultimate purpose of implementing spillover prevention actions. While actors at the national level (e.g., ministries) have a critical role in legitimizing the N4H project throughout the implementation phase, information on daily human-animal interactions could not be accessed without going directly to people at the community level. The downside of holding scoping workshops in different locations is the inability to dive deep into systems methodologies over a prolonged period of time. At each workshop we had to introduce and provide background on systems thinking to prime participants for the workshop activities. Fortunately, having Core Team members participate in multiple workshops provided a through line to ensure continuity and consistency across workshops which alleviated the challenges with having a different group of workshop participants each time.

Figure 2. Scoping workshop locations

The first workshop was held in the Ashanti Region; second in the Savannah Zone; third in the Western Region; fourth in the Greater Accra Region.

The other major decision discussed at this Core Team meeting was where to hold the regional workshops - recognizing we couldn't go to every region in Ghana. The criteria to decide on workshop locations centered on ecological differences, types of human-animal interactions, locations of anthropogenic change (e.g., deforestation, mining, logging), history of zoonoses outbreaks, cultural practices, and logistical feasibility. Ultimately the Core Team decided to host 4 workshops which are detailed below. In between each workshop, the Core Team met to reflect on what worked well at the previous workshop and what improvement could be made for the next one. A snapshot of the workshop methods is presented in Table 3.

Table 3. Overview of workshop methods used in each of the four scoping workshops.

Workshop	Methods
Ashanti Region (one day)	1. Presentation on a regionally specific One Health topic 2. Rich Picture: hand drawn representation of a complex situation and its relationship with the wider environment. For the scoping workshops in Ghana, rich picture scenarios were based on the country's list of priority zoonotic diseases 3. Mental model: Series of individual and group questions aimed to understand and extract the beliefs, perceptions, and understanding of workshop participants relating to spillover prevention
Savannah Zone (two days)	1. Presentation on a regionally specific One Health topic 2. Rich Picture 3. Mental Model 4. Risk Interfaces: In small groups, participants identify specific settings, or interfaces, where people come into contact with animals, both wild and domestic (and their potential diseases), factors that decrease or increase exposure, and the stakeholders with the power to make changes (to reduce risk) at each specific human-animal-environment interface. 5. Risk Management Actions: In small groups, participants identify and prioritize realistic actions people and groups can take to manage and prevent zoonotic disease risk (aka "risk management actions"), including the stakeholders involved, expected outcomes, resources needed for it to work well, and factors to motivate or hinder its success
Western Region (two days)	1. Presentation on a regionally specific One Health topic 2. Rich Picture 3. Mental Model 4. Risk Interfaces 5. Risk Management Actions
Greater Accra Region (two half days)	1. Presentation on the outputs from the three previous workshops noting the different local perspectives, strengths, needs, and settings where humans and animals come into contact at the district and regional level 2. Presentation on the findings from the three previous workshops using systems thinking methodologies including causal loop diagrams to identify leverage points for spillover prevention 3. Combined and condensed version of the "Risk Interfaces" and "Risk Management Actions" activities 4. In-depth group discussion on sectoral priorities and key needs to prevent spillover. Representatives from wildlife, veterinary services, agriculture, environmental health, and human/public health sectors were called on, while all participants were given the chance to ask questions and input on the discussions

Workshop #1 - Ashanti Region (Kumasi)

Regional Background

The first workshop was held on 29 February in Kumasi, the capital of the Ashanti region. Kumasi is a vibrant economic hub attracting visitors from across the country and the West Africa sub-region. The region is endowed with rich mineral resources, home to diverse fauna, vast forests and farmlands and has numerous large poultry establishments. Kumasi is home to the largest bushmeat market in the country, Atwemonom market, which attracts bushmeat from other regions and neighboring countries. Bushmeat hunting and trade, widespread mining activities, deforestation among others, have contributed to ecological disruptions in the region. The first confirmed cases of both Lassa fever and Marburg virus disease in Ghana were reported from the Ashanti region. The poultry industry in the region is embattled with frequent outbreaks of avian influenza.

Workshop Content and Activities

After introductions and a short background presentation on the Nature for Health initiative, Core Team member Dr. Meyir Ziekah provided a briefing on the bushmeat value chain in Kumasi - a common human-wildlife interface in the region. Following this presentation, workshop participants worked through two systemic practice activities. The first, rich picturing, was chosen for several reasons: (1) most participants were not familiar with systems thinking methods and rich picturing is a relatively easy exercise that doesn't require knowledge of systems thinking methods or One Health technical expertise; (2) it allows all people to participate and share their knowledge regardless of their reading/writing ability; (3) it gets people talking, working together, and energized around a hands-on activity.

Rich picturing is also a good way to explore complex inter-relationships between humans, animals, and ecosystems, identify motivations that put people in contact with animals (wildlife and livestock), the people most at risk of disease, and specific actions to prevent spillover of disease from animals to people. Rich picture scenarios were chosen to reflect four of the six priority zoonoses in Ghana (anthrax, avian influenza, and the viral hemorrhagic fevers (Marburg virus and Lassa fever) and written using real data and information from peer-reviewed literature and reputable sources. Each scenario also showcases different pathways of disease emergence and spread, including pathogen-host relationships, seasonal dynamics, routes of transmission, and environmental and ecological drivers (Figure 3).

Figure 3. Rich pictures, first scoping workshop, Ashanti region

Based on scenarios related to select priority zoonoses of Ghana, workshop participants drew rich pictures depicting zoonoses in local communities, drivers of disease, and stakeholder interactions. The rich pictures for Lassa fever and Marburg virus in the Ashanti region are depicted below.

The second activity, "mental modeling" is an activity based on the Evolutionary Learning Laboratory systems thinking method (a method facilitator Dr. Banson has strong experience in) that aims to understand and extract the beliefs, perceptions, and understanding of workshop participants through a series of individual and group questions. The questions asked participants about what needs to be done generally to prevent spillover, who (agencies and groups of people) should be involved in prevention, what is already in place, and what are the biggest challenges to spillover prevention. The questions were targeted so the Core Team could better understand the inter-relationships among One Health stakeholders and identify potential entry points for spillover interventions.

Given this was the first workshop, there were several lessons learned that the Core Team took to future workshops. First, the workshop began in English, but we realized quickly that participants had differing levels of English proficiency. Fortunately, several members of the Core Team are fluent in the local language, Twi, and were able to translate and moderate group discussions to ensure full participation and inclusion from all participants. Second, we realized that a one-day workshop was not enough time to deeply engage in systemic practice activities and a two-day workshop would be better. Finally, we learned that we needed to do a better job in communicating with workshop participants after the workshop by building in unstructured discussion at the end of the workshop, creating a post-workshop feedback survey (Annex 2), and providing a workshop report to all participants for their records. All these lessons were incorporated into the subsequent workshops.

Workshop #2 - Savannah Zone (Mole National Park)

Regional Background

The second workshop was held on 21-22 March in the Savannah zone and included participants from Savannah, Upper East and Upper West regions. Relative to the forest zone (which includes the Ashanti Region), the Savannah zone has seen very little ecological disturbances. The workshop was held in Mole National Park, the largest national park in Ghana, home to a plethora of wildlife, including over 90 mammalian species and approximately 335 species of birds. The park attracts thousands of visitors (international and domestic) annually. The park is surrounded by 33 fringe communities who primarily engage in crop farming, animal rearing and game hunting. Anthrax is endemic in the savannah zone, and the most recent outbreak of anthrax in the country occurred in the Upper East region resulting in one human mortality and about 100 animal deaths. The region came under scrutiny during the 2022 Marburg virus disease outbreak response as it hosted the burial and funeral of the index case.

Workshop Content and Activities

Participants attended from several regions across the north of Ghana which encompass the Savannah ecological zone. The participant makeup was also quite different from the first workshop. Given the location in Mole National Park, this workshop had many more park rangers and protected area staff as well as farmers in addition to district and regional government representatives (see Annex 1 for a list of participating organizations from each workshop).

Day 1

- Day one of the workshop was similar to the workshop in the Ashanti Region. It began with a presentation from the Upper East Regional Veterinary Officer on the recent anthrax outbreak in the region. The presentation provided a real scenario, specific to the Savannah zone, about the on the ground realities of responding to a zoonotic disease outbreak and ways to effectively prevent zoonotic spillovers in the future. Following the presentation, the same rich picture and mental modeling activities were completed.

Day 2

- Building on the outputs of day one, the second day consisted of two small group activities (dubbed “risk interfaces” and “risk management actions”) focused on specific settings, or interfaces, where people come into contact with animals, both wild and domestic. In the first activity, participants grouped according to their line of duty, or the groups they work with, to identify groups of people exposed to animals (and their potential diseases), factors that decrease or increase exposure, and the stakeholders with the power to make changes (to reduce risk) at each specific human-animal-environment interface.
- Specific examples of interfaces were provided based on broader contexts like communities living in/around conserved protected areas, agriculture landscapes, natural resource extraction (mining areas, etc.), access and resource use, biodiversity

management, tourism and research. The settings selected by participants were (1) animal rearing/livestock farming, (2) protected areas, including biodiversity management, tourism, poaching/hunting, and fringe communities, (3) agriculture, crop production, and beekeeping (4) veterinary services and clinical care (Table 4).

Table 4. Risk interface activity output, second scoping workshop, Savannah zone.

In groups participants identified specific settings where people come into contact with animals and factors that may increase/decrease to animals (and their potential diseases). Participants ranged from farmers, hunters, and park rangers to veterinarians and epidemiologists and had a wide range of background knowledge on One Health and zoonoses.

Risk Interface	**Factors that Increase Exposure to Animals** (and their potential diseases)	**Factors that Decrease Exposure to Animals** (and their potential diseases)
Protected areas (PAs)	Living in PA, irregular screening of PA staff, poaching/wildlife conflict, children picking fruit, conducting research in PAs, festive occasions/tourism	Knowledge wildlife behavior, training on disease investigation, land zoning, use of PPE, briefings for PA visitors, preventing domestic animals from entering PAs
Animal rearing	Handling animals w/o PPE, meat consumption, free ranging livestock, mixed rearing with multiple species, cultural practices	Closed animal housing, biosecurity (e.g., footbath), vaccination/treatment, keeping areas clean (no rodents), being located away from residential area
Slaughterhouses and chop bars	Inadequate PPE, limited meat inspection, multiple animal species together in close proximity, inappropriate animal transport, lack of clean wash water, poor meat preparation	Proper meat preparation, inspection and certifications from veterinary services, PPE, education, proper slaughterhouse draining, proper animal transport
Veterinary clinics	Proximity sick animals, not wearing PPE (staff and visitors to clinic), multiple animal species together	Isolate sick animals, enact biosecurity measures, enforce bye laws, education and sensitization, lab diagnostics and pathogen confirmation, poultry farm evaluations, community compensation

**This is a non-exhaustive list of factors that alter exposure to animals, but lists all factors mentioned by workshop participants during the group exercise.*

Day 2 Cont.

- The second activity focused on identifying and prioritizing realistic actions people and groups can take to manage and prevent zoonotic disease risk (Table 5). Group discussions centered on actions related to (1) land planning/zoning (2) surveillance and monitoring (3) safe wildlife viewing, handling, and use (4) biosecurity (5) risk communication and awareness raising and (6) One Health information sharing and coordination. Each group designed a risk management action, including the stakeholders involved, expected outcomes, resources needed for it to work well, and factors to motivate or hinder its success. Each group presented their proposed actions and conducted an analysis to assess the impact of their actions with the required effort to implement them.

Table 5. Risk management actions activity output, second scoping workshop, Savannah zone.

In groups participants identified specific actions people and groups can take to manage and prevent zoonotic disease risk. Participants ranged from farmers, hunters, and park rangers to veterinarians and epidemiologists and had a wide range of background knowledge on One Health and zoonoses.

Categories of Actions to Reduce Spillover Risk	**Risk Management Actions**
Surveillance and monitoring	Trainings vet officers & PA staff, develop standard operating procedures (SOP) and case definitions, community reporting, lab confirmation, data analysis at the district and regional level, improve information flow from district to national level, improved transportation of samples and information
Land planning	Demarcated areas for livestock grazing and PAs, environmental health certifications, animal welfare checks, provide electricity and clean water services for farmers, livestock vaccination
Safe wildlife viewing and handling	New wildlife viewing platform, zoning of PAs for waste disposal, tourist briefings, regular trainings for PA staff on zoonoses, education for people keeping wildlife pets, hunting licensing, collaboration wildlife handlers' association

**This is a non-exhaustive list of actions to reduce spillover, but lists all actions mentioned by workshop participants during the group exercise.*

Workshop #3 - Western Region (Tarkwa)

Regional Background

The third workshop was held on 17-18 April in Tarkwa, a resource rich municipality with a vibrant agricultural sector. It borders Prestea Huni Valley municipality which was one the three districts linked with the first confirmed outbreak of Marburg virus disease in Ghana in 2022. The Western region is home to several gold fields, tropical rainforests, oil fields as well as large cocoa, oil palm and rubber plantations. The rich biodiversity of the region has been impacted negatively by the extractive industry, agricultural intensification, bushmeat hunting and logging.

Workshop Content and Activities

In addition to municipal and district government officials, this workshop had a large NGO and youth presence, which provided more opportunities for education and sensitization on the drivers and transmission pathways of zoonotic diseases compared to previous workshops.

- The workshop structure was the same as the second workshop in the Savannah zone beginning with a regionally specific presentation and discussion – in this case avian influenza – followed by the rich picture, mental modeling, risk interfaces (Table 6), and risk management (Table 7) activities.

Table 6. Risk interface activity output, third scoping workshop, Western region.

In groups participants identified specific settings where people come into contact with animals and factors that may increase/decrease to animals (and their potential diseases). Participants ranged from students, miners, and farmers to veterinarians and epidemiologists and had a wide range of background knowledge on One Health and zoonoses.

Risk Interface	**Factors that Increase Exposure to Animals** (and their potential diseases)	**Factors that Decrease Exposure to Animals** (and their potential diseases)
Mining	Land degradation, contaminated water, entering forests	Ecological buffer zones, afforestation, eliminate chemical use in mining, education, regular health check-ups
Oil palm plantation farming	Eating fruits bitten by animals, no protective clothing, improperly cooked food, exposed injuries/cuts, drinking water shared by animals	PPE, desist from ingesting half-eaten fruit & shared animal water, seek medical treatment if bitten/scratched by animal
Forest communities	No PPE for forestry staff, miners, hunters, etc., contact with animal feces, eating contaminated/bitten fruits	Enforcement of Forestry Commission laws, health facilities equipped with medicine/treatment

Community livestock breeding	Handling/slaughtering animals w/o PPE, poor biosecurity, lack of vaccination, free range animals	PPE, good biosecurity, inspection and certification of meat by FDA, vaccinate animals, training vet officers, education, surveillance
Wildlife hunting	Cultural beliefs, handling animals w/o PPE, entering forests	Law enforcement, safe handling animals
Tourism and forest reserves	Regular caring for animals, unauthorized hunting/deforestation, shared water bodies for people/animals	Educate visitors, PPE for staff, license hunters/loggers and educate them, health checks for forestry staff

**This is a non-exhaustive list of factors that alter exposure to animals, but lists all factors mentioned by workshop participants during the group exercise.*

Table 7. Risk management actions activity output, third scoping workshop, Western region.

In groups participants identified specific actions people and groups can take to manage and prevent zoonotic disease risk. Participants ranged from farmers, hunters, and park rangers to veterinarians and epidemiologists and had a wide range of background knowledge on One Health and zoonoses.

Categories of Actions to Reduce Spillover Risk	**Risk Management Actions**
Safe wildlife viewing, handling, and use	Tourist education, requiring/enforcing hunting permits, proper handling dead animals, wearing of PPE
Information, communication, and education	Mass communication/education for communities and farmers
Surveillance and monitoring	Form wildlife surveillance team: provide screening and treatment, vaccination, lab investigation, law enforcement, site assessment, reporting suspected cases, risk comms
Biosecurity in livestock rearing	Proper housing for animals, disinfection system, monitor animal health, checks on transportation system

**This is a non-exhaustive list of actions to reduce spillover, but lists all actions mentioned by workshop participants during the group exercise.*

Workshop #4 - Greater Accra Region (Accra)

Regional Background

The fourth and final scoping workshop was held on 8-9 May in Accra, the capital of Ghana. Greater Accra is the smallest region by land, but largest in population. Accra houses all the key government ministries. The region is rapidly urbanizing resulting in ecological disruptions and increasing population density. The most recent disease outbreak of Lassa fever in the country occurred in Accra, in 2023.

Workshop Content and Activities

Building on the prior workshops, the purpose of this workshop was to (1) inform national-level stakeholders about the N4H initiative (2) present findings from the three previous stakeholder consultation workshops held in the Ashanti region, Savannah zone, and Western region, and (3) gain insight from Accra stakeholders to understand sector-specific priorities and needs relating to preventing zoonotic spillover in Ghana.

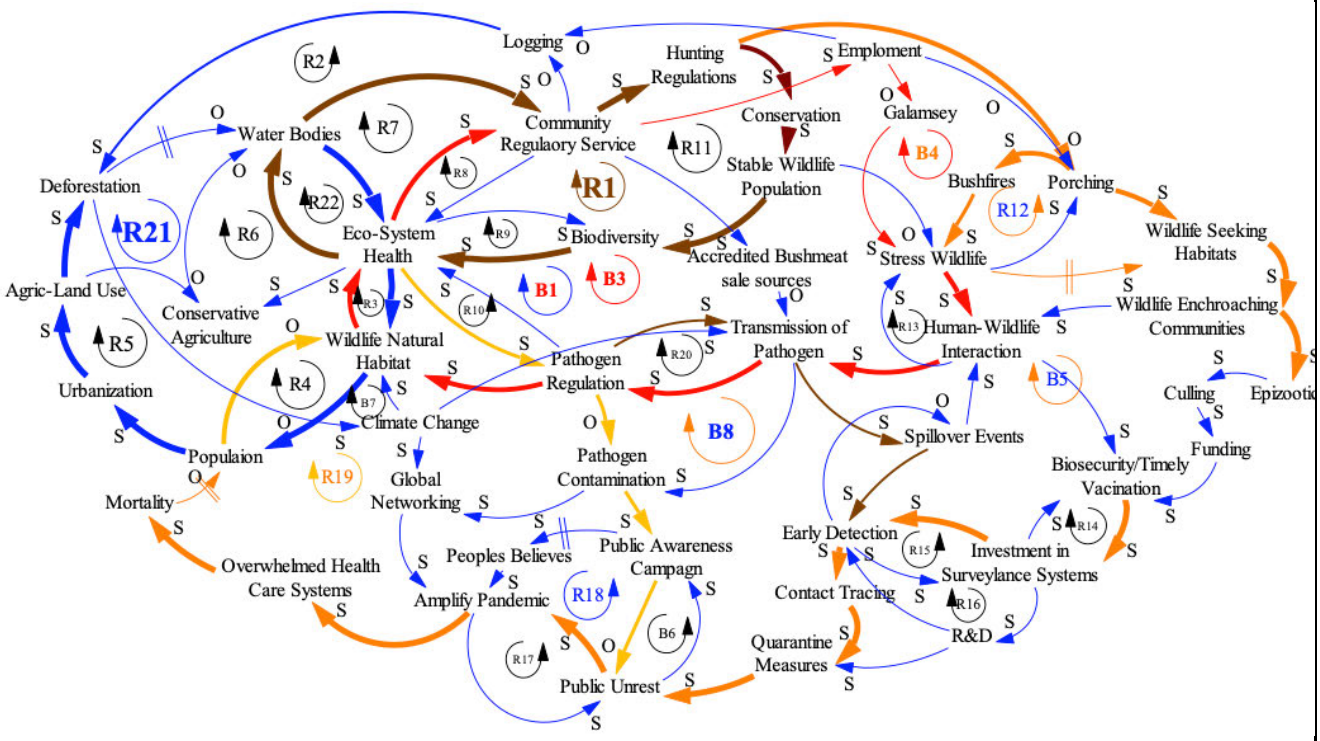
Day 1

- On day one, Core Team members presented the outputs from the three previous workshops noting the different local perspectives, strengths, needs, and settings where humans and animals come into contact at the district and regional level. The presentations outlined the on-the-ground realities of zoonotic disease outbreak risks at the subnational level and ways to effectively prevent a zoonotic spillover in the future. The final presentation came from systems thinking facilitator Dr. Banson, who provided a synthesis and analysis of the regional findings using systems thinking methodologies including causal loop diagrams to identify leverage points where specific action could be taken to address potential root causes of spillover risks (attached to the end of this document; see also example in Figure 4).
- In the afternoon, workshop participants completed an activity that combined the risk interfaces and risk management activities conducted in the previous workshops so they could provide additional insight and understand what other regional participants went through.

Figure 4. Excerpt causal loop diagram from systems analysis conducted by scoping phase

facilitator Dr. Banson.

