



Prioritization of zoonoses of wildlife origin for multisectoral one health collaboration in Guyana, 2022

Kirk O. Douglas^{a,*}, Govindra Punu^b, Nathalie Van Vliet^b

^a Centre for Biosecurity Studies, The University of the West Indies, Cave Hill Campus, Cave Hill BB11000, Barbados

^b Center for International Forestry Research (CIFOR), Jalan CIFOR Situ Gede, Bogor Barat, Bogor 16115, Jawa Barat, Indonesia

ARTICLE INFO

Keywords:
Zoonoses
Pathogens
Wildlife
One health
Guyana

ABSTRACT

Background: The human population in Guyana, located on the South American continent, is vulnerable to zoonotic diseases due to an appreciable reliance on Neotropical wildlife as a food source and for trade. An existing suboptimal health surveillance system may affect the effective monitoring of important zoonotic diseases. To effectively address this deficit, a One Health zoonotic disease prioritization workshop was conducted to identify nationally significant zoonoses.

Methods: Prioritization of zoonotic diseases was conducted for the first time in Guyana & Caribbean region using literature review, prioritization criteria and a risk prioritization tool in combination with a consultative One Health workshop. This involved multisectoral experts from varied disciplines of social, human, animal, and environmental health to prioritize zoonotic diseases using a modified semi-quantitative One Health Zoonotic Disease Prioritization (OHZDP) tool. The inclusion and exclusion criteria were applied to pathogen hazards in existence among wildlife in Guyana during the hazard identification phase.

Results: In total, fifty zoonoses were chosen for prioritization. Based on their weighted score, prioritized diseases were ranked in order of relative importance using a one-to-five selection scale. In Guyana, this zoonotic disease prioritization method is the first significant step toward bringing together specialists from the fields of human, animal, and environmental health. Following discussion of the OHZDP Tool output among disease experts, a final zoonotic disease list, including tuberculosis, leptospirosis, gastroenteritis, rabies, coronavirus, orthopoxvirus, viral hemorrhagic fevers, and hepatitis were identified as the top eight priority zoonoses in Guyana.

Conclusions: This represents the first prioritization of nationally significant zoonotic diseases in Guyana and the English-speaking Caribbean. This One Health strategy to prioritize these eight zoonoses of wildlife origin is a step that will support future tracking and monitoring for disease prevalence among humans and wildlife and can be used as a decision-making guide for policymakers and stakeholders in Guyana.

1. Introduction

Zoonotic agents are infectious pathogens that exist in animals and can infect humans. They are becoming a bigger threat to public health, in part because of the chance of spillover events happening where people and animals meet. Hunting has recently sparked epidemiological interest, as zoonotic disease outbreaks have been continuously growing since the 1940s, with over 70% of zoonoses originating in wild animals [1]. Countries around the globe remain vulnerable to the emergence of numerous novel zoonoses over the last three decades and these diseases often have no specific diagnostics, medications, or vaccines and there is no pre-existing immunity in human populations [2]. Wild animals used

for food are major reservoirs for many foodborne pathogens and zoonotic diseases that are transmitted through direct human-animal contact [3]. Compelling evidence exists showing the emergence of zoonotic diseases follows complicated patterns and is connected to human activities that bring wildlife, domestic animals, and people into more intensive and protracted interaction. This includes the destruction and degradation of natural areas [4], intensive livestock rearing [5], and hunting, trade, and consumption of wildlife [6]. In urban and peri-urban areas located on the coast of Guyana, wild meat consumption is common. >60% of the population consumes wild meat [7]. In Region 4, the most populated region of Guyana, including the capital Georgetown, the amount of wild meat consumed reaches an estimated minimum of 625

* Corresponding author.

E-mail address: kirk.douglas@cavehill.uwi.edu (K.O. Douglas).