Current state of zoonotic disease spillover in the Ashanti Region according to workshop participants based on the "Mental Model" activity.



Each arrow represents a causal link between two variables; Different colors and numbers are used to make it easier to visually differentiate between loops; B = Balancing loop; R = Reinforcing loop; The two vertical hash marks (||) represent a delay, where the situation takes time before the effect plays out.

Day 2

- Day two began with a short presentation of the N4H initiative in other countries from a representative of the N4H Secretariat at the United Nations Environment Programme. This allowed Ghanian stakeholders to see some of the similarities and differences in how the scoping process is unfolding in the five other N4H phase one countries.
- Most of the day was dedicated to an in-depth group discussion on sectoral priorities and key needs to prevent spillover. Representatives from these sectors: wildlife, veterinary services, agriculture, environmental health, and human/public health were called on, while all participants were given the chance to ask questions and input on the discussions. Key themes that arose from the discussion were One Health surveillance and data sharing, training and workforce development, legislation and enforcement, and public awareness and community engagement. Participants also raised the mandates of different agencies in a One Health frame, particularly the role of multiple agencies contributing to environmental sector activities.
- Following the close of the meeting, the Core Team met to discuss reflections and priority ideas for the Implementation Project.

Planning for the Implementation Stage

To complete the scoping process and plan for the implementation phase, the Core Team held an implementation plan "writeshop" on 20-21 June, building on the model from the N4H scoping in Mongolia. During this workshop, the Core Team reviewed a synthesis of the findings from the four scoping workshops and the implementation plan template. Going activity-by-activity, the Core Team selected activities for the implementation phase, including identifying (1) the location the activity will be carried out; (2) organizations responsible for leading the activity; (3) affected stakeholders; (4) resources required to complete the activity; and (5) timeline for activity implementation.

The Core Team also discussed how to ensure systemic practice will be continued through the project implementation, including budgeting for Core Team members to return to regional workshop locations to provide community feedback on the outputs of the scoping phase at the onset of the implementation phase. Additionally, the Core Team discussed having flexibility to slightly alter the planned implementation activities as needed to meet an ever-changing environment, build on findings in real time, and align with other initiatives.

2. Stakeholder Engagement

Describe the process undertaken to map and engage stakeholders, including other N4H partners in the scoping phase. Please list stakeholders involved and their role in an annex.

The stakeholder mapping process began through Ghana's initial expression of interest (EOI) to N4H. Several organizations, including the Veterinary Services Directorate, Wildlife Division of the Forestry Commission, National Disaster Management Organisation, and University of Ghana worked in collaboration to develop and submit the EOI, building on existing One Health efforts in the country. Once accepted as an N4H Phase I country, these organizations formed the basis for the Core Team; in the scoping phase, the team was expanded to include additional representatives from the Ministry of Environment, Science, Technology and Innovation and Ghana Health Services, to ensure One Health representation from across the human, animal, and environment spectrum.

In January 2024, country coordinator, Dr. Richard Suu-Ire, supported by colleagues from N4H global partner EcoHealth Alliance conducted partner sensitization meetings in Accra with key government agencies and N4H partners (WHO and UNDP) to garner support for N4H and better understand how N4H can support their institutional mandates and priorities. Shortly after, at the first Core Team meeting, we collectively developed a master spreadsheet of potential stakeholders to invite to each regional workshop, including representatives of government, NGOs, universities, intergovernmental organizations, trade associations (e.g., farming, mining, or bushmeat sellers associations) from across the One Health spectrum.

By hosting the scoping workshops in different regions of the country, we were able to engage with a diverse group of stakeholders in their home regions, which would not have been possible if all the scoping workshops were held in Accra. In the end, more than 100 people across greater than 20 disciplines participated in the N4H scoping workshops. A full list of participating organizations can be found in Annex 1.

The regional workshops allowed for participation by those working and interacting with situations at different scales - ranging from national, regional, and park level, individual farm level, trade associations, etc. The workshops demonstrated that these groups have differing baseline understanding of situations, including awareness of zoonotic disease transmission, but have a willingness to engage in solutions.

Participants received workshop reports following each workshop; and plans for continued engagement of stakeholders have been developed as part of the proposed IPD.

Importantly, through the scoping phase the team gave attention to the overlapping and complementary mandates among government agencies, particularly in the environment sector, which shed a light on some of the challenges of working with and across so many different organizations. While this was a known challenge going into N4H, the scoping phase allowed for constructive and additive discussions and understanding, helping to clarify the roles

and opportunities for different departments and organizations in One Health and to participate in the N4H implementation phase.

The final activity of the scoping phase – the implementation plan writeshop – was the culminating event to design implementation activities based on the collective input from all the scoping workshops and activities. We collated a bank of potential project ideas and gaps to address based on the summarized findings of the regional workshops in a shared Google Doc for all Core Team members to review and add any other activities they wanted considered for the implementation phase. This resulted in a wide range of activities, some beyond the scope of N4H, but elucidating the multiple entry points and action from different sectors to reduce spillover risks and impacts.

During the writeshop, the Core Team went activity by activity to prioritize and discuss how each activity should be implemented, including which agencies would be responsible, where should each activity be carried out, a proposed timeline, and identification of resources needed for the activity. When discussing feasibility/desirability, the Core Team also ensured that activities aligned with existing projects to promote sustainability beyond the project and be additive. For example, one planned implementation activity is to conduct wildlife surveillance for avian influenza and ecological site analyses in wetlands, which will directly build upon existing human and domestic poultry sentinel surveillance sites and feed into existing data systems for a high value add that comes with less resources and allows additional sectors to meaningfully engage to better characterize and manage situations and sources of risk. After agreeing to the proposed implementation activities, the final step was for Core Team members to take the proposed plan back to their agencies for final review from their directors to ensure high level departmental support - a necessity for multi-year sustainability and collective commitment toward success.

3. Programmatic alignment

Describe how the implementation project document aligns with and contributes to the outputs and outcome of the N4H Theory of Change.

N4H aims to reduce health risks by implementing preventative One Health approaches under four pillars of change: (1) Assess (2) Operationalize (3) Enable (4) Sustain. The scoping process in Ghana was well aligned with the N4H Theory of Change, as is the implementation plan. During the scoping phase we participated in CBD SBSTTA-26, including several side events highlighting the connections between biodiversity and health. N4H Ghana Co-Leads Dr. Catherine Machalaba and Prof. Richard Suu-Ire co-organized or spoke at multiple side events, including one event dedicated to sharing N4H country experiences to raise awareness of N4H and the linkages between nature, climate, and health at the country level. Directly following SBSTTA-26, we participated in the N4H partners meeting in Nairobi on 20-21 May. This was a meaningful opportunity to learn from other N4H partners, the secretariat, and technical advisory group and to share experiences from Ghana.

The N4H Ghana team also presented a poster at the World One Health Congress outlining the findings of the N4H scoping process in Ghana. This was an important opportunity to showcase the value of the scoping process and demonstrate how systemic practices can be operationalized to design a project to prevent zoonotic spillover.

Building on the scoping phase, the N4H Ghana implementation project document is designed to address the N4H pillars of change, align with Ghanaian government priorities, and meet the expectations of local stakeholders.

Assess

Achieve a shared and deeper understanding of the links between nature, climate change and health across sectors and stakeholder groups, while demonstrating the value of multidisciplinary evidence and participatory models to raise awareness and provide a strong rationale for investment.

The proposed IPD emphasizes both the importance of education and awareness raising on known drivers of spillover and their linkages to nature as well as the need to generate additional evidence and knowledge on local spillover risk interfaces. A core component of the proposed project plan is increased education and sensitization for a wide range of stakeholders, including farmers, protected area managers, abattoir workers and others along the bushmeat value chain, and general community members. In addition to broad sensitization, we will host more in-depth, targeted trainings for select groups of people (e.g., park rangers). The educational materials we create and use throughout the project will explicitly highlight the links between nature, health, and living safely with wildlife. Sensitization activities will double as a place for trained educators to sensitize people as well as learn from people about their interactions with animals, both wild and domestic, to document context-specific zoonotic spillover risk factors. Importantly, awareness raising will build on existing systems, e.g. risk communication expertise, but apply a One Health lens and reflect targeted needs of specific

groups.

Our proposed wildlife surveillance activities will demonstrate the value of multidisciplinary evidence, including design, generation, interpretation, and use. We will conduct surveillance for avian influenza (one of the six priority zoonoses in Ghana) in or around wetlands that are also preexisting human and domestic fowl sentinel surveillance sites run by the government of Ghana in order to better understand the potential for mixing of avian influenza strains across species and the conditions that drive risk (which could potentially be managed through policy and planning measures, for example). Data will be collected by multidisciplinary field teams and linked to existing surveillance systems. To complement wildlife or environmental samples, field teams will also conduct ecological site assessments to document and draw linkages between humans, animals, and the environment.

Further, N4H in Ghana will also conduct a national filovirus risk assessment for Ghana, which will include using citizen science to identify and collect data on locations of caves and bat roosting sites (potential filovirus reservoirs). An improved understanding of wildlife locations and habitats is an important precursor to understand which communities may be at increased risk and where to target awareness raising activities. These activities will show the potential for multidisciplinary collaboration and stimulate creative and low-cost ways to mobilize collective expertise and other resources to reduce spillover risk. For example, these activities can be paired with existing or future biodiversity surveys and serve as a basis to monitor biotic and abiotic changes; protection of wetland and bat cave/cat habitat could end up as priorities based on findings, with N4H evaluating co-benefits of nature-based solutions to climate and biodiversity and the protection of ecosystem services.

Operationalize

Operationalize action and policy to foster enabling environments for disease prevention at source.

Operationalizing disease prevention at source comes in many forms. Education, sensitization, training, and awareness raising mentioned above are important components of creating an enabling environment, so is advocacy with local governments to enact and enforce existing policies that aim to reduce disease spillover and improve biosecurity. Although many policies and bylaws exist, enforcement is a challenge at the municipal and district level. We plan to educate and advocate for implementation of existing policies and guidelines (e.g., newly passed Wildlife Resources Management Act) that are already in place but do not have the broad awareness of their relevance for One Health or the support needed for their success.

Having clear and tested standard operating procedures (SOPs) and guidelines also helps to operationalize upstream prevention activities. This project will review and update (as needed) existing SOPs for disease detection and reporting in wildlife, especially in relation to priority zoonotic diseases (e.g., avian influenza, hemorrhagic fevers, anthrax) which will be disseminated to district health officials for implementation. Other guidelines that have been requested by the Core Team for review include biosecurity guidelines for wildlife at quarantine

at points of entry as well as national biosecurity guidelines for poultry and pigs.

Enhancing data linkages and information sharing also promotes an enabling environment for collaboration. We therefore plan to conduct an assessment of data sharing between the different health management information systems that are currently being used, with a focus on integrating wildlife and veterinary data.

Enable

Enable and strengthen the capacity and knowledge of key stakeholders to manage knowledge, action, advocacy and decision-making, leveraging the links between nature, climate change and health.

Capacity and knowledge development cut across all the proposed activities in the IPD. Each activity will be led by at least one organization based in Ghana (e.g., government agencies, University of Ghana, local NGOs) to steward knowledge ownership. To ensure localized knowledge management, project outputs will be stored in a repository of One Health documents on the University of Ghana website; all surveillance data will be owned and housed within government reporting systems; and the review of SOPs and guidelines will be accompanied by training on standard practices for continued use after this project ends. Linking and sharing data is another critical part of turning information into actions. Our planned assessment of data sharing and data system interoperability will identify roadblocks to data sharing and outline steps that could be taken to improve data management between sectors. Strategic linkages to existing data forms (e.g., FAO Empress-i and VSD field forms) will encourage integration of wildlife and ecological data into data systems.

Sustain

Sustain effective collaboration and governance structures to facilitate preventive planning, action, accountability and policy.

Sustainability is a critical component of N4H's success in Ghana. The foundational work to nurture N4H's sustainability started in the scoping phase by actively engaging with all the important One Health ministries in Ghana. The Core Team, made up of government representatives and long-term Ghanaian capacity building and technical institutions is the throughline for all project activities. Sustainability has also been considered in each proposed IPD activity. Updated SOPs and guidelines developed from this project will be owned by the government and used beyond the implementation phase, as will wildlife surveillance data collection forms (which are not only needed in Ghana, but many other West African countries, and thus could serve as a template for expanded use). Data collection and reporting will all be integrated into existing government systems that will not require additional funding post N4H in Ghana. Moreover, all educational and awareness raising materials will be co-developed with relevant government agencies and owned by the government and local NGOs for future use and updating as needed.

4. Challenges and Lessons Learned

Describe challenges faced and key lessons learnt in the scoping phase.

As the first cohort of N4H countries, and one of the first to begin the scoping phase, we encountered several challenges and learned many lessons along the way.

- The ability to extend the scoping phase timeline was highly beneficial to ensure we had ample time to conduct an "implementation plan writeshop", solicit feedback on the scoping report and implementation plan, and hold an additional core team meeting to discuss publications. Initially, the scoping phase in Ghana was planned for 5 months. Between sensitization, planning and prioritization of regions/contexts, the systems thinking process, and design of a full project, the scoping phase was rapid. The gap between the Phase I EoI and scoping phase was lengthy; in other countries, we could envision how a long gap between the EoI and the scoping phase could be detrimental. Thanks to the Core Team's serious commitment and ongoing engagement, this allowed for rapid start-up, decisions to be made quickly, and strong momentum throughout the process. Once in the scoping phase, there were many logistical arrangements that need to be made with agility to host multiple workshops, and one inherent challenge of multi-sectoral One Health work is the need to schedule events around the availability of many organizations and sectors that all have other competing priorities and are not always incentivized to participate due to the projects inability to pay for government workers participation. Ultimately, we were extremely pleased with the engagement and participation we received at the scoping workshops, but without a strong Core Team with vast existing relationships this would have been much more challenging.
- The concept of systemic practice and systems thinking methods were unfamiliar to most people, which required additional time to sensitize the Core Team, government agencies, and workshop participants to the N4H process. However, some key institutional leaders had experience with systems thinking from their involvement in international fora, and immediately saw the value of staff participation in N4H. The nonprescriptive nature of the scoping guide and the flexibility we had in selecting and modifying activities from the guide was essential for successful systemic practice in the Ghanaian context. Ultimately, we see the systemic approach as necessary from project start to finish and look forward to continuing to examine the situations prioritized in the implementation phase through this lens to inform our work and strengthen systems thinking capacity. Stakeholders appreciated this approach, including the Western Regional Director of Veterinary Services who noted during the third scoping workshop that he planned to use rich picturing in the future to better understand communities and to engage community members in vet services.
- Although we used activities from the scoping guide (e.g., rich picturing), we found it to be quite theoretical at times and felt it necessary to develop our own activities that were more targeted with the explicit N4H purpose of implementable spillover prevention actions with environment sector relevance that could be taken up during the implementation phase. The scoping phase timeline demanded this more rapid evolution of the process and likely better met the needs of government colleagues and

local participants with limited time for meetings.

- While the intention of collaboration was excellent, the timing of the scoping phase was dynamic and it was essential to prioritize the availability of colleagues in each country; the fact that each of the 6 phase one N4H countries is working through the scoping phase on different timelines made it hard to participate in workshops from other countries; in addition, the time demand of arranging 4 workshops in Ghana in 3 months precluded participation in other scoping meetings. The participation from UNEP in a Ghana scoping workshop was sincerely appreciated and extremely beneficial. In the next phase, the global partner in each country could consider copying the focal points into initial communications to help reinforce the relevance to many sectors and help build broad support.
- Lack of clarity about what and how items can be funded - including common questions across multiple countries and partners - requires more attention from the Secretariat, funder, and MPTFO. In addition, the expectation of time for government partners needs to be reasonable - In Ghana, the Core Team was extremely generous with their time and expertise; but it is important that value addition to government partners be clear to incentivize and maintain participation. In addition, where activities are best suited for government services, reasonable exceptions should be allowed under the project to reinforce existing capacity (for example, government laboratories that could effectively and efficiently build wildlife screening into their existing operations).
- Within each sector (animal health, human health, environmental health) there may be several organizations, or even departments within the same organization (e.g., Ministry of Environment, Science, Technology and Innovation), with similar mandates. Flexible processes should be in place to support official participation (delegated authority) for vital high-level prioritization and decision making, while also providing more flexible ways to engage with the project based on interest. Finding skilled facilitators, particularly those with experience in systems thinking methods can be difficult. To identify potential facilitators, we conducted a short literature review for publications using systems methods from Ghana, searched websites such as ResearchGate and LinkedIn, and leveraged our partnership networks for contacts. Having two facilitators with complementary expertise and sectoral experience required more planning and coordination but was a major contributor to the success of the scoping phase and provided greater agility in scheduling workshops and richness in the interpretation of outputs.
- The concept of upstream spillover prevention is complex; hosting scoping workshops for one day was not enough time to fully engage in meaningful discussions and activities to identify actions to reduce spillover. Given different levels of baseline awareness among participants, a training would have been useful to provide a common understanding about disease and risk going into the workshops. The Core Team debrief after the first workshop allowed us to recognize this and expand the others to two days, but it was an important lesson learned.
- It was essential to begin the scoping phase with project sensitization meetings with government ministries and project partners to inform them about the project, set expectations (e.g., timeline, funder restrictions), and gather contacts to invite to future workshops. Relatedly, developing background materials on N4H globally and in Ghana

(e.g., PowerPoint presentations, one-pager, etc.) was helpful for sensitization meetings and scoping workshops throughout the project. Specifically, having editable versions from the Secretariat that could be adapted for country-specific use was helpful.

- The benefit of being dynamic and responsive to participant needs and contexts in workshops – some which are not always obvious in the planning – was clear. The utility of transitioning to Twi language mid-workshop demonstrated this to us in terms of ease of communication and richness of information generated; however, the trade-offs might have been harder to balance if an investment in travel and time had been made for other N4H global partners to attend that workshop.

5. Conclusion and Recommendations

Outline key recommendations for the implementation phase of the project.

The N4H scoping process in Ghana underscored the importance of relationship building and flexibility to meet participant needs and regional contexts. Keys to a successful implementation phase in Ghana are presented here:

- Strong commitment and engagement from the Core Team were essential to the success of the scoping phase; continuing to incentivize participation, including demonstrating clear value to government partners, will be critical in the implementation phase.
- Identifying specific entry points for systemic practice at the onset of the implementation phase will be important for integrating systems thinking concepts into implementation activities throughout the project.
- Building in opportunities for cross-country exchange and experience sharing across N4H Phase I and forthcoming Phase II countries and partners will be an integral part of the implementation phase and key to the global success of N4H.
- The implementation plan writeshop was an important moment for boundary setting and empowering the Core Team to make project decisions. Continued empowerment will require two things: (1) regular opportunities for Ghanaian stakeholders, primarily the Core Team, to influence the activities and direction of the implementation plan; (2) a dynamic implementing partner with the freedom to be flexible and responsive to country needs.

Ultimately, the sustainability of N4H lies within our abilities to support context-specific interventions informed by local communities and experts. The scoping phase was a reminder that true multi-sector One Health work is complex, but integral to upstream prevention. We look forward to an implementation phase that will reduce the risk of zoonotic spillover in Ghana and showcase the unique model of N4H globally.

Annex 1.

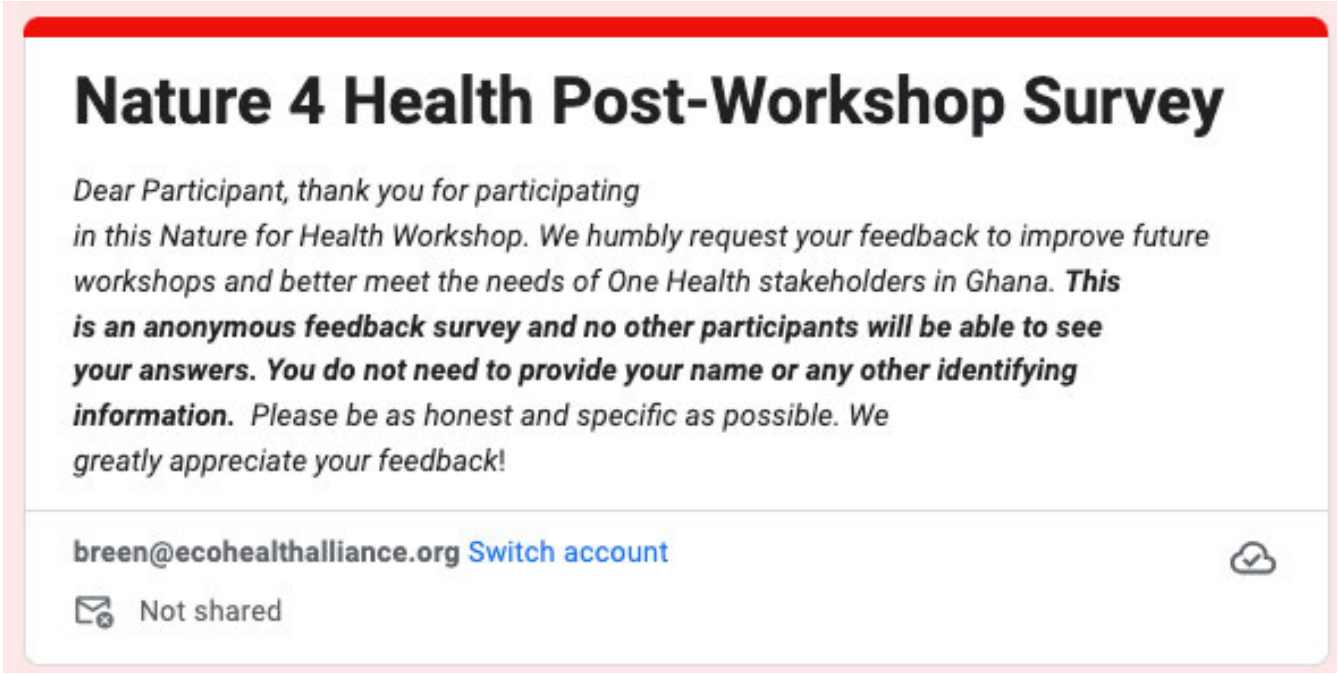
Supplementary Table 1. Regional scoping workshop participants

Region	Participating Organisations	
Ashanti Region	• Wildlife Division of the Forestry Commission • Veterinary Services Directorate • Animal Production Directorate • Ghana Health Service • Environmental Protection Agency • National Disaster Management Organisation (NADMO)	• Kumasi Centre for Collaborative Research (KCCR) • Regional Coordinating Council • Abattoir • Farmers associations (crop, poultry, and pig) • Small Scale Miners Association • Bush Meat Traders Association • Arocha Ghana (NGO)
Savannah Zone	• Stakeholders from the Upper East and Upper West regions including: • Veterinarians • Extension officers • Wildlife rangers • Park managers	• Farmers (crop and livestock) • Hunters • Ghana Health Service • Disaster Management Organisation • Environmental Protection Agency • NGOs (Arocha Ghana, North Code and Green for Change Ghana)
Western Region	• Veterinary Services Directorate • Ghana Health Service • Forestry Commission • University of Mines and Technology • Environmental Health and Sanitation Department • Environmental Protection Agency	• Department of Agriculture • Farmers • Bushmeat traders • Butchers • Loggers (Ayum Forest Products Ltd.) • NGOs (Leanita International, Progressive Network Forum, and West African Cooperatives Network)
Greater Accra Region	• Ministry of Food and Agriculture (Veterinary Services Directorate and Animal Production Directorate) • Veterinary Council • Ministry of Environment, Science, Technology, and Innovation (Environmental Protection Agency, CSIR Animal Research Institute, and Ghana Atomic Energy Commission) • Ministry of Lands and Natural Resources (Wildlife Division of Forestry Commission)	• Ministry of Health (Public Health Directorate, Health Promotion Directorate, Allied Health Directorate) • Ministry of the Interior (Disaster Management Organisation) • University of Ghana (Noguchi Memorial Institute for Medical Research, School of Public Health, School of Veterinary Medicine, Department of Nutrition and Food Science, Centre for Biodiversity Conservation Research, and Department of Sociology) • Communication for Change (NGO)

Annex 2.

Post scoping workshop survey

One of the key lessons learned during the scoping process was to create and deploy a post-workshop anonymous feedback survey. We had the idea after the second workshop, so we only have responses from participants from the 3rd scoping workshop held in the Western Region (see below). The fourth workshop was structured differently than the first three, so we chose to solicit feedback in person rather than through a Google form.



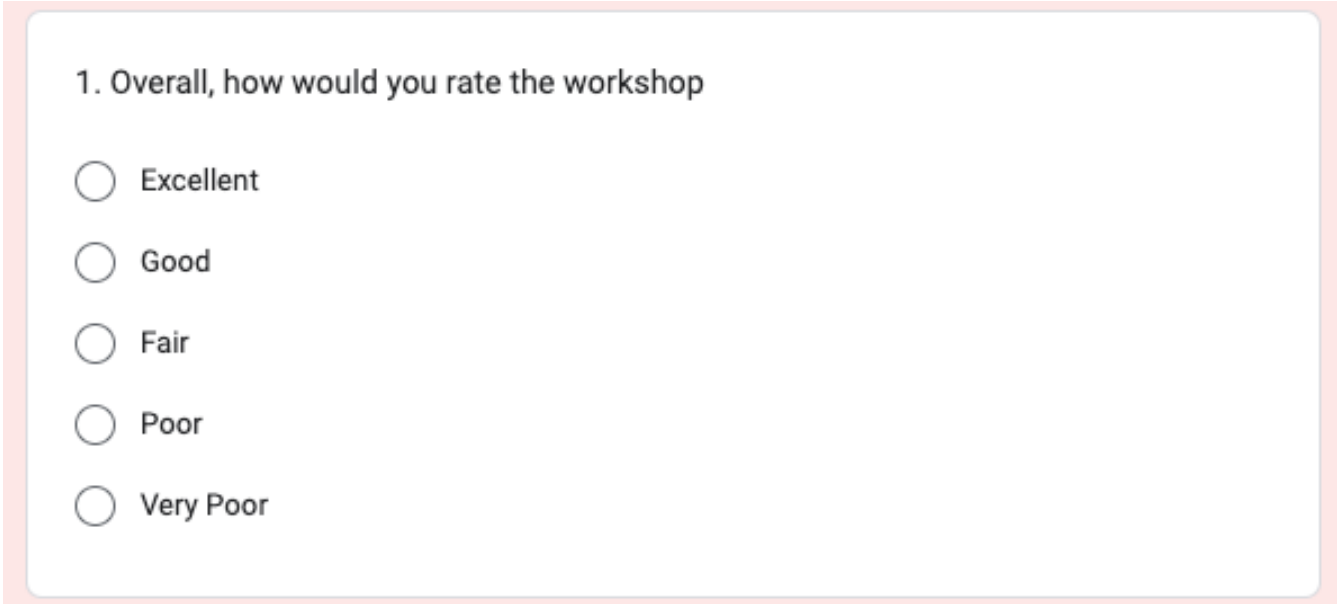
Nature 4 Health Post-Workshop Survey

Dear Participant, thank you for participating in this Nature for Health Workshop. We humbly request your feedback to improve future workshops and better meet the needs of One Health stakeholders in Ghana. ***This is an anonymous feedback survey and no other participants will be able to see your answers. You do not need to provide your name or any other identifying information.*** *Please be as honest and specific as possible. We greatly appreciate your feedback!*

breen@ecohealthalliance.org Switch account

Not shared

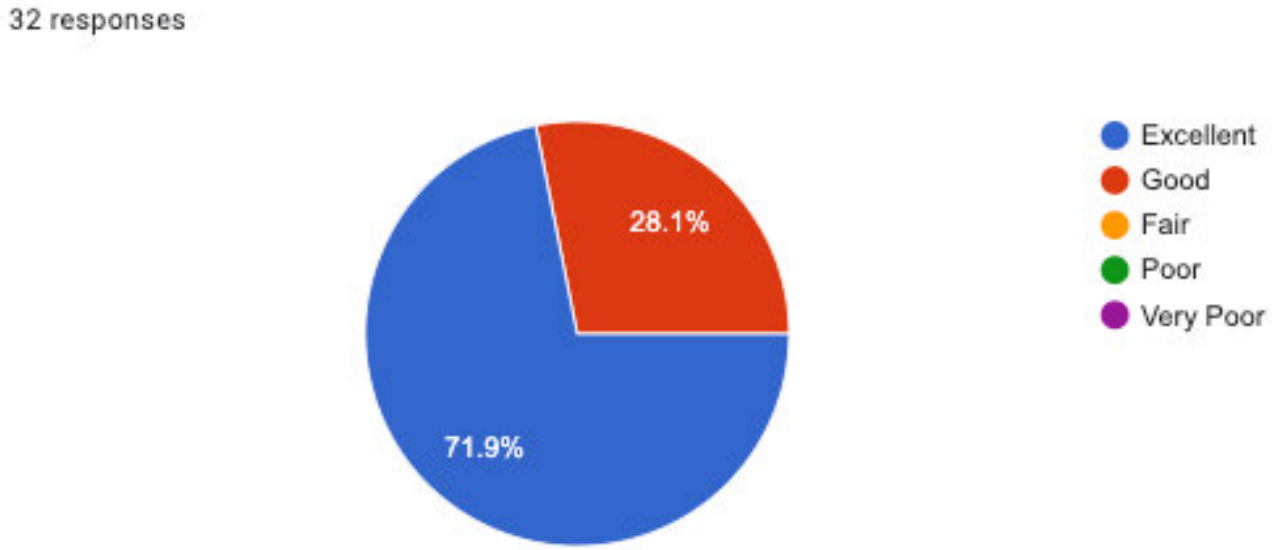
Question 1



1. Overall, how would you rate the workshop

- ◯ Excellent
- ◯ Good
- ◯ Fair
- ◯ Poor
- ◯ Very Poor

Response Question 1 *(Western Region Workshop)*



Question 2

2. Did the workshop meet your expectations? Please explain.

Your answer

Response Question 2 *(Western Region Workshop)*

Nearly all participants responded, “yes”, their expectations were met. Many participants noted that they previously did not know about the zoonotic spillover connection between animals and people, but they learned something about methods to prevent spillover. The two people who did not respond “yes” noted that some important stakeholders were left out and more workshops are needed.

Question 3

3. What could the workshop organizers have done to better prepare for a successful workshop

Your answer

Response Question 3 *(Western Region Workshop)*

By far the most prevalent response was a request for broader inclusion of more stakeholders, people, and organizations to be involved/included (e.g., mining companies, farmers, more community members). Other responses included a request for more printouts of workshop materials for people to take home, slightly shorter days, more inclusion of local languages, and additional food.

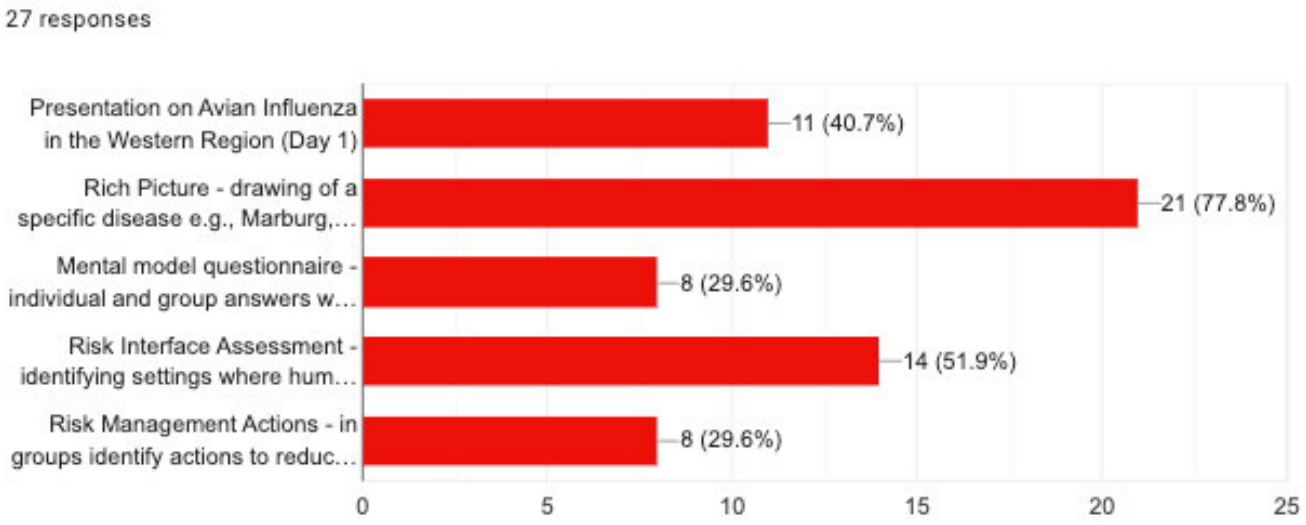
Question 4

4. Which specific activities did you find most valuable or engaging? **Select up to two activities** (Note: Activities are listed in the order in which they were carried out)

- ☐ Presentation on Avian Influenza in the Western Region (Day 1)
- ☐ Rich Picture - drawing of a specific disease e.g., Marburg, Lassa Fever, Anthrax, Avian Influenza (Day 1)
- ☐ Mental model questionnaire - individual and group answers written on sticky notes (Day 1)
- ☐ Risk Interface Assessment - identifying settings where humans and animals come into contact and ways to decrease/increase exposure (Day 2)
- ☐ Risk Management Actions - in groups identify actions to reduce spillover risk, including expected outcomes, how to measure success. This activity also includes the impact-effort chart.

Response Question 4 *(Western Region Workshop)*

The most valuable/engaging activity mentioned by participants was the rich picture, followed by the risk interface assessment.



Question 5

5. Are there any specific organizations, sectors, or people that were not present at this workshop that you think should be invited to a future workshop?

Your answer

Response Question 5 *(Western Region Workshop)*

Many organizations and groups of people were mentioned as additional participants to include:

• Local government • Schools (headteachers and students) • Traditional leaders • Extension officers • Pharmacists	• More farmers • Data scientists • Members of parliament • Hunters • Vet officers • Market women	• Miners (companies and individuals) • Police • Cocoa farmers • Regional leaders • Galamseyers • Media

Question 6

Response Question 6 *(Western Region Workshop)*

Many improvements were suggested, including adding more stakeholders and other local languages, expanding workshops to other municipalities, districts, and regions, providing hardcopies of the PowerPoint presentations, and providing accommodation for participants.

A Systems Thinking Analysis of the

Nature for Health Ghana

Scoping Phase

Author: Dr. Kwamina Ewur Banson

Acknowledgments

The Core Team was comprised of Richard Dery Suu-Ire, Amos Sarpong Agyei, Ruth Nana Friba Arthur, Sherry Ama Mawuko Johnson, Anna Sekyibea Bekai, Meyir Yiryele Ziekah, Theophilus Odoom, Kwamina Ewur Banson, Juliana Yartey Enos, Robin William Burrows Breen, and Catherine Machalaba.

This systems analysis was performed by Dr. Kwamina Ewur Banson.

We are grateful for the collaboration and vital inputs from all workshop participants who provided their insight and expertise. We express our appreciation for their kind collaboration.

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The information and conclusions do not necessarily represent the views of Core Team institutions. The report, including any errors or omissions, remains the responsibility of author.

Executive Summary

Zoonotic diseases, which originate in animals and can transmit to humans, pose significant public health threats globally. In Ghana, efforts to prevent zoonotic disease spillovers face multifaceted challenges, influenced by factors such as funding limitations, inadequate law enforcement, socio-cultural beliefs, and economic drivers, among others. To address these challenges effectively, a systems thinking approach was employed to analyze zoonotic disease prevention efforts in three distinct regions/ecological zones in Ghana: the Ashanti Region (Kumasi), the Savannah zone (Mole National Park), and the Western Region (Tarkwa). In the Ashanti Region (Kumasi), funding constraints and inadequate law enforcement contribute to the proliferation of zoonotic disease risks, exacerbated by socio-cultural beliefs and economic pressures. Public awareness campaigns and enhanced biosecurity measures are recommended to mitigate these risks, along with targeted investments in surveillance systems and early detection measures. Similarly, in the Savannah zone, the interconnected dynamics of population growth, agricultural expansion, and wildlife habitat destruction increase the likelihood of zoonotic disease spillovers. Strengthening community regulatory services, improving public education, and enhancing funding for disease surveillance and control efforts are vital interventions to address these challenges. In Western Region (Tarkwa), the nexus of urbanization, unemployment, and illegal mining activities creates an environment conducive to human-wildlife interactions and potential zoonotic disease transmission. Addressing socio-economic disparities, enforcing environmental regulations, and promoting sustainable land use practices are essential strategies to reduce zoonotic disease risks in this region. Overall, this analysis underscores the importance of interdisciplinary collaboration and community engagement in zoonotic disease prevention efforts. By leveraging the expertise of diverse stakeholders and adopting a One Health approach that integrates human, animal, and environmental health considerations, Ghana can build resilience in preventing zoonotic diseases spillover while promoting sustainable development. The systemic interventions outlined in this report provide actionable insights for policymakers, health officials, and local communities to strengthen zoonotic disease prevention strategies and safeguard the health and well-being of people, animals, and ecosystems.

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Introduction

Zoonotic spillovers are the transmission of diseases from animals to humans. Zoonotic diseases, originating in animals but transmissible to humans, constitute a significant threat to public health, environmental sustainability, and economic stability worldwide. In Ghana, like many other countries, combating these diseases requires a comprehensive, interdisciplinary approach that addresses both immediate health concerns and the systemic drivers of disease emergence and transmission.

This report focuses on the analysis of zoonotic disease spillover prevention efforts in three distinct regions/ecological zones in Ghana: the Ashanti Region (Kumasi), the Savannah zone (Mole National Park), and the Western Region (Tarkwa). Through a systems thinking framework, we delve into the intricate web of factors influencing the prevalence and spread of zoonotic diseases in each region/zone.

Importantly, our examination is enriched by the on-the-ground insights from a diverse array of stakeholders including the forestry commission, the veterinary service department, Ministry of Food and Agriculture, and the Environmental Protection agency, staffs from National Parks, livestock farming communities, environmental agencies, NGOs, health services, disaster management organizations, academia, and local communities, contributed their expertise and experiences to the discussion.

Facilitating these workshops were Core Team members, comprising of experts in veterinary medicine, public health, wildlife conservation, environmental management, and disaster response. Their guidance and facilitation ensured that the workshops were productive and fostered meaningful discussions and knowledge exchange among participants.

The subsequent sections of this report delve into the findings of our analysis, highlighting the systemic challenges and opportunities for zoonotic disease spillover prevention in each region. By identifying leverage points and systemic interventions, we aim to provide actionable recommendations for policymakers, officials from One Health-related agencies, and local communities to enhance resilience and mitigate against the risks associated with zoonotic diseases. Through collaborative efforts and informed strategies, we endeavour to safeguard human and animal health, preserve ecosystems, and promote sustainable development in Ghana.

Background and Methods

Between February – April 2024, workshops were held in three regions/ecological zones of Ghana, with the aim of bringing together diverse stakeholders to understand the zoonotic disease situation across different contexts. These were convened as part of the Nature for Health (N4H) Ghana scoping phase, intended to inform a 2–3-year project focused on reducing spillover risk. The workshops included systems thinking exercises to gain input and provide a holistic understanding across sectors and stakeholders.