<https://doi.org/10.1016/j.oneht.2024.100730>

Received 26 October 2023; Accepted 10 April 2024

Available online 16 April 2024

2352-7714/© 2024 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC license (<http://creativecommons.org/licenses/by-nc/4.0/>).

tons, or 1.2 kg per person, annually. The top five species sold are labba, deer (*Mazama spp.*), tapir, peccary (unknown species), and capybara (*Hydrochoerus hydrochaeris*). Iguana and caiman are the only two reptiles, whereas powis (*Crax alector*) is the only bird species [7]. Consumption and sales occur openly because the wild meat trade is still unregulated in Guyana despite the recent decrees to establish a licensing system and hunting seasons, which have not yet moved into the implementation phase. Along the coast, wild meat is sold at market stalls, restaurants, rum bars, trader's homes, and other small shops, as well as along the roadside [8]. The frequent contact between hunters and wildlife and the handling of bodily fluids during butchery and consumption (especially of undercooked meat) greatly increase the opportunities for pathogens to cross species barriers [9].

The risks of zoonotic infections in Guyana are diverse, with multiple potential modes of transmission and several related factors, including socioeconomic conditions, social and human behaviors, and trade (hunting, exotic pets, and wild meat). Several zoonotic infections with direct links to wildlife or exposure to meat, bodily fluids or fecal matter have been recorded in Guyana among peer-reviewed literature, including leishmaniasis, leptospirosis, and histoplasmosis [10–14]. However, at present, there is no documented prioritization of zoonoses at local and national levels utilized for evidence-based policy formulation and effective implementation of public health control measures and activities. Prioritization of zoonotic diseases is crucial to permit maximization of the use of resources, improve surveillance and data quality, and foster multi-sectoral collaboration. To address such challenges, Sustainable Wildlife Management (SWM) in Guyana, under its program, launched a One Health initiative. Its overarching goal is to improve the preparedness of Guyana regarding the emergence of zoonotic diseases related to wildlife. The project supports local communities and governmental institutions in Guyana with the information, analysis, and tools necessary to contribute toward a better understanding of the prevention of outbreaks of zoonotic diseases related to wildlife. A zoonotic disease prioritization workshop using a One-Health approach was organized by the SWM, and the prioritization of zoonotic diseases was done for the first time in the country.

The SWM Program directly contributes to a number of Sustainable Development Goals, such as Goal 2 (Zero Hunger), Goal 12 (Responsible Consumption and Production), and Goal 15 (Life on Land). The prioritization workshop organized by this project was the first significant step toward bringing together specialists from the fields of human, animal, and environmental health. The main goals of the prioritization process were to identify the most important zoonotic diseases in Guyana, foster connections between the human, animal, and environmental health sectors so that they can work together to combat zoonotic diseases, and increase coordination, collaboration, and networking mechanisms among stakeholders on zoonotic disease prevention and control activities.

Prior to the workshop, extensive research was conducted to review existing methodologies and tools to prioritize zoonotic diseases related to wildlife use. A preliminary list of fifty zoonotic diseases to be considered for prioritization was compiled, and a literature review was conducted on zoonotic pathogens under surveillance by the human and animal health agencies in Guyana. The criteria for prioritization were established, which utilized the existence of any evidence that the pathogen is zoonotic, the existence of evidence that the pathogen may be associated with wildlife species endemic to Latin American countries (LACs), evidence that the wildlife species is able to transmit the pathogen (versus a dead-end host), and the possibility that the pathogen can be directly transmitted to humans.

The focus of the OHZDP workshop was on the zoonotic pathogens directly transmissible from Neotropical wildlife found in Guyana. Vector-borne diseases (VBDs) are important zoonotic diseases in Guyana, however they were excluded due to the focus on zoonotic diseases that are directly transmissible from wildlife to humans. For this reason, the VBDs in Guyana, such as dengue, malaria, filaria, etc., that originate

in animals and are indirectly transmitted to humans through the bite of an infected vector such as mosquitoes, were disregarded.