Holistic Approach and the Scooping Process to Zoonotic Spillover Prevention

The ELLab (Figure 1) represents a unique methodology integrating a system's components holistically, leveraging both existing and new knowledge to manage complex issues effectively (Bosch *et al.*, 2013). Between February – April 2024, workshops were held in three ecological zones in Ghana, with the aim of bringing together diverse stakeholders to understand the zoonotic spillover situation across different contexts. These were convened as part of the Nature for Health (N4H) Ghana scoping phase, intended to inform a 2–3-year project focused on reducing spillover risk. The proposed methodology integrates the scooping process into the ELLab framework, structured into six comprehensive steps. The integration of the scooping process into the ELLab methodology enhances systems thinking research by providing a structured approach to stakeholder engagement, detailed project planning, and iterative learning. This combined methodology ensures a more comprehensive understanding of complex issues and facilitates the development of effective, sustainable interventions. The workshops included systems thinking exercises to gain input and provide a holistic understanding across sectors and stakeholders. Five important questions (Q) addressed during the workshops were: Q1: Leaving behind our bias about what our own field of work can do, what needs to be done in general to prevent spillover risk while preserving the health and livelihoods of people, animals, and ecosystems? Q2: From the things that need to be done, who (which stakeholders) should do what? Q3: What is the role of the community, district assembly, farmers, hunters, miners, etc. in the prevention of spillovers? Q4: What measures to reduce spillover risk are already in place? What is working already? And Q5: What are the biggest challenges to preventing spillovers? Think about individual beliefs, economic incentives, policies, resources, etc**.**

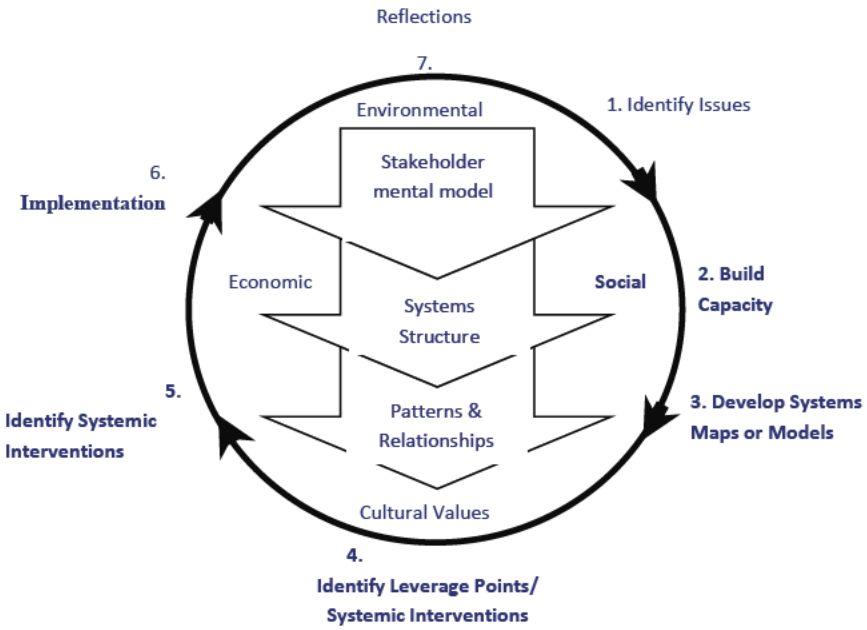

Figure 1: ELLab Process for managing complex issues (adapted from Bosch et al. 2013)

This approach has demonstrated success across diverse contexts (Nguyen & Bosch, 2013). In the context of preventing zoonotic spillovers, this study began by engaging a diverse array of stakeholders in Step 1 of the ELLab process. Through extensive literature review and focused group discussions, participants included representatives from environmental agencies, the veterinary service directorate (VSD), farmers, hunters, bushmeat dealers, the forestry commission, and the environmental protection agency (EPA). During the focus group discussion, participants were asked questions and provided anonymous answers on sticky notes. Gender equity was ensured among stakeholders' participants, and due to cultural norms and societal expectations that often inhibit women from freely expressing themselves or stating certain truths in the presence of men, a two-step questionnaire process was adopted. First, we gathered individual responses to the questions, followed by group responses to the same questions. This approach allowed us to collect more candid and diverse feedback, particularly evident in the individual answers compared to the group answers. The gathered information was collated and categorized. These stakeholders provided insights into system operations, identified barriers to success, highlighted key drivers, and proposed potential strategies (solutions). Step 2 involved capacity building with stakeholders in various locations: the Ashanti Region, Mole National Park in the North, and Tarkwa in the Western Region. This collaboration aimed to aggregate, and sort given answers into common themes, patterns, and relationships within the data. This helps in understanding how different variables interact and influence each other. This step involves arranging the key variables and mapping out their interactions.

VENSIM software (Ventana Systems UK, 2013) was utilized in Step 3 to develop causal loop diagrams (CLDs) that illustrate interconnected issues related to zoonotic spillover prevention in these diverse regions. The CLDs were then examined for reinforcing and balancing feedback loops and key interactions factors that drive the behaviour of the system. Different colours were used to enable you track the loops. Reinforcing feedback loop is observed in situations where actions or conditions reinforce

themselves, leading to amplification or growth in a particular direction. For example, in the analysis, reinforcing feedback loops are evident in scenarios such as the increase in population leading to urbanization, which in turn leads to more agricultural land use and deforestation. Balancing feedback loop describes situations where actions or conditions work to maintain equilibrium or stability within a system. For instance, the presence of water bodies contributes to ecosystem health, which supports the regulation of pathogens within the ecosystem, creating a balancing feedback loop. By understanding how these factors influence each other, stakeholders can develop more effective strategies for spillover prevention. Step 4 focused on interpreting and analysing these mental models to identify patterns in their interconnected components, including pinpointing leverage points within the complex systems. A leverage point, in the context of systems thinking, refers to a place within a complex system where a small shift in one element can lead to significant changes in the overall behaviour of the system (Banson *et al.*, 2015). These points are areas where interventions or changes can be strategically applied to achieve desired outcomes or to influence the system in a favourable direction. In essence, leverage points are places where relatively small investments of resources, effort, or influence can result in disproportionately large effects on the system as a whole. Identifying leverage points is crucial for effective intervention and systemic change because it allows stakeholders to focus their efforts on the most impactful areas. Examples of leverage points include:

1. Systemic Feedback Loops: Identifying and altering feedback loops within the system can lead to changes in behaviour or outcomes. For example, reinforcing positive feedback loops that encourage desirable behaviours or weakening negative feedback loops that perpetuate undesirable outcomes.
2. Structural Changes: Making structural changes to the system's design or organization can have far-reaching effects. This could involve reconfiguring incentives, changing rules or regulations, or redesigning processes to promote desired behaviours.
3. Changing Paradigms or Mental Models: Shifting underlying beliefs, assumptions, or mental models can fundamentally alter how individuals and organizations perceive and interact with the system. This can lead to transformative changes in behaviour and decision-making.
4. Building Resilience: Strengthening the system's resilience to external shocks or disturbances can enhance its ability to adapt and thrive in the face of uncertainty or change. This may involve investing in redundancy, diversity, or adaptive capacity.
5. Empowering Key Actors: Empowering key stakeholders or actors within the system to drive change can be a powerful leverage point. This could involve providing resources, training, or support to enable these actors to catalyse positive transformations.

Identifying leverage points requires a deep understanding of the underlying dynamics and structures of the system, as well as careful analysis of potential intervention strategies. By targeting leverage points strategically, stakeholders can maximize their impact and drive meaningful systemic change.

Step 5 aimed to use the identified leverage points within the complex system to develop systemic interventions through meetings with directors, who are heads of those involved in the workshop participation, within the Greater Accra Region. A leverage point refers to a place within a complex system where a small shift in one component can lead to significant changes in the overall behaviour of the system. These points are areas where interventions or changes can be strategically applied to achieve desired outcomes or to influence the system in a favourable direction. In essence, leverage points are places where relatively small investments of resources, effort, or influence can result in disproportionately large effects on the system. Identifying leverage points is crucial for effective

intervention and systemic change because it allows stakeholders to focus their efforts on the most impactful areas. Step 6 utilized the outcomes to develop a 2–3-year implementation project to address the root causes of spillover within the country systemically.

Step 7. Since no systems model can ever be completely "correct" in a complex and uncertain world, the only way to manage complexity is by regularly reflecting on the outcomes of actions and decisions to be used in the interventions. This reflection helps determine whether the interventions are successful and identifies significant unintended consequences and new barriers that were previously unforeseen (Bosch et al., 2013).

Systems Thinking

Systems thinking in the context of zoonotic spillover prevention involves understanding the interconnectedness and complexity of factors contributing to the emergence and spread of zoonotic diseases. It emphasizes viewing the problem holistically, considering the relationships and feedback loops among various components of the system, including human behavior, animal health, environmental factors, socio-economic dynamics, and institutional frameworks.
Key aspects of systems thinking in zoonotic spillover prevention include:

1. **Interdisciplinary Approach:** Recognizing that zoonotic spillover is influenced by a multitude of factors across diverse disciplines such as ecology, epidemiology, veterinary medicine, public health, sociology, economics, and policy.
2. **Complexity and Uncertainty:** Acknowledging the complexity and uncertainty inherent in zoonotic disease dynamics, including the interactions between pathogens, hosts, vectors, environments, and human activities.
3. **Feedback Loops:** Identifying feedback loops within the system, both reinforcing and balancing, which can amplify or mitigate the risk of zoonotic spillover. For example, deforestation may lead to increased human-wildlife contact, which in turn raises the risk of disease transmission.
4. **Nonlinear Relationships:** Understanding that cause-and-effect relationships in zoonotic spillover prevention are often nonlinear, with small changes in one part of the system potentially leading to significant consequences elsewhere.
5. **Unintended Consequences:** Recognizing the potential for unintended consequences of interventions aimed at spillover prevention, such as the displacement of disease vectors or the emergence of antimicrobial resistance.
6. **Dynamic Behaviour:** Appreciating the dynamic nature of zoonotic disease systems, characterized by feedback loops, delays, thresholds, and tipping points, which can result in sudden shifts or outbreaks.
7. **Holistic Solutions:** Emphasizing the need for holistic, multisectoral approaches to spillover prevention that address underlying drivers and leverage points across the entire system, rather than focusing solely on individual components or symptoms.

By applying systems thinking principles, stakeholders can develop more effective strategies for zoonotic spillover prevention that consider the broader context, anticipate unintended consequences, and promote resilience in the face of changing conditions. This approach fosters collaboration across disciplines and sectors, enhances adaptive capacity, and ultimately contributes to a more sustainable and resilient

approach to managing zoonotic disease risks. The analysis integrates systems thinking tools such as ***Causal Loop Diagrams (CLD), mental models, and systems archetypes*** to gain a comprehensive understanding of the challenges related to zoonotic disease prevention in the Ashanti Region (Kumasi), Savannah Zone, and Western Region (Tarkwa).

Systems Archetypes

Systems archetypes were also identified from the various system structures are essential systems thinking tools for enhancing our understanding of the complex interactions driving zoonotic spillovers. By applying these tools, stakeholders can identify key management interventions pertaining to each system archetypes for sustainable spillover prevention.

Systems archetypes are recurring patterns of behaviour that arise from the structure of complex systems. They provide insight into common systemic issues and dynamics, such as reinforcing feedback loops leading to exponential growth or balancing feedback loops maintaining stability. Systems archetypes offer valuable insights into the underlying causes of spillover risks and potential interventions. For instance, the "Limits to Growth" archetype might apply if unchecked population growth or resource depletion increases the likelihood of human-animal contact and spillovers. By recognizing these archetypal patterns, stakeholders can develop more targeted and effective interventions to address systemic issues.

By applying these tools, stakeholders can identify leverage points for intervention, anticipate unintended consequences, and design more holistic and sustainable approaches to spillover prevention.

Understand Zoonotic Spillover Risks Through Mental Models of Stakeholders for Spillover Prevention in Ghana

Mental models are individuals' internal representations of how the world works, shaped by their beliefs, experiences, and perceptions (Andrews *et al.*, 2023). They influence how people interpret information, make decisions, and act within a given system. Understanding stakeholders' mental models regarding zoonotic spillovers is crucial for designing targeted interventions and communication strategies
The following questions (Tables 1-5) were explored in a mental model exercise to better understand the perspectives and beliefs of local government officials and community members relating to human-animal-ecosystem interactions and zoonotic disease prevention.

Tables 1-5 below provide a concise overview of the questions and the frequencies of thematic answers.

Table 1: "Mental Model" Activity Question One with Analyzed Answers

Q1: Leaving behind our bias about what our own field of work can do, what needs to be done in general to prevent spillover risk while preserving the health and livelihoods of people, animals, and ecosystems?		
Ashanti Region: Kumasi	**Savannah Zone: Mole National Park**	**Western Region: Tarkwa**
1. Public Awareness Campaigns: 13 times 2. Biosecurity: 11 times 3. R&D (Research and Development): 3 times 4. Surveillance: 3 times 5. Vaccination: 2 times 6. Afforestation: 2 times 7. Early Detection/Report: 2 times 8. Policy: 2 times 9. Systemic Intervention: 1 time 10. Hunting/Poaching: 1 time 11. Ecosystem Health: 1 time 12. Conservation Agriculture: 1 time 13. Agric Land Use: 1 time 14. One Health: 1 time	1. Public Awareness Campaigns: 20 times 2. Vaccination: 9 times 3. Laws: 9 times 4. Biosecurity: 4 times 5. One Health: 2 times 6. Extension Services: 2 times 7. Job Creation: 3 times 8. Ghana Health Service: 2 times 9. Collaboration: 2 times 10. Training: 1 time 11. Deforestation/Farming: 1 time 12. Galamsey: 1 time 13. Scavenged Remnants: 1 time 14. Eat not Tainted Meat: 1 time 15. Stakeholder: 1 time 16. Market Enumeration: 1 time 17. Afforestation: 1 time	1. Public Awareness Campaigns: 17 times 2. Biosecurity: 10 times 3. Early Detection: 4 times 4. Funding: 3 times 5. Vaccination: 2 times 6. Land Use Zoning: 2 times 7. Law Enforcement: 2 times 8. Eat not Tainted Meat: 2 times 9. Employment: 2 time 10. Loggers: 1 time 11. Vigilance: 1 time 12. Protections: 1 time 13. Tracking Wildlife Movement: 1 time 14. Preservation: 1 time 15. Interconnectedness: 1 time 16. Well Cooked: 1 time 17. Abstain Bushmeat Consumption: 1 time 18. Rodent Control: 1 time 19. VSD (Veterinary Services Department): 1 time 20. Training VS Staffs: 1 time

	18. Conservation Agriculture: 1 time 19. Veterinary Services: 1 time 20. Information Sharing Platform: 1 time	21. Proper Disposal of Infested Carcasses: 1 time 22. Ghana Health Service: 1 time 23. Capacity Building: 1 time 24. Community Vigilante Group: 1 time 25. Fumigation: 1 time 26. One Health: 1 time

Common variables mentioned in Ashanti Region (Kumasi), Savannah Zone (Mole National Park), and Western Region (Tarkwa):

1. **Public Awareness Campaigns**: This variable appears frequently across all three regions, indicating a shared emphasis on educating the public and raising awareness about issues, such as disease prevention, environmental conservation, and legal regulations.
2. **Biosecurity**: Biosecurity measures are mentioned in all three regions, highlighting the importance of strategies aimed at preventing and controlling the spread of infectious diseases, particularly those with zoonotic potential.
3. **Vaccination**: Vaccination programs were referenced in Kumasi and Tarkwa, suggesting a focus on immunization efforts to prevent the spread of infectious diseases among both human and domestic animal populations.
4. **Early Detection**: Early detection strategies were mentioned in both Kumasi and Tarkwa, underscoring the importance of timely identification and response to disease outbreaks or other emerging threats.
5. **Laws Enforcement**: Legal regulations were mentioned in the Savannah Zone and Tarkwa, indicating the role of policy and governance in addressing issues, such as land use zoning, wildlife protection, and disease control.

Table 2: "Mental Model" Activity Question Two with Analyzed Answers

Q2: From the things that need to be done, who (which stakeholders) should do what?	
Ashanti Region: Kumasi	1. Veterinary Services - 21 times 2. Ghana Health Service (GHS) - 14 times 3. Forestry Commission - 12 times 4. Environmental Protection Agency (EPA) - 9 times 5. Law Enforcement Agencies (Police) - 8 times 6. Ministry of Health (MoH) - 6 times 7. District Assemblies (MMDAs) - 5 times 8. Non-Governmental Organizations (NGOs) - 4 times 9. Education Sector - 3 times 10. Farmers - 3 times 11. Traditional Leaders (Chiefs) - 2 times 12. Media - 2 times 13. National Commission for Civic Education (NCCE) - 1 time
Savanna Zone: Mole National Park	1. Ghana Health Service (GHS) - 12 times 2. Veterinary Services - 10 times 3. Environmental Protection Agency (EPA) - 5 times 4. Forestry Commission (FC) - 7 times 5. District Assemblies - 6 times 6. Police - 4 times 7. National Disaster Management Organization (NADMO) - 3 times 8. Chiefs - 5 times 9. Non-Governmental Organizations (NGOs) - 5 times 10. Community Members (Farmers) - 2 times 11. National Commission for Civic Education (NCCE) - 2 times
Western Region: Tarkwa	1. Veterinary Services - 12 times 2. Ghana Health Services - 10 times 3. Forestry Commission - 9 times 4. Law Enforcement Agencies - 6 times 5. Environmental Protection Agency (EPA) - 5 times 6. Ministry of Health - 4 times 7. District Assemblies (MMDAs) - 4 times 8. Chiefs - 4 times 9. Education Sector - 4 times 10. Mass Media - 4 times 11. Individual Citizens - 4 times 12. Non-Governmental Organizations (NGOs) - 3 times 13. Wildlife - 2 times 14. World Health Organization (WHO) - 1 time

Common stakeholders mentioned in Ashanti Region (Kumasi), Savannah Zone (Mole National Park), and Western Region (Tarkwa):

1. **Ministry of Health (MoH) -** Mentioned in all regions, crucial for public health interventions and disease management.
2. **Police -** Law enforcement is essential for enforcing regulations and preventing illegal activities related to spillover risks.
3. **NGOs -** non-governmental organizations often play a significant role in community engagement, education, and implementation of initiatives.
4. **Environmental Protection Agency (EPA) -** Responsible for environmental regulations and awareness creation, critical for ecosystem health and disease prevention.
5. **Forestry Commission -** Vital for biodiversity conservation, forest management, and enforcement of laws related to wildlife protection.
6. **District Assemblies (MMDAs) -** Local government authorities responsible for implementing policies, enforcing regulations, and community engagement.
7. **Media -** Important for disseminating information, raising awareness, and educating the public about spillover risks and preventive measures.
8. **National Commission for Civic Education (NCCE) -** Responsible for civic education and awareness creation, playing a role in community mobilization and engagement.
9. **Chiefs -** Traditional leaders have influence in their communities and can play a significant role in enforcing regulations, community education, and mobilization.
10. **Veterinary Services -** Crucial for animal health management, disease surveillance, and public education on zoonotic diseases.

Table 3: "Mental Model" Activity Question Three with Analyzed Answers

Q3: What is the role of the community, district assembly, farmers, hunters, miners, etc. in the prevention of spillovers?	
Ashanti Region: Kumasi	1. **Communities**: Practice proper health, sanitation, and environmental protocols. They should report any suspicious activities and diseases symptoms to authorities. 2. **District Assemblies**: Ensure all bylaws are enforced, provide regulatory services, and create more awareness. They should also educate the community on spillover risks. 3. **Farmers**: Practice sustainable farming and harvesting regimes, adhere to biosecurity standards, and avoid using bat droppings for farming. They should report any unusual activities seen on the farm. 4. **Hunters**: Follow rules and regulations governing hunting, avoid overhunting and using poison, and refrain from selling dead animals. Hunters should report bites, scratches, and unusual dead animals to health authorities. 5. **Miners**: Contribute to environmental conservation to avoid exposing wildlife to danger, avoid environmental degradation, and report any environmental ill health or forest destruction. 6. **Bushmeat Handlers**: Always wear personal protective equipment (PPE) and observe safety precautions in preparation, transportation, and selling of meat. They should reject poisoned animals and ensure meat comes from accredited sources. 7. **Law Enforcement Agencies**: Enforce bylaws, regulations, and laws governing activities related to spillover prevention. They should provide support for case management and allocate resources for enforcement. 8. **Environmental Protection Agencies**: Educate the public on zoonoses, enforce environmental regulations, and ensure proper disposal of harmful chemicals used in mining. 9. **Health Services**: Provide treatment, disease diagnosis, and prevention services. They should educate the community on spillover risks and provide medicine when necessary. 10. **Educational Institutions**: Educate students and the community on spillover risks, proper hygiene practices, and environmental conservation.
Savannah Zone: Mole National Park	1. **Community**: Stop illegal practices, adhere to public health measures such as good hygiene, and serve as whistleblowers or watchdogs by volunteering information. 2. **Hunters**: Stop killing animals illegally, take licenses from the Forestry Commission before hunting, organize into associations for early inspection of meat before sale, and hunt only healthy animals for the community. 3. **Farmers**: Stop illegal farming practices, use personal protective equipment (PPE) in their activities, ensure regular vaccination of animals, report any deaths of livestock quickly, and regulate the use of chemicals and agrochemicals in farming. 4. **District Assemblies (MMDAs)**: Enforce bylaws, collaborate with Ghana Health Service (GHS) and NGOs to provide education on zoonotic diseases,

	support financially to prevent spillovers, implement community sensitization and education, and intensify law enforcement. 5. **Veterinary Services Department (VSD)**: Visit communities to vaccinate livestock frequently, notify in case of any outbreak, and educate the public on zoonotic diseases in collaboration with GHS. 6. **Park Rangers**: Increase protection of the forest and wildlife, prevent illegal hunting of wildlife, notify VSD in case of an outbreak, and avoid drinking contaminated water in the field. 7. **Non-Governmental Organizations (NGOs)**: Develop projects to sensitize communities, support communities to be more educated, and provide support to Wildlife Division for providing water points and grazing grounds for livestock farmers to avoid invasion into protected areas (e.g., Mole National Park). 8. **Assembly**: Enact bylaws, provide resources to other stakeholders to aid their activities, intensify education and law enforcement, and bring all other stakeholders under one roof for better decision-making.
Western Region: Tarkwa	1. **Community**: Report any illegal activities, adhere to public health measures, comply with education or laws, establish task forces to prevent illegal activities, and ensure safety in illegal mining. 2. **District Assemblies**: Serve as a link between the central government and the people to enforce laws, provide resources and logistics, organize workshops, ensure public education, enforce bylaws, and prevent illegal mining. 3. **Farmers**: Develop proper farming methods, avoid the use of chemicals harmful to soil fertility, ensure biosecurity at farms, report any unwell animals, use personal protective equipment (PPEs), and practice sustainable farming practices. 4. **Hunters**: Use proper hunting methods, avoid bushfires, test animals before selling them, stop killing animals illegally, and seek veterinary inspection before selling or consuming wild animals. 5. **Miners**: Use the open shaft method, avoid illegal mining activities, comply with environmental regulations, wear PPE for safety, provide free health screenings and education to communities, and be well-regulated and educated to protect the environment. 6. **Park Rangers**: Enforce laws and rules, prevent animals from entering communities by fencing parks, enforce park regulations, and prevent environmental destruction and indiscriminate poaching. 7. **Health Facilities**: Sensitize the community, use PPE, provide health screenings, and educate the public about zoonotic diseases. 8. **Government**: Provide resources, enforce laws, organize workshops, and ensure compliance with regulations at all levels.

Common community stakeholders mentioned in Ashanti Region (Kumasi), Savannah Zone (Mole National Park), and Western Region (Tarkwa):

1. **Community**: Engage in proper health and sanitation practices, adhere to public health measures, report illegal activities, and promote environmental conservation.
2. **District Assemblies**: Enforce bylaws, provide resources, serve as a link between government and the people, organize workshops, ensure public education, and prevent illegal activities such as mining and hunting.
3. **Farmers**: Follow sustainable farming practices, adhere to biosecurity standards, report unusual animal deaths or illnesses, use personal protective equipment (PPEs), and practice proper food safety and hygiene.
4. **Hunters**: Use proper hunting methods, avoid illegal activities such as bushfires and hunting without permits, test animals before selling them, and collaborate with authorities to maintain law and order.
5. **Miners**: Engage in legal mining practices, avoid environmental degradation, wear PPEs for safety, provide education to communities, and comply with regulations to protect natural habitats.
6. **Park Rangers**: Enforce laws and regulations, prevent illegal activities such as poaching and deforestation, provide protection to wildlife and natural resources, and collaborate with other stakeholders to maintain ecosystem balance.

Table 4: "Mental Model" Activity Question Four with Analyzed Answers

Q4: What measures to reduce spillover risk are already in place? What is working already?		
Ashanti Region: Kumasi	**Savannah Zone: Mole National Park**	**Western Region: Tarkwa**
1. Public Awareness Campaigns: Emphasizing campaigns only during outbreaks: 13 times 2. Surveillance: 8 times 3. Biosecurity: 4 times 4. Policies or laws: Implemented only during outbreaks with measures like quarantines and lockdowns 3 times 5. Vaccinations/Immunizations: Mostly conducted by commercial poultry farmers and not typically by household subsistence farmers, and by humans only during outbreaks 2 times 6. R&D (Research and Development): 1 time 7. Early Detection: Significantly prioritized only during outbreaks: 1 time 8. One Health Approach: 1 time 9. Afforestation: 3 times 10. Culling: Mostly conducted for slaughtering and sales purposes if not done by VSD: 1 time 11. Galamsey Regulation: 1 time 12. Avoiding Harmful Chemicals: 1 time 13. Rapid Response Teams: Activated only	1. Public Awareness Campaigns: Emphasizing campaigns only during outbreaks: 10 times 2. Vaccination: Mostly conducted by commercial poultry farmers and not typically by household subsistence farmers, and by humans only during outbreaks: 7 times 3. Land Use Zoning: 4 times 4. Park Rangers: 6 times 5. Biosecurity: 4 times 6. Veterinary Services: 3 times 7. Extension Services: occur mainly where incentives are provided 1 time 8. Training and Licensing Hunters: 1 time 9. Infographics: 1 time 10. Law Enforcement: Implemented only during outbreaks with measures like quarantines and lockdowns: 3 times 11. Quarantine: Especially emphasized after deaths occur: 1 time 12. One Health Approach: Exists but is typically activated only during outbreaks; lacks proper coordination among One Health members: 1 time 13. Ghana Health Service: 1 time 14. Meat Certification: Typically conducted by slaughterhouses, but many households	1. Law Enforcement: Implemented only during outbreaks with measures like quarantines and lockdowns: 9 times 2. Vaccination: Mostly conducted by commercial poultry farmers and not typically by household subsistence farmers, and by humans only during outbreaks: 6 times 3. Surveillance: 6 times 4. Early Detection: Significantly prioritized only during outbreaks: 5 times 5. Veterinary Certification Before Slaughter: 5 times 6. Public Awareness Campaigns: Emphasizing campaigns only during outbreaks: 4 times 7. Biosecurity: 2 times 8. Community Vigilante Group: 2 times 9. Stakeholders Engagement: 1 time 10. Contact Tracing: Especially emphasized after deaths occur: 1 time 11. Farm Visits: occur mainly where incentives are provided: 1 time 12. Culling: Mostly conducted for slaughtering and sales purposes if not done by VSD: 2 times 13. Train and License Hunters: 1 time 14. Land Use Zoning: 1 time 15. Outbreak Response: 1 time 16. One Health Approach: Typically activated only

during serious outbreaks	conducting slaughtering do not obtain certification: 1 time 15. Surveillance: 1 time 16. Funding: 1 time	during outbreaks; lacks proper coordination: 1 time 17. Inspection and Certification Team: Typically conducted by slaughterhouses, but many households slaughter without a certification: 3 time

The terms "outbreak response," "early detection," and "rapid response" can indeed fall under the broad umbrella of surveillance, but their intended meanings can vary significantly depending on the perspectives and objectives of different stakeholders hence presented as given by stakeholders. While all three terms are related to the concept of surveillance in public health and safety, their specific meanings and purposes can vary based on the stakeholder's role and objectives. Public health officials and healthcare providers focus on health outcomes, government authorities emphasize control and safety, and the public often views these measures through the lens of their immediate impact on daily life. Understanding these nuanced perspectives is crucial for effective communication and policymaking.

Common measures mentioned in Ashanti Region (Kumasi), Savannah Zone (Mole National Park), and Western Region (Tarkwa), along with the number of times they appeared across all regions:

1. **Public Awareness Campaigns:** Emphasizing campaigns only during outbreaks
2. **Vaccination:** Mostly conducted by commercial poultry farmers and not typically by household subsistence farmers, and by humans only during outbreaks.
3. **Law Enforcement:** Implemented only during outbreaks with measures like quarantines and lockdowns.
4. **Rapid Response Teams:** Activated only during serious outbreaks
5. **Veterinary Certification Before Slaughter:** Typically conducted by slaughterhouses, but many households conducting slaughtering do not obtain certification.
6. **Biosecurity:** Mostly involves using footbaths but lacks proper PPEs
7. **Stakeholders Engagement:** Typically occurs only in response to issues or outbreaks
8. **Certification:** Hunters are not certified, but some bushmeat dealers who buy from these hunters have been certified by forestry commission
9. **Contact Tracing:** Especially emphasized when its life threatening or after deaths occur
10. **Culling:** Mostly conducted for slaughtering and sales purposes if not done by VSD
11. **Land Use Zoning:** Due to increased interest in land sales for profit, its effectiveness is compromised.
12. **Outbreak Response:** Becomes significant when outbreaks result in higher mortality rates; farmers often lack knowledge on containment
13. **One Health Approach:** Exists but is typically activated only during outbreaks; lacks proper coordination among One Health members.

Table 5: "Mental Model" Activity Question Five with Analyzed Answers

Q5 What are the biggest challenges to preventing spillovers? Think about individual beliefs, economic incentives, policies, resources, etc.		
Ashanti Region: Kumasi	**Savannah Zone: Mole National Park**	**Western Region: Tarkwa**
1. Funding - 9 times 2. Beliefs - 5 times 3. Unemployment - 3 times 4. Unenforced Regulations - 2 times 5. Uncoordinated Policies - 2 times 6. Climate Change - 1 time 7. Galamsey (Illegal Mining) - 1 time 8. Deforestation - 1 time 9. Public Awareness Campaigns – 1 10. Biosecurity -1	1. Funding - 14 times 2. Beliefs - 12 times 3. Public awareness campaigns - 10 times 4. Laws - 8 times 5. Biosecurity - 5 times 6. Veterinary services - 2 times 7. Land use zoning - 2 times 8. Early detection - 1 time 9. Veterinary diagnostic laboratory - 1 time 10. Park rangers - 1 time 11. One health - 1 time 12. Gender - 1 time 13. Motivation - 1 time 14. Technology - 1 time 15. Spelt roles - 1 time	1. Funding - 15 times 2. Unforced Law - 14 times 3. Public awareness campaigns - 10 times 4. Beliefs - 8 times 5. Unemployment - 7 times 6. Biosecurity - 3 times 7. Rapid response team - 3 times 8. Veterinary hospitals - 1 time 9. Ghana Health Service - 1 time 10. Subsidy - 1 time 11. Poverty - 1 time 12. Poor farm gate price - 1 time 13. Corruption - 1 time 14. Incentives - 1 time 15. Training - 1 time 16. One health - 1 time 17. Inspection and certification team - 1 time

Common challenges mentioned in Ashanti Region (Kumasi), Savannah Zone (Mole National Park), and Western Region (Tarkwa):

1. Funding
2. Unforced Law
3. Public awareness campaigns (only done when there is outbreak)
4. Beliefs
5. Unemployment
6. Biosecurity

Biggest Challenges to Preventing Spillovers Among the Three Regions:

1. Funding:

- **Commonality:** Insufficient funding emerged as a significant challenge across all three regions. Inadequate financial resources hinder the implementation of preventive measures, including surveillance, public education, healthcare infrastructure development, and response to outbreaks.
- **Explanation of Challenge:**
  - **Ashanti Region (Kumasi):** Lack of resources limits the capacity to implement policies effectively, such as providing incentives to stakeholders, enhancing surveillance systems, and investing in healthcare infrastructure.
  - **Savannah Zone:** Inadequate funding constrains efforts to raise awareness, conduct surveillance, enforce regulations, and provide necessary resources for disease control and prevention.
  - **Western Region (Tarkwa):** Limited financial resources hinder the provision of subsidies to farmers, procurement of personal protective equipment (PPE), enforcement of regulations, and rapid response to outbreaks. Economic constraints exacerbate existing challenges, such as poverty and unemployment, often forcing youth to turn to illegal mining, timber logging, and hunting as alternative sources of income. Engaging in these activities brings them into proximity with wildlife, increasing the risk of zoonotic disease transmission through direct contact or environmental contamination. Further impeding zoonotic disease prevention efforts.

2. Unenforced Law:

- **Commonality:** Weak enforcement of laws and regulations was identified as a challenge in all three locations. Failure to enforce laws undermines compliance with regulations aimed at mitigating zoonotic disease risks.
- **Explanation of Challenge:**
  - **Ashanti Region (Kumasi):** Lack of enforcement allows stakeholders to disregard regulations, such as those related to biosecurity measures, animal vaccination, and safe handling of food products, leading to increased risks of zoonotic disease transmission.
  - **Savannah Zone:** Weak enforcement of laws contributes to non-compliance with regulations regarding wildlife hunting, animal husbandry practices, and land use zoning, exacerbating the risk of zoonotic spillovers.
  - **Western Region (Tarkwa):** Failure to enforce laws and regulations results in non-compliance with measures such as the use of personal protective equipment (PPE) by miners, adherence to veterinary standards, and reporting of disease outbreaks. This increases the likelihood of zoonotic disease transmission and outbreaks.

3. Public Awareness Campaigns (only done when there is an outbreak):

- **Commonality:** Limited public awareness campaigns, often conducted reactively during outbreaks, were observed across all three locations. Inadequate proactive education and awareness efforts hinder preventive behaviours and early detection of zoonotic diseases.
- **Explanation of Challenge:**
  - **Ashanti Region (Kumasi):** Lack of sustained public awareness campaigns reduces community understanding of zoonotic disease risks, preventive measures, and early symptom identification, leading to delayed responses and increased transmission rates during outbreaks.

- **Savannah Zone:** Infrequent public awareness campaigns fail to educate communities about the importance of proper hygiene, safe handling of animals, and early reporting of suspected cases, resulting in gaps in disease surveillance and control.
- **Western Region (Tarkwa):** Reactive public awareness campaigns during outbreaks limit opportunities for preventive education and behaviour change communication. This results in continued misconceptions, low levels of risk perception, and suboptimal compliance with preventive measures, contributing to zoonotic disease transmission.

4. Beliefs:

- **Commonality:** Cultural and religious beliefs were identified as significant barriers to zoonotic disease prevention across all three locations. Deeply ingrained beliefs influence behaviours related to food consumption, animal handling, and healthcare-seeking practices.
- **Explanation of Challenge:**
  - **Ashanti Region (Kumasi):** Cultural beliefs may lead to practices such as consuming bushmeat or engaging in traditional healing rituals, increasing the risk of zoonotic disease transmission. Religious beliefs may also influence perceptions of disease causation and treatment, affecting healthcare-seeking behaviours.
  - **Savannah Zone:** Cultural taboos and traditional practices, such as communal drinking from rivers or consuming certain animal products for medicinal purposes, may conflict with modern public health recommendations, leading to continued exposure to zoonotic disease risks. One prominent belief involves the use of talismans, which are believed to possess protective powers against harm or illness. These talismans often incorporate certain parts of wild animals in their ritual preparations, further complicating efforts to mitigate zoonotic disease transmission.
  - **Western Region (Tarkwa):** Superstitious beliefs and traditional practices, such as worshiping forests and rivers or consuming specific animal parts for perceived health benefits, perpetuate behaviours that increase the likelihood of zoonotic disease transmission. Misconceptions and fear of vaccines or modern healthcare may further hinder disease prevention efforts.

5. Unemployment:

- **Commonality:** High levels of unemployment pose challenges to zoonotic disease prevention efforts in all three locations. Economic insecurity and lack of alternative livelihoods contribute to behaviours that increase exposure to zoonotic disease risks.
- **Explanation of Challenge:**
  - **Ashanti Region (Kumasi):** Unemployment may drive individuals to engage in risky behaviours, such as hunting wildlife for food or income, without adequate precautions, increasing the likelihood of zoonotic disease transmission.
  - **Savannah Zone:** Limited employment opportunities may lead to reliance on natural resources for livelihoods, such as farming or hunting, which can increase exposure to zoonotic disease vectors and reservoirs.
  - **Western Region (Tarkwa):** Economic hardship may incentivize individuals to engage in illegal mining activities or consume unsafe food products, such as sick animals, for economic gain, amplifying zoonotic disease transmission risks.

6. Biosecurity:

- **Commonality:** Inadequate biosecurity measures were identified as a challenge across all three locations. Poor biosecurity practices in animal husbandry, agriculture, and mining contribute to zoonotic disease transmission and outbreaks.
- **Explanation of Challenge:**
  - **Ashanti Region (Kumasi):** Insufficient biosecurity measures on farms, wildlife trade and in food production systems increase the risk of zoonotic disease introduction and spread among animals and humans. Lack of biosecurity protocols in healthcare facilities may also contribute to nosocomial transmission.
  - **Savannah Zone:** Inadequate biosecurity practices in livestock farming, such as poor sanitation, lack of quarantine measures, and mixing of species, create opportunities for zoonotic pathogens to emerge and spread within animal populations and to humans. One challenge that may be contributing to the spread of zoonotic diseases is the practice of cattle herders grazing their animals in wildlife protected areas. This practice increases the risk of transmission between domestic livestock and wildlife, potentially facilitating the spread of zoonotic pathogens.
  - **Western Region (Tarkwa):** Limited adherence to biosecurity protocols in mining operations, such as inadequate PPE use and waste management practices on farms, pose a significant challenge to preventing zoonotic diseases. Farmers often use waste from poultry and animal dung as manure for their crops, which can inadvertently introduce zoonotic pathogens into the agricultural environment. exposes workers to zoonotic disease risks from environmental contamination and wildlife interactions. Insufficient biosecurity measures in wildlife trade, food handling and consumption further contribute to disease transmission pathways.

Applying a systems thinking approach to analyse the challenges mentioned during the three workshops in the Ashanti Region (Kumasi), Savannah Zone, and Western Region (Tarkwa) regarding the prevention of spillovers helps understand the interconnectedness and complexities of these issues. The specific contexts and dynamics of each location necessitate tailored approaches to address spillover risks effectively. Understanding the interplay between funding, legal frameworks, public awareness, cultural beliefs, unemployment, and biosecurity is essential for developing comprehensive strategies for spillover prevention in diverse settings.

The Systems Structures

Below are the causal loop diagrams obtained from the analyses of the key variables obtained during the workshops in the Ashanti Region (Kumasi), Savannah Zone and Western Region (Tarkwa). In the context of zoonotic disease prevention, understanding the CLDs entails identifying the key components, feedback loops, and causal relationships that shape the dynamics of zoonotic spillovers and control. These diagrams use specific symbols and notation to convey how variables influence each other. The Following Table present key symbols and elements commonly used in CLDs:

Table 6: key symbols and elements commonly used in CLDs

Symbols/Phrase	Definitions
Variables	Represented as words or phrases, these are the elements or components of the system being analyzed
Arrows (Links)	Show the direction of influence from one variable to another. An arrow points from the influencing variable to the influenced variable
Positive Polarity Indicated by a "+" or "s" sign near the arrowhead	it shows that an increase (or decrease) in the influencing variable causes an increase (or decrease) in the influenced variable.
Negative Polarity Indicated by a "-" or "o" sign near the arrowhead	it shows that an increase in the influencing variable causes a decrease in the influenced variable (or vice versa).
Reinforcing (R) Feedback Loops	A loop where an initial change in a variable leads to further change in the same direction, often indicated with an "R" in the center of the loop
Balancing (B) Feedback Loops	A loop where an initial change in a variable leads to a counteracting change, bringing the system back to equilibrium, often indicated with a "B" in the center of the loop.
Delays  sign	Represented by two short parallel lines across the arrow, indicating a delay in the effect of one variable on another.

The links shown in the CLDs are derived from two main sources: direct inputs from workshop participants during the regional workshops rich pictures presentations and inferences made from subsequent analyses. This dual approach ensures that the CLDs capture both the grounded insights of local stakeholders and the broader analytical perspectives necessary for a comprehensive understanding of the system. However, it is important to note that interpretations can vary across different sectors, and not all possible scenarios regarding directionality, trade-offs, and benefits are covered in this report. The following diagrams should be viewed as a synthesis of workshop inputs and analytical interpretations rather than an exhaustive mapping of all potential dynamics.

Ashanti Region: Kumasi

Based on the data provided, Figure 2 presents the current state of zoonotic spillover prevention in the Ashanti Region according to workshop participants. The CLD illustrates the complex interactions and feedback loops influencing zoonotic disease prevention in the region. As presented in Figure 2, a growing population leads to increased demand for urbanization and development, prompting the expansion of urban areas. Urbanization results in the conversion of natural landscapes into built environments, leading to the encroachment of cities into rural areas. The need for more agricultural lands to support the growing population results in deforestation and land clearing to make way for farming activities. The clearing of forests for agriculture reduces forest cover and biodiversity, leading to habitat loss and ecosystem degradation (R21). Deforestation contributes to changes in hydrological cycles, which eventually leads to the depletion of water bodies and reduced water availability (R6). Declining water availability and habitat loss negatively impact ecosystem health, disrupting ecological balance and biodiversity. Deteriorating ecosystem health forces wildlife species to seek new habitats, bringing them into closer proximity to human settlements. Wildlife displacement increases the likelihood of human-wildlife contact, creating opportunities for zoonotic spillover events. This sequence forms a reinforcing loop (R21), also known as a "vicious cycle" in this context. This reinforcing loop amplifies the initial drivers (population growth and urbanization) and exacerbates the subsequent factors (deforestation, ecosystem degradation, and increased human-wildlife contact) in a self-reinforcing manner. As each element reinforces the growth of the next, the loop perpetuates and intensifies the overall impact, leading to a compounding effect on zoonotic disease transmission.