2. Methods

2.1. Workshop organization and participant selection

Prior to the OHZDP workshop, a series of pre-workshop meetings were held with varied national ministries and agencies to obtain relevant data and information on current national zoonotic threats in Guyana ahead of time. The OHZDP workshop for Guyana was held in Georgetown, Guyana on September 20, 2022. Guyana is a CARICOM territory on the South American continent (Fig. 1). The core workshop participants consisted of twenty-five (25) human, animal, agricultural, and environmental health, food safety, wildlife, and social welfare experts (Table 1). These experts were selected from a range of national entities including the Guyana Livestock Development Authority, Guyana Food Safety Authority, Ministry of Health (Vector Control Services, Epidemiology and Surveillance Unit, Analytical Science and Veterinary Public Health), North Rupununi District Development Board, South Rupununi District Council, Protected Areas Commission, Environmental Protection Agency, Guyana Wildlife Conservation Management Commission, Rupununi Livestock Producers Association and Ministry of Amerindian Affairs (Table 1). This was done in the presence of One Health technical advisors from the Center for International Forestry Research (CIFOR) and the Food and Agriculture Organization of the United Nations (FAO-UN) in Guyana. Technical assistance was available from the Centre for Biosecurity Studies (The University of the West Indies, Cave Hill Campus) in Barbados and the University of Antioquia in Colombia.

2.2. Literature review and initial list of zoonotic diseases

The workshop utilized an adapted mixed methods prioritization tool previously developed and previously described. A preliminary list of fifty zoonotic diseases to be considered for prioritization was generated from a scoping literature review. Due to the absence of an official list of zoonoses present in Guyana, several sources were consulted to develop an initial list of disease search terms. In brief, scientific literature databases PubMed (<https://pubmed.ncbi.nlm.nih.gov/>), Google Scholar (<https://scholar.google.com/>), Web of Science (WoS) and Google search engine (<https://www.google.com>) were used to perform exhaustive searches for peer-reviewed publications and other scholarly reports on zoonotic pathogens from the Neotropical wildlife animals resident in Guyana that have been found elsewhere in the world. These countries included those from within Caribbean islands of the Greater and Lesser Antilles (Antigua and Barbuda, Barbados, Cayman Island, Cuba, Curacao, Dominica, Dominican Republic, Grenada, Guadeloupe, Haiti, Jamaica, Martinique, Puerto Rico, St. Vincent, St. Kitts and Nevis, St. Lucia and Trinidad and Tobago), neighboring South and Central American countries (Brazil, Suriname, Venezuela, Honduras, Costa Rica, Panama, Chile, Argentina, and Bolivia) and around the world as well. This provided a list of diseases that potentially may be present in Neotropical wildlife species found in Guyana. Prevalence data on major human infectious diseases were provided by the surveillance unit at the Ministry of Health in Guyana. Infectious disease syndromes such as fever and respiratory symptoms - Acute Respiratory Infections (ARIs), gastroenteritis, skin diseases and undifferentiated fever were provided to understand the national health burden (Fig. 2). Based on these health data, comparisons were made with the list of zoonoses from wildlife species and infectious disease syndromes and infectious diseases among humans in Guyana. Zoonoses from wildlife species fitting the observed clinical infectious disease profiles in Guyana were included. Input gathered from pre-workshop meetings with workshop participants was considered in designing the prioritization criteria. Additionally, other data on disease transmission, severity, human disease prevalence,