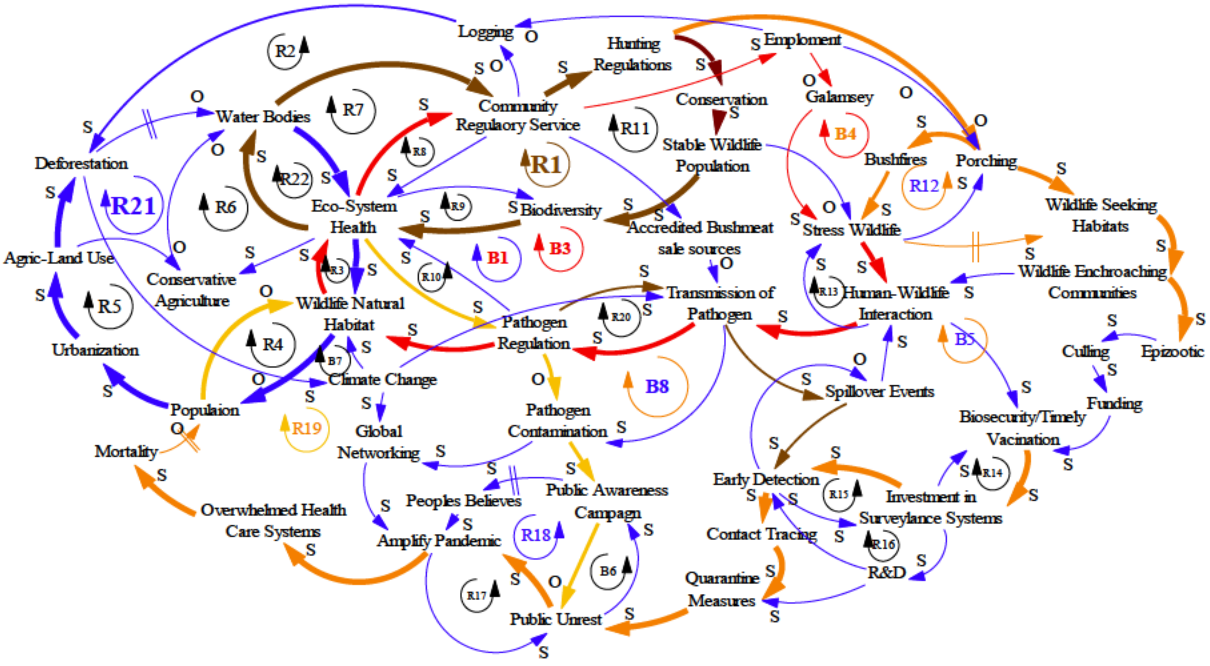

Figure 2: Current State of Zoonotic Spillover Prevention in the Ashanti Region according to workshop participants based on a mental model exercise.

Shown in Figure 2, the loop begins with the state of ecosystem health. A healthier ecosystem is better equipped to regulate populations of wildlife and pathogens, reducing the risk of disease transmission (B1). In response to the importance of maintaining ecosystem health and preventing disease spread, regulatory services are established within the community. These services may include monitoring wildlife populations, enforcing hunting regulations, and ensuring the safety of bushmeat trade. Regulatory services inspect and provide accreditation or certification to hunters or bushmeat traders who comply with established regulations. This accreditation ensures that the bushmeat trade meets certain standards of safety and hygiene, reducing the risk of zoonotic pathogen transmission.

Accredited or certified hunters and traders participate in a regulated bushmeat trade, where one of the goals is safe meat consumption. This trade contributes to public health by ideally providing a safe source of protein without the risk of/with lower risk of disease transmission. By promoting a safer trade, the transmission of zoonotic pathogens is reduced. A reduction in transmission contributes to maintaining ecosystem health by preventing disease outbreaks among wildlife populations and mitigating the risk of spillover events to humans. The loop closes as the improved ecosystem health resulting from reduced pathogen transmission reinforces the effectiveness of regulatory services. This creates a balancing feedback loop (B1), where healthier ecosystems lead to better regulatory practices, further reducing the transmission of zoonotic pathogens and supporting ecosystem health. Adequate funding is essential for implementing various measures aimed at preventing and controlling zoonotic diseases. It enables investments in biosecurity measures, timely vaccinations, surveillance systems, research, and public awareness campaigns.

As shown in Figure 2, Funding allows for the implementation of biosecurity protocols and timely vaccination programs, which are crucial for preventing the spread of zoonotic pathogens among animals and humans. Funding for surveillance systems enables the monitoring of disease outbreaks and early detection of potential threats. This leads to proactive measures such as quarantine and containment efforts to prevent the spread of diseases. Investments in research and development contribute to advancing our understanding of zoonotic diseases and developing new diagnostic tools, treatments, and vaccines. This enhances the capacity for early detection and response to outbreaks. Improved surveillance and early detection capabilities facilitate prompt action, including quarantine measures to isolate infected individuals or populations and prevent further transmission. In response to outbreaks or public health emergencies, public awareness campaigns are initiated to educate the population about preventive measures and behaviour changes. These campaigns aim to mitigate public unrest and foster community cooperation in disease control efforts. Public awareness campaigns seek to influence people's belief systems and attitudes towards zoonotic diseases, encouraging compliance with preventive measures and reducing risky behaviours that can amplify disease transmission. Failure to address beliefs and behaviours that contribute to disease transmission can lead to the amplification of zoonotic epidemics, resulting in increased morbidity and mortality rates. This may overwhelm health facilities and strain healthcare resources. High mortality rates from zoonotic epidemics can lead to a reduction in population growth and urbanization rates. This decreased demand for agricultural land use and reduced deforestation helps preserve water bodies and natural habitats of wildlife as demonstrated in Figure 1. With reduced pressure on eco system health or natural resources, there is an opportunity to engage

community regulation services in preventing zoonotic diseases. These services help enforce regulations and promote sustainable practices that minimize disease risks. Community engagement and employment opportunities in regulated sectors reduce dependency on unsustainable practices like illegal mining (galamsey) and poaching. This reduces human-wildlife interactions and the displacement of wildlife from their natural habitats (Figure 2). Despite efforts to prevent zoonotic diseases, occasional epizootic events may occur, leading to the culling of infected animals to control disease spread. Adequate funding closes the loop by sustaining investments in disease prevention and control measures, ensuring ongoing surveillance, research, and public health interventions to minimize the risk of zoonotic pandemics (Figure 1). In summary, this causal loop diagram highlights the interconnectedness of various factors influencing zoonotic disease dynamics in the Ashanti Region (Kumasi), emphasizing the importance of integrated approaches that address funding gaps, behavioural factors, community engagement, and sustainable development practices to mitigate disease risks and promote public health.

Savannah Zone: Mole National Park

As illustrated in Figure 3, an increase in population leads to higher demand for resources, including land for settlement and agriculture. As the population grows, there is a greater need for agricultural land to produce food and sustain livelihoods. This leads to the conversion of natural habitats, such as forests, into agricultural fields, livestock and housing. The expansion of agriculture results in deforestation and the overexploitation of natural resources (R1). Forests are cleared to make way for farmland, and resources like timber are harvested at unsustainable rates. Deforestation and resource exploitation disrupt wildlife habitats, forcing animals out of their natural environment and into human settlements and farms in search of food and shelter. The encroachment of wildlife into communities and farms increases the frequency of human-wildlife contact, creating opportunities for zoonotic spillovers (R2). Increased human-wildlife contact raises the risk of disease transmission, leading to more frequent occurrences of epizootic (animal) and zoonotic (animal-to-human) disease outbreaks as shown in Figure 3. Epizootic and zoonotic diseases can result in illness and death among both animal and human populations, causing significant morbidity (illness) and mortality (death) rates. This reinforcing loop (R1) highlights the interconnectedness of human activities, environmental degradation, and disease emergence in the Savanna Region. The reinforcing loop (R3) described in the causal loop diagram for the Savannah Zone suggests that as human populations grow and encroach further into natural habitats, there is a higher likelihood of contact between humans and wildlife.

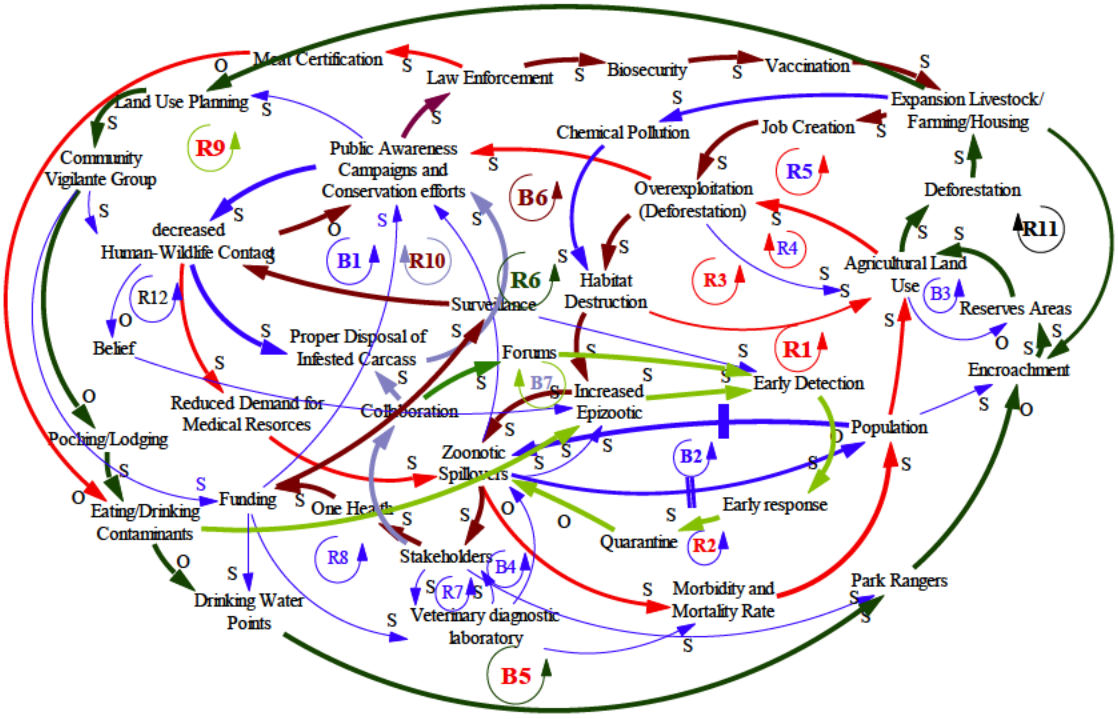

Figure 3: Current State in Zoonotic Spillover Prevention in the Savannah Zone according to workshop participants based on a mental model exercise.

Increased population and contact with wildlife increase the risk of zoonotic disease transmission, leading to more frequent and severe disease outbreaks among both animal and human populations (R1). The

continuous cycle of deforestation, habitat destruction, and human-wildlife contact poses significant public health risks. zoonotic diseases, such as Ebola, COVID-19, and various forms of influenza, can have devastating consequences for human health, causing illness, death, and economic disruption. “R1” underscores the role of human activities, such as deforestation and overexploitation of natural resources, in driving environmental degradation. This not only threatens biodiversity but also disrupts ecosystem functioning and resilience, further exacerbating the risk of disease emergence. The implications extend beyond public health and environmental concerns to socioeconomic factors (R10). Disease outbreaks can undermine livelihoods, disrupt food security, and strain healthcare systems, particularly in resource-limited settings where communities may already face socioeconomic challenges.

As demonstrated in Figure 3, adequate funding is essential to kickstart zoonotic spillover prevention initiatives (R12). It provides the financial resources needed to support various interventions, including public awareness campaigns, conservation efforts, law enforcement, and biosecurity measures. Investment in public awareness campaigns and conservation efforts helps raise awareness about the risks of zoonotic spillovers and the importance of wildlife conservation. These initiatives also promote sustainable land use practices and environmental conservation to mitigate habitat destruction. Public awareness campaigns play a crucial role in equipping communities with the knowledge and understanding necessary for spillover prevention (B1). Poverty is indeed more than just a lack of financial resources; it often reflects a broader deprivation of opportunities, including access to education and information. By providing targeted and culturally sensitive messaging, public awareness campaigns can bridge knowledge gaps and empower communities to make informed decisions regarding zoonotic disease prevention (R9). This leads to effective law enforcement, implementation of biosecurity measures, widespread vaccination programs. and contribute to zoonotic spillover prevention. The adoption of vaccination practices will enhance the expansion of livestock/farming and housing in the Savannah Zone as seen in Figure 3, (R10). The competitive expansion of agribusiness stimulates job creation across multiple sectors of the economy, fostering economic growth, income generation, and livelihood improvement. By leveraging opportunities in agricultural value chains, infrastructure development, technology adoption, market access, and support services, agribusiness expansion contributes to job creation and prosperity in rural and urban communities alike. Job creation resulting from agribusiness expansion in line with land use planning reduces the economic dependency on unsustainable practices such as poaching and timber stealing. This leads to a decline in wildlife habitat destruction, which is crucial for mitigating the risk of epizootic and zoonotic spillovers (R6). While job creation from agribusiness in line with proper land use planning can reduce reliance on unsustainable practices like poaching and timber stealing, it is also possible that large-scale agribusiness expansion could lead to overexploitation and contribute to wildlife habitat loss (R3). This occurs as production systems stabilize and Agri-corporations increase their investments, potentially leading to larger land concessions. The rise in epizootic and zoonotic spillovers prompts stakeholders to initiate One Health initiatives. One Health approaches recognize the interconnectedness of human, animal, and environmental health and advocate for collaborative efforts to address zoonotic disease threats comprehensively. This reinforcing feedback loop R10 emphasizes the importance of holistic approaches, collaboration among stakeholders, and sustained financial support in mitigating the risk of zoonotic spillovers and promoting global health security (B5 & B6).

Western Region: Tarkwa

This causal loop diagram highlights the complex interactions and feedback loops driving zoonotic spillovers in the Western Region (Tarkwa) as illustrated in Figure 4. The loop begins with population increase, which drives urbanization as people migrate to urban areas in search of employment opportunities and improved living conditions (B2). Urbanization further exacerbates population growth through factors like migration and natural increase, creating a reinforcing feedback loop (R1). As urban areas expand, there is increased pressure on natural resources and ecosystems, leading to habitat destruction and encroachment into wildlife reserved territories. Urbanization can lead to unemployment as the influx of people into urban areas outpaces job creation and economic opportunities. In response, individuals may turn to illegal activities such as galamsey (illegal mining) and logging to generate income. These activities contribute to environmental degradation, habitat loss, and biodiversity loss, creating a reinforcing feedback loop that perpetuates the cycle of unemployment and resource exploitation (R6). Encroachment into wildlife territories brings humans into closer contact with wildlife as demonstrated in Figure 4, (R1) increasing the likelihood of zoonotic transmission. Activities such as consuming wild fruits and hunting wildlife for food or traditional medicine further elevate the risk of exposure to zoonotic pathogens. As human-wildlife contact intensifies, the potential for zoonotic spillovers and disease transmission grows, creating a reinforcing feedback loop that amplifies the risk of outbreaks (R5). Zoonotic outbreaks resulting from increased human-wildlife contact can have detrimental effects on population health, including morbidity and mortality (B1). The negative impact of outbreaks on public health serves as a balancing feedback loop" B3" that exerts a corrective influence on the system. Outbreaks may trigger public health responses, such as disease surveillance, containment measures, and healthcare interventions, which aim to mitigate the spread of zoonotic diseases and protect human populations as demonstrated by Figure 3, "R10".

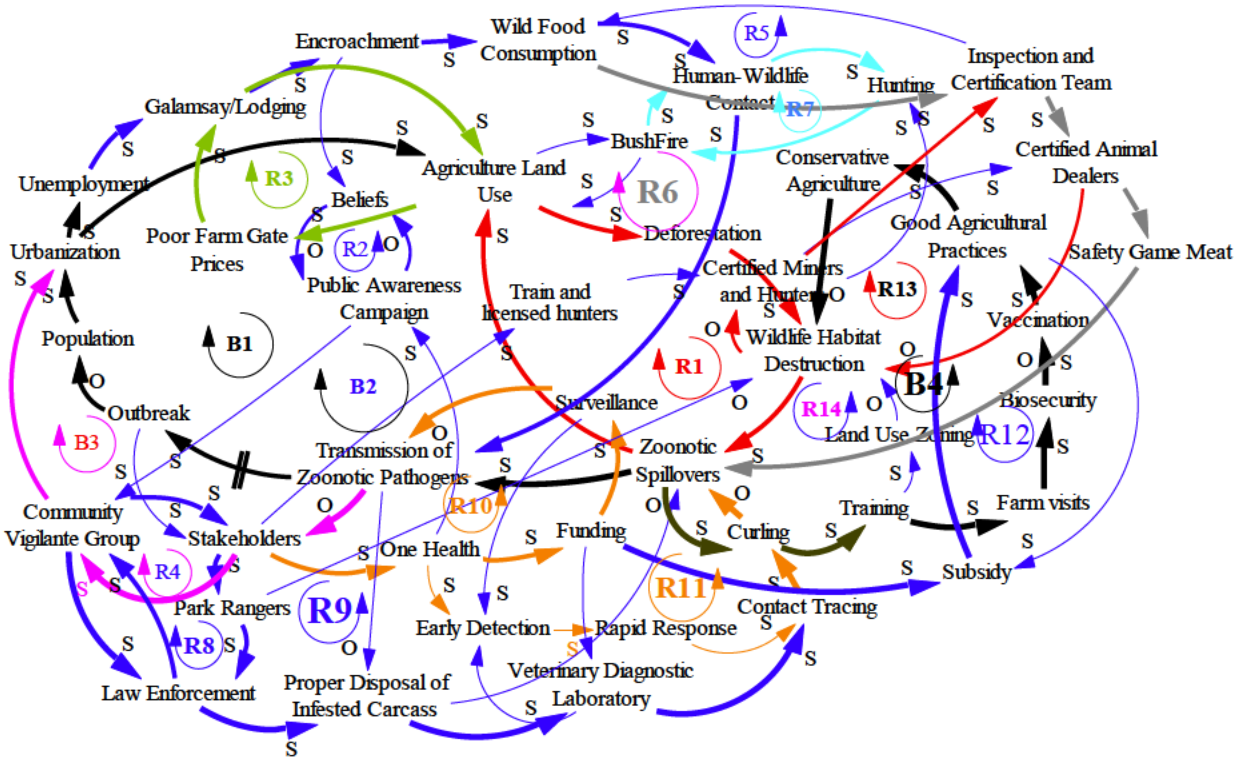

Figure 4: Current State of Zoonotic Disease Spillover in the Western Region according to workshop participants based on a mental model exercise.

Identified Systems Archetypes

The systems archetypes identified through this analysis include:

1. **Eroding Goal** archetype describes a situation where actions intended to achieve a particular goal inadvertently undermine that goal over time. In the context of zoonotic disease prevention, this archetype could manifest when short-term interventions aimed at addressing immediate challenges end up eroding the long-term effectiveness of prevention efforts. For example, suppose a region implements a vaccination campaign to control a specific zoonotic disease outbreak. While the campaign may successfully contain the outbreak in the short term, if it does not address underlying factors contributing to zoonotic disease transmission (such as habitat destruction or wildlife trade), the region may remain vulnerable to future outbreaks. In this case, the short-term focus on vaccination may erode the long-term goal of preventing zoonotic spillovers by failing to address root causes. Similarly, if public awareness campaigns are only conducted during disease outbreaks and not as part of sustained efforts to educate communities about zoonotic risks and prevention strategies, the effectiveness of these campaigns may erode over time as public attention wanes between outbreaks.
2. **Fixes that Fail** archetype describes a situation where solutions implemented to address a problem inadvertently exacerbate or create new problems.
3. **Limit to Growth** archetype suggests that growth in one aspect of the system is limited by another factor. In the context of zoonotic disease prevention, limitations to growth may arise from factors such as funding constraints, inadequate resources, or lack of public awareness.
4. **Shifting the Burden** archetype occurs when a problem symptom is treated without addressing the underlying root cause. For example, focusing solely on treating zoonotic diseases without addressing the factors contributing to their transmission may lead to temporary relief but fail to solve the underlying issues.
5. **Tragedy of the Commons** archetype refers to situations where individuals or groups exploit shared resources for their own benefit, leading to depletion or degradation of the resource. In the context of zoonotic disease prevention, this may occur when communities engage in practices such as illegal mining or deforestation without considering the long-term consequences for public health and ecosystem stability.

Eroding Goal Archetype

The "Eroding Goals" archetype illustrates a situation where well-intentioned goals, such as economic growth or addressing food security, gradually erode due to unintended consequences that undermine the original objectives.

Figure 4 illustrates that as the human populations grow, there is an increased demand for food, housing, and other resources. This puts pressure on agricultural systems to produce more food to meet the needs of a growing population. To boost economic growth and meet the demand for food, there is a focus on expanding agricultural production. This may involve clearing forests or converting other natural habitats into agricultural land to increase crop yields and expand livestock production. The expansion of agriculture often comes at the expense of environmental conservation (Figure 5). Forests, wetlands, and other ecosystems are cleared or degraded to make way for agricultural activities (B2). This encroachment on natural habitats disrupts ecosystems, reduces biodiversity, and degrades ecosystem services. The conversion of natural habitats into agricultural land leads to ecosystem degradation and biodiversity loss (B1). Clearing forests, draining wetlands, and intensifying agricultural practices disrupts ecological balance, reduces habitat availability for wildlife, and threatens the survival of many species. Ecosystem and biodiversity loss increase the risk of zoonotic spillovers. Disrupted ecosystems and increased human-wildlife interactions due to habitat destruction create opportunities for the transmission of diseases from wildlife to humans (B1). This can lead to outbreaks of zoonotic diseases, such as Ebola, Zika, and COVID-19.

In this archetype, the erosion of goals unfolds as efforts to achieve economic growth and address food security inadvertently contribute to environmental degradation, biodiversity loss, and increased risks of zoonotic spillovers (B2). The original goals of economic prosperity and food security become undermined as the health of ecosystems, biodiversity, and human well-being are compromised (B1).

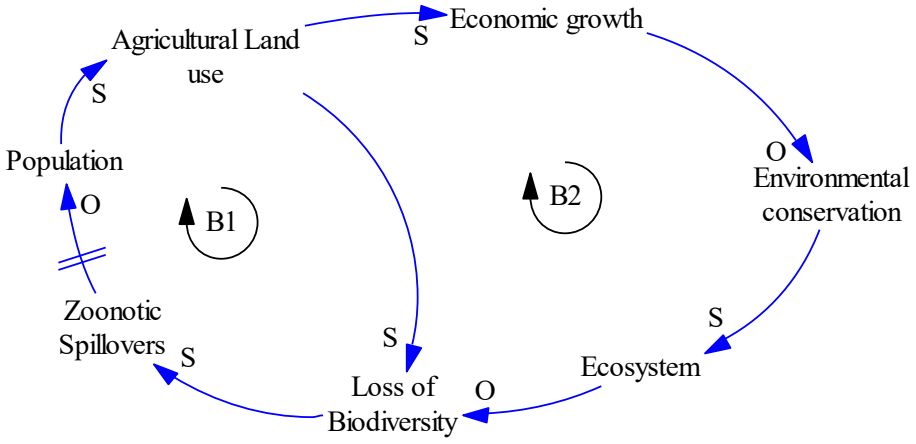

Figure 5: Eroding Goal Archetype

Systemic Interventions for Eroding Goal Archetype

To address the "Eroding Goals" archetype, it's crucial to adopt holistic and sustainable approaches that balance economic development with environmental conservation and public health. This may involve:

1. **Sustainable Agriculture**: Promoting sustainable agricultural practices that enhance productivity while minimizing environmental impact. This includes agroecological approaches, conservation agriculture, and sustainable intensification methods that prioritize soil health, water conservation, and biodiversity conservation.
2. **Integrated Land Use Planning**: Implementing integrated land use planning and management approaches that consider the ecological, social, and economic dimensions of land use. This involves zoning regulations, land-use planning tools, and spatial planning processes that protect critical ecosystems, biodiversity hotspots, and wildlife corridors.
3. **Ecosystem-Based Adaptation**: Investing in ecosystem-based adaptation strategies to enhance ecosystem resilience and reduce vulnerability to climate change impacts. This includes restoring degraded ecosystems, implementing green infrastructure projects, and conserving natural habitats to mitigate the risks of zoonotic disease emergence.
4. **One Health Approach**: Adopting a One Health approach that recognizes the interconnectedness of human, animal, and environmental health. This involves strengthening disease surveillance systems, promoting responsible wildlife management practices, and fostering interdisciplinary collaboration between public health, veterinary, and environmental sectors to prevent and mitigate zoonotic spillovers.
5. **Policy Integration and Coherence**: Ensuring policy coherence and integration across sectors such as agriculture, environment, health, and development. This includes aligning policies, incentives, and investments to support sustainable development goals, biodiversity conservation objectives, and public health priorities.

By implementing these strategies in a coordinated and integrated manner, we can work towards overcoming the "Eroding Goals" archetype and achieving sustainable development that promotes economic prosperity, environmental conservation, and public health for current and future generations.

Fixes That Fail Archetype

The "Fixes that Fail" archetype in Figure 5 describes a situation where solutions implemented to address a problem inadvertently exacerbate or create new problems.

In Figure 6, as the human population grows, there's increased demand for resources, including food. In response, there might be efforts to increase agricultural production to feed the growing population. To meet the demand for food, there's a tendency to clear forests and convert them into agricultural land (R). This expansion of agriculture might initially seem like a solution to feed more people, but it leads to significant negative consequences. Clearing forests for agricultural expansion results in the loss of biodiversity (Figure 6). Forests are incredibly diverse ecosystems, home to countless species of plants, animals, and microorganisms. When forests are cleared, many species lose their habitat, leading to declines in biodiversity. When forests are cleared, it disrupts ecosystems and reduces the availability of suitable habitat for many species. Habitat destruction is a major driver of species extinction and ecosystem degradation. Habitat destruction and biodiversity loss increase the risk of zoonotic spillovers (B). When humans encroach into natural habitats or come into close contact with wildlife due to habitat destruction, it creates opportunities for the transmission of diseases from animals to humans (B). This can lead to outbreaks of zoonotic diseases, Ebola, and COVID-19.

In this archetype, the "Fixes that Fail" dynamic emerges when solutions aimed at addressing one problem—such as increasing food production to feed a growing population (R) end up creating or exacerbating other problems, including biodiversity loss, habitat destruction, and the risk of zoonotic spillovers (B). The expansion of agriculture, while initially intended to meet the needs of a growing population, ultimately contributes to environmental degradation and public health risks.

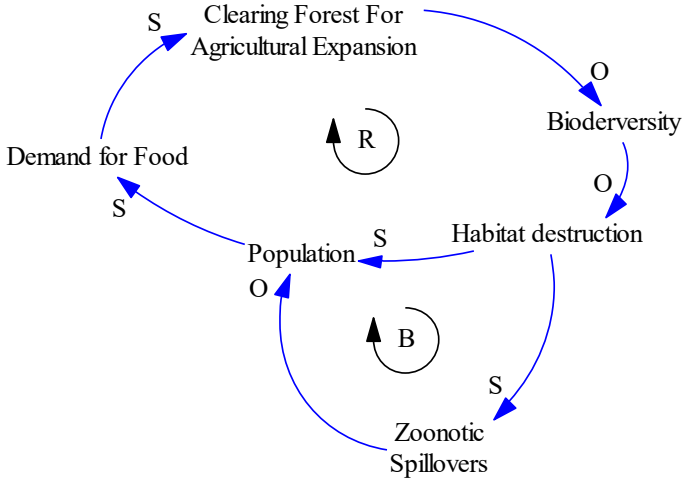

Figure 6: Fixes That Fail Archetypes.

Systemic Interventions for Fixes That Fail Archetypes

To overcome the "Fixes that Fail" archetype associated with population growth, clearing forests for agricultural expansion, biodiversity loss, habitat destruction, and zoonotic spillovers, a multifaceted approach is needed. Management strategies:

1. **Sustainable Land Use Planning**: Develop and implement land use planning strategies that prioritize conservation of natural habitats, forests, and biodiversity-rich areas. This involves zoning regulations, protected area designations, and land-use policies that restrict or minimize agricultural expansion into critical ecosystems.
2. **Agroecological Farming Practices**: Promote agroecological farming practices that mimic natural ecosystems, enhance biodiversity, and reduce reliance on harmful inputs such as pesticides and synthetic fertilizers. Agroforestry, crop rotation, and pest management are examples of sustainable agricultural methods that can improve soil health, conserve water, and support biodiversity.
3. **Restoration of Degraded Habitats**: Invest in habitat restoration efforts to rehabilitate degraded ecosystems and enhance their resilience to environmental stressors. This could involve reforestation, afforestation, wetland restoration, and restoration of riparian zones to rebuild habitat connectivity and support native wildlife populations.
4. **Protected Areas and Conservation Initiatives**: Expand and effectively manage protected areas and conservation reserves to safeguard biodiversity hotspots and critical habitats. Implement conservation programs that engage local communities, promote sustainable resource use, and provide alternative livelihood options to reduce pressure on natural ecosystems.
5. **Population Management and Family Planning**: Implement policies and programs that support voluntary family planning, reproductive health services, and education to stabilize population growth rates. Empowering women and girls, improving access to education and healthcare, and addressing socio-economic inequalities can help reduce fertility rates and alleviate pressure on natural resources.
6. **One Health Approach to Disease Prevention**: Adopt a One Health approach that integrates human, animal, and environmental health considerations to prevent zoonotic spillovers and mitigate disease risks. Enhance disease surveillance systems, strengthen biosecurity measures, and promote responsible wildlife management practices to reduce the transmission of zoonotic pathogens.
7. **Policy Integration and Cross-Sectoral Collaboration**: Foster collaboration and coordination across sectors such as agriculture, environment, health, and development to address the complex interconnections between population dynamics, land use change, biodiversity loss, and zoonotic disease emergence. Integrate biodiversity conservation and ecosystem health considerations into agricultural, forestry, and land-use policies to promote synergies and avoid unintended consequences.
8. **Public Awareness and Education**: Raise awareness among policymakers, stakeholders, and the public about the interconnected nature of environmental, social, and health issues, and the importance of adopting holistic and sustainable approaches to address them. Promote education and outreach initiatives that highlight the benefits of biodiversity conservation, sustainable land management, and responsible stewardship of natural resources.

By implementing these management strategies in a coordinated and integrated manner, we can work towards overcoming the "Fixes that Fail" archetype associated with population growth, agricultural expansion, biodiversity loss, habitat destruction, and zoonotic spillovers. These approaches aim to promote sustainable development, protect ecosystems, safeguard biodiversity, and enhance resilience to environmental and public health challenges.

Limit to Growth Archetype

"Limit to Growth" systems archetype in Figure 7 is a concept from systems thinking that explores the interconnectedness of various factors within a complex system, often leading to unintended consequences or limitations.

As the population grows, there's increased demand for resources, including land for housing, food, and infrastructure. This puts pressure on natural ecosystems and leads to urbanization. Rapid population growth often results in the expansion of cities and towns to accommodate the increasing number of people. Urbanization requires land development, which can lead to the conversion of agricultural land into urban areas, contributing to deforestation (B). As urbanization expands, there's a greater need for food production. Agricultural land is converted or intensified to meet the demand for food, leading to deforestation as forests are cleared for farmland. This conversion reduces biodiversity and disrupts ecosystems (R). Clearing forests for agriculture, logging, and urban development reduces the amount of habitat available for wildlife (R). Deforestation not only displaces wildlife but also fragments habitats, making species more vulnerable to extinction. Loss of habitat due to deforestation forces wildlife into closer proximity to human settlements in search of food and shelter (Figure 7). This increases the likelihood of human-wildlife contact. As humans encroach further into natural habitats, interactions between humans and wildlife become more frequent (B). This can lead to conflicts, spread of diseases from wildlife to humans (zoonotic diseases), and other health risks. Increased contact between humans and wildlife creates opportunities for the transmission of pathogens from animals to humans. Factors such as habitat destruction, wildlife trade, and changes in land use patterns can facilitate the spillover of zoonotic pathogens. When zoonotic pathogens successfully transmit to humans and spread rapidly within human populations, it can lead to a pandemic.

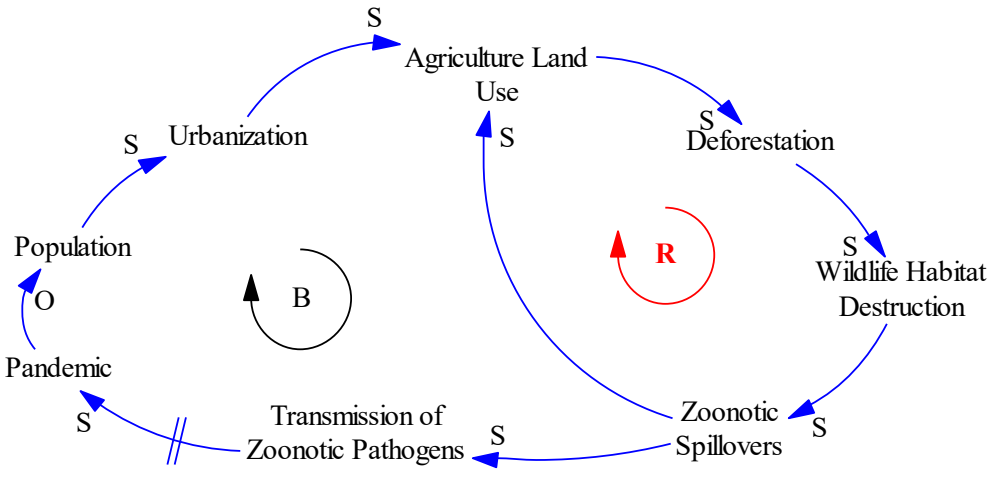

Figure 7: Limit to Growth Systems Archetype

Systemic Intervention for Limit to Growth Systems Archetype

Addressing the "Limits to Growth" archetype requires comprehensive management strategies that target multiple levels of the system, from local to global. Here are some key strategies:

1. **Sustainable Development**: Promote sustainable development practices that balance economic growth with environmental conservation and social equity. This involves adopting policies and practices that minimize resource depletion, reduce pollution, and promote resilience in ecosystems.
2. **Urban Planning and Management**: Develop and enforce urban planning regulations that promote compact, efficient, and sustainable cities. Encourage mixed land use, compact development, public transportation, green spaces, and affordable housing to reduce urban sprawl, preserve natural habitats, and improve quality of life.
3. **Land Use Planning and Conservation**: Protect and restore natural habitats through effective land use planning, conservation strategies, and protected area management. Prioritize the preservation of critical ecosystems, biodiversity hotspots, and wildlife corridors to maintain ecosystem services and mitigate the impacts of habitat destruction.
4. **Sustainable Agriculture**: Promote sustainable agricultural practices that minimize environmental impact, conserve soil and water resources, and enhance resilience to climate change. Encourage agroecological approaches, diversified farming systems, conservation agriculture, and organic farming methods to improve food security while reducing deforestation and habitat loss.
5. **Forest Management and Restoration**: Implement Forest management practices that promote sustainable timber harvesting, reforestation, and afforestation efforts. Combat illegal logging, promote community-based forest management, and incentivize forest conservation through payments for ecosystem services and carbon offset programs.
6. **Wildlife Conservation and Protection**: Strengthen wildlife conservation efforts through habitat restoration, protected area management, anti-poaching measures, and wildlife corridors. Combat illegal wildlife trade, promote responsible tourism practices, and engage local communities in conservation initiatives to reduce human-wildlife conflicts and protect endangered species.
7. **One Health Approach**: Adopt a One Health approach that recognizes the interconnectedness of human, animal, and environmental health. Enhance surveillance systems for zoonotic diseases, improve biosecurity measures, and promote interdisciplinary collaboration between public health, veterinary, and environmental agencies to prevent and mitigate the spread of emerging infectious diseases.
8. **Global Cooperation and Governance**: Foster international cooperation, multilateral agreements, and partnerships to address global environmental challenges. Support initiatives such as the United Nations Sustainable Development Goals (SDGs), the Convention on Biological Diversity (CBD), the Paris Agreement on climate change, and the World Health Organization's International Health Regulations (IHR) to promote sustainable development, biodiversity conservation, climate resilience, and pandemic preparedness.

By implementing these management strategies in a coordinated and integrated manner, we can work towards addressing the "Limits to Growth" archetype and creating a more sustainable and resilient future for both humans and the planet.

Shifting the Burden Archetype

The "Shifting the Burden" archetype illustrates a situation where a quick fix or short-term solution is relied upon to address an immediate problem, but this solution leads to unintended consequences that exacerbate the underlying issue in the long run.

Figure 8 explore how this archetype unfolds within the system elements. In response to immediate economic needs, such as poverty or unemployment, communities may turn to activities like hunting wildlife or illegal lodging in natural areas (B1). These activities can provide a source of income and livelihood for local communities in the short term. As hunting and illegal lodging activities expand to meet economic demands, they may lead to unsustainable exploitation of wildlife resources and destruction of natural habitats. Increased demand for wildlife products, such as bushmeat, exotic pets, or traditional medicines, fuels illegal wildlife trade and poaching. Additionally, the development of lodging infrastructure in ecologically sensitive areas can lead to habitat fragmentation and degradation (R). Over time, the unsustainable exploitation of wildlife and habitat destruction undermine the very resources that communities rely on for economic provision and may increase risk of zoonotic spillover (R). Declines in wildlife populations, loss of biodiversity, and degradation of ecosystems diminish the ecological services that support local livelihoods, such as pollination, water purification, and carbon sequestration. In this archetype, the "Shifting the Burden" dynamic occurs when communities rely on short-term solutions, such as hunting and illegal lodging, to address immediate economic needs without considering the long-term sustainability of these activities (B2). While these activities may provide temporary relief, they ultimately contribute to the degradation of natural resources and undermine the resilience of ecosystems, exacerbating poverty and vulnerability in the long run (R).

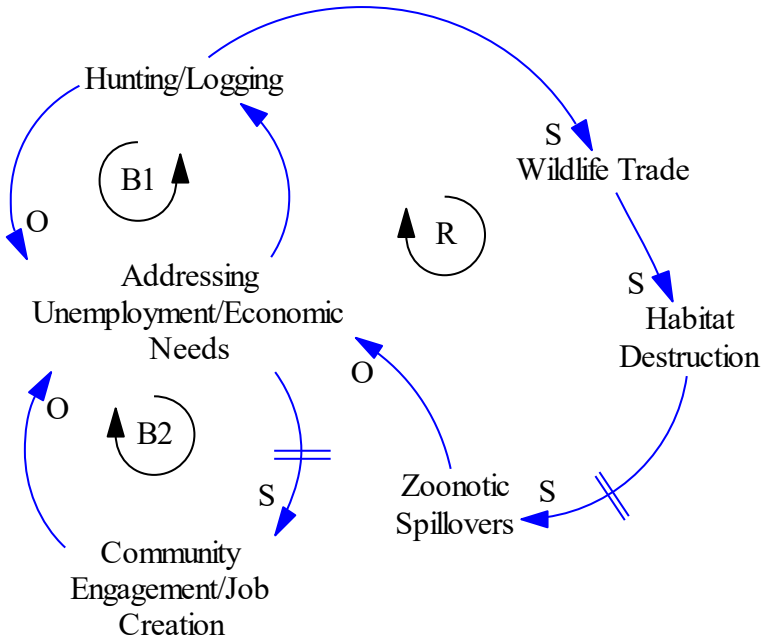

Figure 8: "Shifting the Burden" Systems Archetype

Systemic Intervention to Address Shifting the Burden Systems Archetype

To address the "Shifting the Burden" archetype and promote sustainable economic development, it's important to adopt holistic and integrated approaches that balance economic prosperity with environmental conservation and social well-being. This may involve:

1. **Alternative Livelihoods**: Provide support for alternative livelihoods that are sustainable and environmentally friendly, such as eco-tourism, sustainable agriculture, agroforestry, or community-based natural resource management. These activities can generate income for local communities while preserving biodiversity and ecosystem services.
2. **Capacity Building and Education**: Invest in capacity building, training, and education programs to empower communities with the knowledge and skills needed to engage in sustainable resource management practices. This includes promoting conservation awareness, sustainable hunting practices, and responsible tourism guidelines.
3. **Regulatory Measures and Enforcement**: Implement and enforce regulations to control wildlife trade, poaching, and habitat destruction. This may involve strengthening law enforcement efforts, increasing penalties for illegal activities, and establishing protected areas and wildlife reserves to conserve biodiversity and habitats.
4. **Community Engagement and Participation**: Foster community engagement and participation in decision-making processes related to natural resource management and economic development. Encourage collaboration between local communities, government agencies, NGOs, and other stakeholders to develop and implement sustainable development initiatives that address local needs and priorities.
5. **Incentives and Recognition**: Provide incentives and recognition for conservation efforts and sustainable practices that contribute to the protection of wildlife and ecosystems. This could include financial incentives, certification programs, eco-labeling schemes, and eco-tourism partnerships that reward communities for their conservation efforts.

By addressing the root causes of unsustainable resource exploitation and promoting holistic approaches to economic development, we can overcome the "Shifting the Burden" archetype and build resilient communities that thrive in harmony with nature.

Tragedy of the Commons Archetype

The Tragedy of the Commons archetype illustrated in Figure 9 illustrates a scenario where shared resources are overexploited due to the self-interest of individuals, leading to negative consequences for the collective well-being.

As the human population grows, there's greater demand for resources such as food, water, and land. With more people needing these resources, the pressure on natural ecosystems intensifies. To feed the growing population, there's an expansion of agricultural activities (R1). This often involves clearing forests and converting natural habitats into farmland. Initially, this expansion may seem beneficial for increasing food production, but it leads to long-term consequences (R2). The expansion of agriculture contributes to deforestation as forests are cleared to make way for crops or pastureland. Deforestation not only destroys habitats for countless species but also disrupts ecosystem functions such as carbon sequestration, water regulation, and soil stabilization (R1). With increasing demand for resources, there's a tendency for individuals to exploit common resources beyond sustainable levels (B1). This could involve overfishing in rivers, excessive logging in forests, or intensive farming practices that degrade soil fertility. Overexploitation and habitat destruction degrade the health of ecosystems (R1). As natural habitats are fragmented and degraded, ecosystem services such as pollination, pest control, and water purification decline. This affects not only wildlife but also human communities dependent on these services (B2). The degradation of ecosystems leads to biodiversity loss as species struggle to adapt or survive in altered environments. Loss of biodiversity weakens the resilience of ecosystems, making them more vulnerable to disturbances such as climate change, invasive species, and diseases. As humans encroach further into natural habitats and interact with wildlife, there's an increased risk of zoonotic disease transmission (R2). Zoonotic pathogens can jump from animals to humans, especially when humans come into close contact with wildlife through activities such as hunting, wildlife trade, and habitat destruction. In this archetype, the Tragedy of the Commons unfolds as individuals, driven by self-interest, exploit shared resources without considering the long-term consequences for the ecosystem or society as a whole. The result is a downward spiral of degradation, where overexploitation and habitat destruction lead to ecosystem collapse, biodiversity loss, and increased vulnerability to zoonotic diseases (R1 and R2). Breaking this cycle requires collective action, effective governance, and sustainable management of natural resources to ensure their long-term viability for current and future generations (B1).