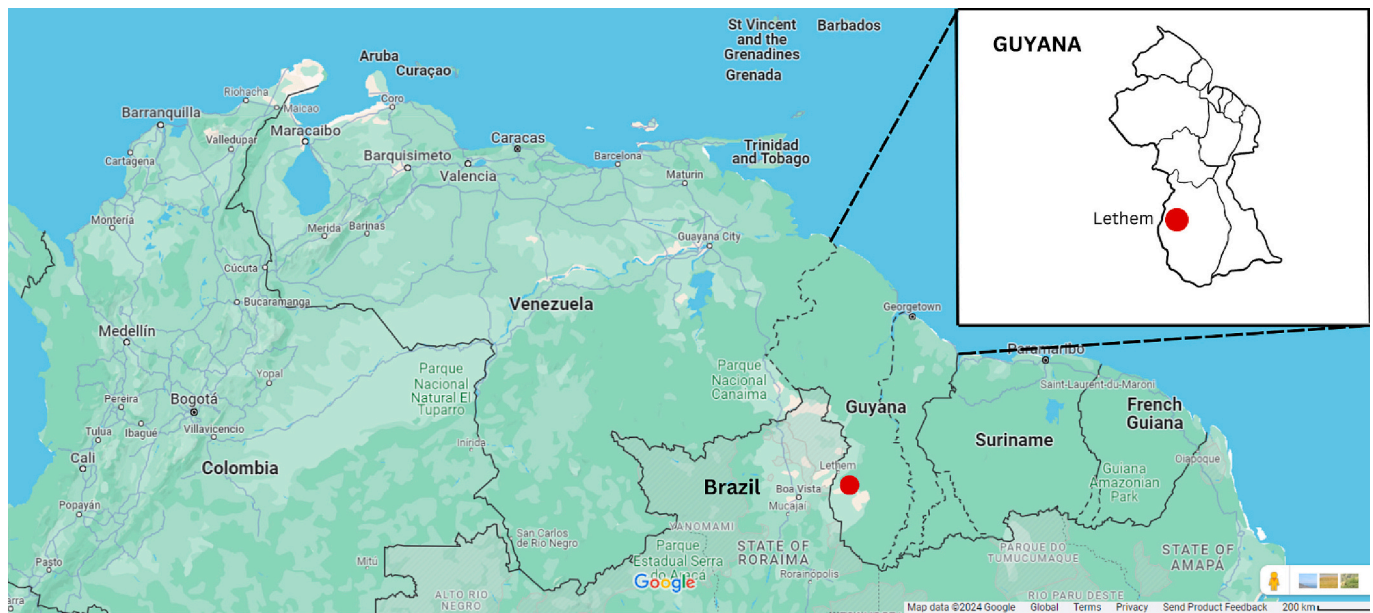


Fig. 1. A map of Guyana and the northern tip of the South American continent showing Lethem (Region 9).

Table 1
Participating Organizations in the One Health Zoonotic Disease Prioritization workshop for Guyana, September 2022.

	Organization	Number of Participants
National	Guyana Livestock Development Authority (GLDA)	1
	Guyana Food Safety Authority	–
	Ministry of Health (Vector Control Services, Epidemiology and Surveillance Unit, Analytical Science and Veterinary Public Health)	4
	North Rupununi District Development Board	1
	South Rupununi District Council	1
	Protected Areas Commission (PCA)	2
	Environmental Protection Agency (EPA)	1
	Guyana Wildlife Conservation Management Commission (GWCMC)	3
	Rupununi Livestock Producers Association	2
	Ministry of Amerindian Affairs	2
	Centre for Biosecurity Studies (University of the West Indies, Cave Hill Campus, Barbados)	1
	University of Antioquia (Columbia)	2
Non-governmental organization (NGO)	Center for International Forestry Research (CIFOR)/ SWM Guyana	4
	Food and Agriculture organization of the United Nations in Guyana	1
TOTAL		25

animal disease prevalence, socioeconomic impact, prevention and control were collected from multiple sources from well-respected and official organizations. With input from focal points of the One Health platform in Guyana, a shortlist of potential zoonoses divided into separate categories of bacterial, viral, parasitic and fungal zoonoses from wildlife was created for the risk prioritization process with the various prioritization criteria and risk ranking. This was done during an OHZDP meeting with all represented One Health sectors. Consideration was given to all zoonotic pathogens currently under surveillance by human and animal health agencies and any zoonoses known to be present in human and animal population in Guyana or in any bordering

countries.