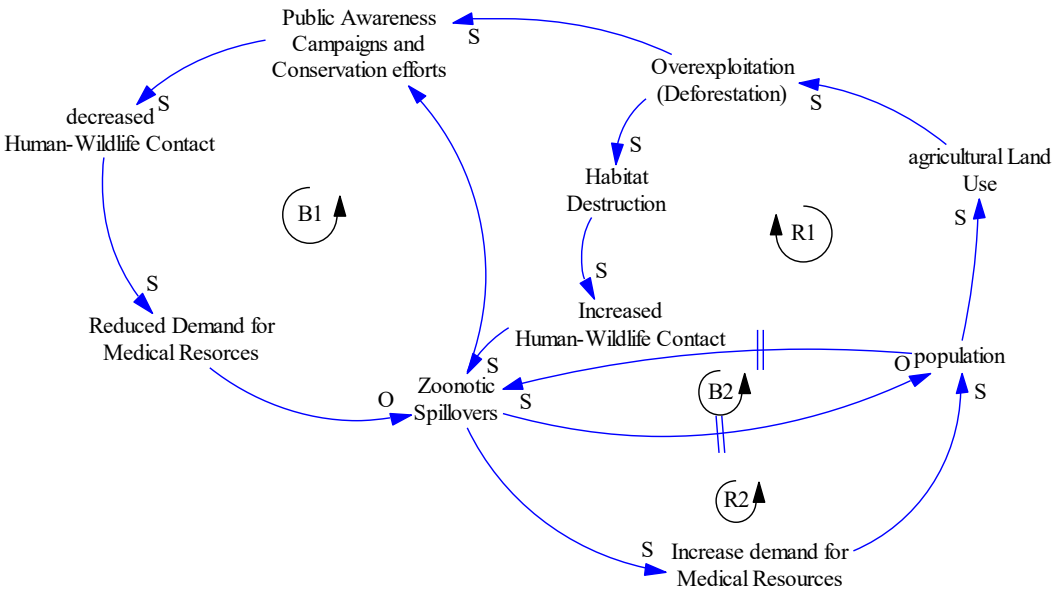

Figure 9: Tragedy of the Commons

Systemic Intervention to Address the Tragedy of the Commons Systems Archetype

Addressing the Tragedy of the Commons requires a combination of management strategies aimed at regulating resource use, promoting sustainable practices, and fostering collective responsibility. Key strategies:

1. **Resource Management and Regulation**: Implement regulations and policies to manage and sustainably use common resources such as fisheries, forests, and grazing lands. This may include setting catch limits for fisheries, establishing protected areas for conservation, and issuing permits for resource extraction to prevent overexploitation.
2. **Community-Based Management**: Empower local communities and stakeholders to manage common resources through participatory decision-making processes. Community-based management approaches involve engaging stakeholders in resource governance, fostering cooperation, and enforcing rules collectively agreed upon by the community.
3. **Property Rights and Ownership**: Clarify and secure property rights over common resources to prevent the tragedy of the commons. Establishing clear ownership or user rights encourages individuals to act responsibly and invest in the sustainable management of resources. This could involve creating community-owned cooperatives, communal land tenure systems, or establishing tradable property rights.
4. **Economic Incentives and Disincentives**: Create economic incentives and disincentives to encourage sustainable resource use and discourage overexploitation. This may include implementing taxes or fees on resource extraction, subsidizing sustainable practices, and providing financial incentives for conservation initiatives.
5. **Technological Innovation**: Invest in research and development of innovative technologies and practices that promote sustainable resource management. This could involve developing eco-friendly farming techniques, sustainable fishing gear, or renewable energy solutions to reduce reliance on finite resources.

6. **Education and Awareness**: Raise awareness and educate stakeholders about the importance of sustainable resource management, biodiversity conservation, and the consequences of the tragedy of the commons. Public education campaigns, training programs, and capacity-building initiatives can empower individuals to make informed decisions and adopt responsible behaviors.
7. **Enforcement and Compliance**: Strengthen enforcement mechanisms to ensure compliance with regulations and deter illegal or unsustainable activities. This may involve increasing monitoring and surveillance efforts, imposing penalties for violations, and collaborating with law enforcement agencies to combat illegal resource extraction and poaching.
8. **International Cooperation**: Foster international cooperation and collaboration to address transboundary issues and global commons. This could involve negotiating multilateral agreements, sharing best practices, and coordinating efforts to manage shared resources such as oceans, biodiversity hotspots, and the atmosphere.
9. **Adaptive Management and Resilience**: Embrace adaptive management approaches that allow for flexibility and learning over time. Monitor resource conditions, evaluate management interventions, and adjust strategies based on feedback and new information. Building resilience in social-ecological systems can help mitigate the impacts of the tragedy of the commons and promote sustainability in the face of uncertainty and change.

By implementing these management strategies in a coordinated and integrated manner, we can work towards overcoming the tragedy of the commons and ensuring the sustainable management of natural resources for current and future generations.

Leverage Points Identified Within the Systems Structures

A leverage point is a place within a system where a small change can lead to significant shifts in behaviour or outcomes. Based on the data provided during the three workshops, below are some recommended leverage points within each region:

Ashanti Region (Kumasi):

1. **Investment in Surveillance Systems:** Strengthening surveillance systems for early detection of zoonotic threats can be a critical leverage point. This includes enhancing the capacity for disease surveillance, monitoring, and rapid response mechanisms.
2. **Public Awareness Campaigns:** Increasing public awareness and education about zoonotic diseases and preventive measures can help change individual behaviors and beliefs. Targeted communication strategies and community engagement initiatives can amplify the impact of awareness campaigns.
3. **Funding for Research and Development:** Investing in research and development initiatives aimed at understanding zoonotic pathogens, their transmission dynamics, and potential interventions can yield valuable insights for prevention and control efforts.
4. **Community Engagement and Stakeholder Collaboration:** Promoting multi-stakeholder collaboration and community engagement is essential for implementing effective zoonotic spillover prevention strategies. Engaging local communities, traditional leaders, healthcare providers, and other stakeholders fosters collective action and ownership of prevention efforts.

Savannah Zone (Mole National Park):

1. **Enhanced Biosecurity Measures:** Implementing robust biosecurity measures in livestock farming and wildlife management practices can mitigate the risk of zoonotic spillovers. This includes measures such as quarantine protocols, vaccination programs, and biosecurity infrastructure improvements.
2. **Investment in Public Health Infrastructure:** Strengthening public health infrastructure, including healthcare facilities and veterinary services, is crucial for early detection, diagnosis, and management of zoonotic diseases. Adequate funding and resource allocation are needed to enhance the capacity of healthcare systems in the region.
3. **Community-Based Surveillance and Response:** Empowering local communities to participate in surveillance and response efforts can enhance the timeliness and effectiveness of disease detection and control. Establishing community-based surveillance networks and training community health workers can strengthen the region's ability to detect and respond to zoonotic threats.
4. **Policy Support and Enforcement:** Enacting and enforcing policies related to land use planning, wildlife conservation, and disease control is essential for preventing zoonotic spillovers. Strong governance structures and regulatory frameworks can help address underlying drivers of spillover risks in the region.

Western Region (Tarkwa):

1. **Regulation and Enforcement of Mining Activities:** Implementing and enforcing regulations to curb illegal mining (galamsey) and logging activities can help mitigate environmental degradation and habitat loss, reducing the risk of human-wildlife interactions and zoonotic spillovers.

2. **Community Education and Awareness:** Promoting community education and awareness programs on the risks of zoonotic diseases and sustainable land use practices can empower local communities to make informed decisions and adopt preventive measures.
3. **Investment in Alternative Livelihoods:** Providing alternative livelihood opportunities for communities dependent on unsustainable practices such as galamsey and illegal logging can reduce reliance on activities that contribute to habitat destruction and ecosystem degradation.
4. **Capacity Building for Wildlife Conservation:** Strengthening capacity for wildlife conservation and management, including the establishment of protected areas and wildlife corridors, can help preserve natural habitats and minimize human-wildlife conflicts.

By focusing on these leverage points, policymakers, stakeholders, and communities in the Ashanti Region (Kumasi), Savannah Zone, and Western Region (Tarkwa) can develop targeted interventions and strategies to prevent zoonotic spillovers and promote sustainable development practices that safeguard human and ecosystem health.

Building resilience is based on the leverage points identified in the systems structures analysis. These leverage points are crucial for building resilience through the One Health approach in addressing zoonotic challenges in the Ashanti Region (Kumasi), Savannah Zone, and Western Region (Tarkwa).

Building Resilience Through One Health: Addressing Zoonotic Challenges in the Ashanti Region (Kumasi), Savannah Zone, and Western Region (Tarkwa)

The following are potential interventions focused on addressing zoonotic challenges with a focus on One Health principles based on the identified leverage points:

1. Integrated Zoonotic Disease Surveillance and Response Program:

- **Objective:** Establish a comprehensive surveillance system for zoonotic diseases in humans, domestic animals, and wildlife, integrating data collection, analysis, and reporting mechanisms.
- **Activities:**
  - Train healthcare workers, veterinarians, and wildlife professionals in One Health approaches to disease surveillance and response.
  - Strengthen laboratory capacity for rapid diagnosis and characterization of zoonotic pathogens.
  - Implement community-based surveillance programs to enhance early detection of zoonotic outbreaks.
  - Establish multi-sectoral coordination mechanisms for information sharing and joint response planning.
- **Impact:** Improved early detection and rapid response to zoonotic disease threats, leading to reduced transmission and better public health outcomes.

2. Integrated One Health Initiative Community-Based Zoonotic Disease Prevention and Control Initiative:

- **Objective:** Empower local communities through one health initiatives to prevent and mitigate the risks of zoonotic diseases through education, awareness, and behavior change interventions.
- **Activities:**
  - Develop and implement culturally sensitive public awareness campaigns on zoonotic disease transmission, prevention, and hygiene practices.
  - Conduct training workshops and community engagement sessions to educate community members on the importance of wildlife conservation, sustainable land use, and responsible animal husbandry practices.
  - Establish community health committees to promote One Health principles and facilitate collaboration between health, veterinary, and environmental stakeholders at the grassroots level.
- **Impact:** Increased community resilience to zoonotic disease threats, reduced human-wildlife conflict, and improved health outcomes through proactive prevention measures.

3. Capacity Building for One Health Research and Innovation:

- Objective: Strengthen research capacity and innovation in the field of One Health to address emerging zoonotic disease challenges and promote sustainable development.
- Activities:
  - Support interdisciplinary research projects focused on understanding the drivers of zoonotic disease emergence, transmission dynamics, and socio-economic impacts.
  - Foster collaboration between academic institutions, research organizations, and local communities to co-design and implement research initiatives that address priority One Health issues.
  - Provide training and mentorship opportunities for young scientists, healthcare professionals, and policymakers in One Health research methods, data analysis, and evidence-based decision-making.
- Impact: Generation of scientific knowledge and evidence-based solutions to inform policy development, public health interventions, and ecosystem management strategies, leading to more effective zoonotic disease prevention and control efforts.

These potential interventions leverage One Health principles to address zoonotic challenges holistically, recognizing the interconnectedness of human, animal, and environmental health. By engaging stakeholders across sectors and fostering collaboration at the local, national, and regional levels, these initiatives have the potential to create lasting positive impacts on health, livelihoods, and ecosystems in the Ashanti Region (Kumasi), Savannah Zone, and Western Region (Tarkwa).

Conclusion

This analysis of zoonotic disease spillover prevention efforts in the Ashanti Region (Kumasi), Savannah Zone, and Western Region (Tarkwa) underscores the complexity of addressing public health challenges within diverse socio-ecological contexts. Through a systems thinking lens, we have identified interconnected factors influencing the prevalence and transmission of zoonotic diseases, ranging from funding constraints and law enforcement gaps to socio-cultural beliefs and economic drivers.

Despite these challenges, our analysis also revealed significant opportunities for intervention and improvement. Leveraging the collective expertise and collaboration of diverse stakeholders, including government agencies, non-governmental organizations, academic institutions, and local communities, can lead to more effective prevention strategies. Enhancing funding mechanisms, strengthening law enforcement, and promoting public awareness campaigns are crucial steps towards mitigating the risks of zoonotic disease spillovers.

Moreover, the engagement of Core Team members, who served as facilitators during regional workshops, highlights the importance of interdisciplinary collaboration and knowledge exchange in addressing complex health and environmental challenges. By harnessing the insights and expertise of these stakeholders, we can develop tailored and context-specific interventions that promote health equity, biodiversity conservation, and sustainable development.

Moving forward, it is imperative to prioritize One Health approaches that recognize the interconnectedness of human, animal, and environmental health. By integrating multisectoral strategies and fostering community participation, Ghana can build resilience against zoonotic diseases and safeguard the well-being of its population and ecosystems. Through concerted efforts and collective action, we can create a healthier, more sustainable future for all.

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Appendix: Workshop Participants

Ashanti Region: Kumasi

Name	Institution	Role
1. Dr Samuel Asumah	Wildlife	Veterinary
2. Dr Mabel Abudu	Veterinary Service Directorate	Regional Veterinary Officer
3. Agyemang Prempeh	Department of Agriculture	Regional Agricultural Officer - Animal Production Department
4. Michael Tongban	Abattoir	Production. Manager.
5. Jacob Kabauda	Wildlife Division of Forestry Commission	Regional Manager.
6. Prosper K. Antwi	A Rocha	Manager
7. Daniel Y. Saim	Farmers Assoc.	Chairman
8. Dr. Magdalene Dontsi	Veterinary Service Directorate	Senior Veterinary Office
9. Michael Adu-Gyamfi	Ghana National Association of Small-Scale Miners	Secretary
10. Richard B. Saddwa	Environmental Protection Agency	Deputy Director
11. Theresah Mensah	Bushmeat Trader	Fourth in Command
12. Petrina Markeh	Forestry Comm	Human Resource Manager.
13. Henrietta Dede Tetteh	Kumasi Center for Collaborative Research	Researcher
14. Dr. Gyimah O. Sasu	Ghana Health Service	Director
15. Amoako Nketia	Poultry Farmers Association	Regional Secretary
16. Patience Apassnaba	Forestry Commission	Park Manager.
17. Patrick Amponsah	Veterinary Service Directorate /Kumasi Veterinary Laboratory	Senior Veterinary Officer
18. Kingsley Ampratwum	GHS	Disease Control Officer
19. Comfort Boadu	Bushmeat	Queen mother
20. Vida Opoku	Bushmeat	Organiser
21. Kelsia Pokua Kwakye	Ashanti Regional Coordination Council	Assistant Director
22. Amoah Paul	Bushmeat	Member
23. Yaw Agyei Mensah	National Disaster Management Organisation	Deputy Director
24. Osei Evans	Hunter	Hunter
25. Isaac Abanga	Ejisu Pig Farmer Association	Organiser

Savannah Zone: Mole National Park

Institution		Name	Role
Mole National Park		1. Franklin Mongo Vug	Assistant Manager
		2. Abraham Oppong Manu	Assistant Manager
		3. Alfred Kofi Bara	Law enforcement officer
		4. Agbernor Benjamin Kwesi	Assistant Manager
		5. Kipo Albert	Tour guide
		6. Kalma Saalia Alhassan	
Gbele Reserve		7. Dr Maabier Polycarp	Park Manager.
FSD		8. Kazaake Francis	Assistant Manager
Livestock Farmers		9. Alhaji Mohammed Amadu	
		10. Abdurrahman Umar	
		11. Iddrisu Akilu	
		12. Mahama Tahiru Douglas	
Agric extension officers		13. Moro Rafiu	Extension
		14. Justina Asagtimbey	Extension
EPA		15. Aikins Akuffo-Addo	Program officer
VSD (Upper East region)		16. Robert Bayuo	
Hunters		17. James K. Bani	
		18. Seidu Munaba	
Municipal vet officer (Damongo)		19. Samuel Kugbenu	
Ghana health service (Damongo)		20. Samuel Ntuwami	Municipal Disease Control Officer
		21. Madi Edmund	Surveillance Officer
NGOs	Ghana Wildlife Society	22. James Braimah	
	Arocha Ghana	23. Godwin E. Dzekoto	Project Manager
	North Code	24. Luke Pampogee	Senior Project Officer
	Green Ghana	25. John Balankuu Sumbo	Executive Director
Abattoir (Damongo)		26. Takora Mahama	Environmental Health Officer
Damongo Agric College		27. Abubakari Fatawu	National Service Personnel
Larabanga Clinic		28. Asare Bright Omaboe	Physician Assistant
Mole Clinic			
NADMO		29. Bavug Adam	Director
RVO		30. Dr Yolanda Y. Ayamdoh	Regional Veterinary Officer

Western Region: Tarkwa

Name	Institution	Role
1. Jennifer S. Boateng	National Disaster Management Organisation	Principal Disaster Control Officer
2. Dr Simon Gbene	Veterinary Service Directorate	Regional Veterinary Officer
3. Dr Eric Gyimah	University of Mines and Technology	Lecturer
4. Evelyn Oduro	Forest Service Division	Manager
5. Comfort Arthur	Bushmeat	Trader
6. Emmanuel Bavor	Prestea Huni-Vally Municipal Assembly	Acting Chief Environmental Health Officer
7. Francis Eshun	Prestea Huni-Vally Municipal Assembly Veterinary	Acting Chief Technical Office
8. Richmond K. Guak	Prestea Huni-Vally Municipal Assembly Veterinary	Veterinary Technician
9. Yakubu H. Rahman	Abattoir	Chief Butcher
10. George Nyamekye	Environmental Protection Agency	Assistant District Officer
11. Ebenezer Tetteh	Environmental Protection Agency	National Service personnel
12. Nana Banyin Acquah-Thompson	Tarkwa Nsuayem Municipal Assembly	Municipal District Assembly
13. Francis Amoah	National Disaster Management Organisation	Director
14. Hawa Abdul Yakubu	Farmer	
15. Paul Appiah	Ayum Timber	Manager
16. David Dzikunu Tetteh	Farmer	
17. Dr Jeffery Wi-Afedzi,	Veterinary Service Directorate	Municipal Veterinary Officer
18. Isaac Abban	Forestry	Security
19. Prof George Agyei	Leanita International	Director
20. Godwin Andinaan	Progressive	Director
21. Apraku Esther Debrah	Progressive	Communications Officer.
22. Fayadatu Yakubu	Progressive	Member
23. Dora Yankey	West Africa	Chief Health Officer
24. Kenneth Apedo	Progressive	Member
25. Agyapong Vicentia	Progressive	Outreach coordinator
26. Emmanuel Ephraim	Leanita	Secretary
27. Theophilus Arthur	Progressive	Social Psychologist
28. Joseph Azumah	Leanita	Program Director
29. Yeboah Esther	Progressive	Head of Production and Management.
30. William Appiah	Progressive	Member
31. Sarah Lantoh	West Africa	Finance officer
32. Alfreda Eshun	Progressive	Research Leader
33. Deborah Akrokoh	West Africa	Communications Officer
34. Patricia B Aboah	West Africa	Assistant Research. Lead
35. Phyllis D. Tetteh	Leanita	Financial Secretary

36. Eric Otoo	Leanita	Communication Officer
37. Amoateng Cornelius KD	West Africa	Research Lead.
38. Edith Alhassan	Progressive	Communications Officer
39. Rukaya Mohammed	Farmer	
40. Wilhemina Duah	Ghana Health Service	Municipal Director of Health

Core Team Members

Dr. Richard Suu-Ire	University of Ghana School of Veterinary Medicine
Dr. Sherry A.M. Johnson	University of Ghana School of Veterinary Medicine
Mr. Robin Breen	EcoHealth Alliance
Dr. Catherine Machalaba	EcoHealth Alliance
Ms. Ruth Arthur	National Disaster Management Organisation
Dr. Theophilus Odoom	Accra Veterinary Laboratory
Dr. Meyir Ziekah	Wildlife Division of Forestry Commission
Dr. Amos Sarpong Agyei	University of Ghana School of Veterinary Medicine
Ms. Anna Sekyibea Bekai	Ministry of Environment, Science, Technology, and Innovation
Dr Kwamina Ewur Banson	Ghana Atomic Energy Commission
Prof Julian Yartey Enos	University of Ghana School of Public Health