2.3. Prioritization of zoonoses in Guyana

Prior to the in-person workshop session in Georgetown, methodologies to prioritize zoonotic diseases were developed based on existing methods. This methodology was adjusted to suit the context of Guyana. The One Health Zoonotic Disease Prioritization (OHZDP) tool, which was developed by the Centre for Biosecurity Studies (The University of the West Indies, Cave Hill Campus), was adopted from Rist et al. (2014) [10]. This OHZDP tool was customized for the context of Guyana. Given the paucity of valid quantitative data and poor surveillance for most zoonotic diseases, the application of other techniques was impractical. The proposed OHZDP tool was equipped with criteria and questions relevant to prioritization for group selection [11–13]. Microsoft Excel program was used for analytical hierarchy operations to rank criteria and was adequately equipped to analyze the decision tree of each zoonotic disease.

2.4. Criteria selection

During the OHZDP workshop, the participants jointly developed criteria for ranking of the eight (8) zoonotic diseases. Examples of criteria used in published methods were shared with the OH platform members to encourage careful consideration of all potentially useful criteria. The list of criteria was reviewed with the members of the OH platform through a moderated discussion to indicate the relevant criteria. Upon confirmation and agreement of the chosen criteria, a suitable question was developed for each criterion. This was done after considering the availability of evidence from Guyana and the surrounding region to enable the best measurement of each question. Questions with categorical answers were developed to measure each criterion and each question was structured in such a way that it could be answered by a single person or group using data sources available for all pathogens on the initial list. The ordinal nature of the questions was necessary to support the scoring process. Each answer was assigned a score based on the scale jointly determined by the OHZDP workshop participants. The inclusion and exclusion criteria applied to the pathogen hazards in existence among wildlife species present in Guyana during the hazard identification phase are shown in Fig. 3 and Table 2. These criteria included: (i) Is there any evidence that the pathogen is zoonotic? (ii) Is there evidence that the pathogen may be

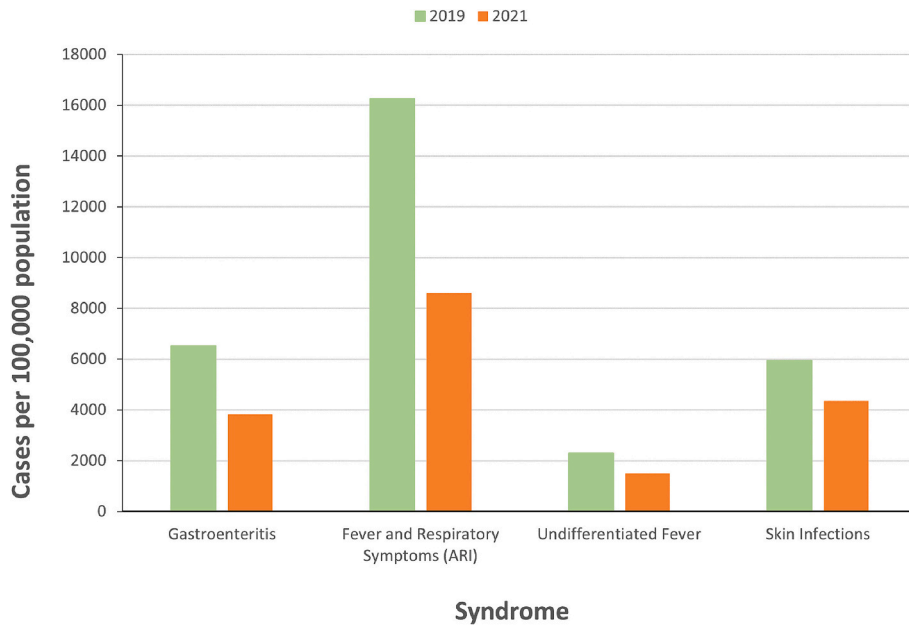


Fig. 2. National health incidence data on top infectious disease syndromes (gastroenteritis, fever and respiratory symptoms ARI, undifferentiated fever and skin infections) in Guyana from 2019 and 2021. Source: Ministry of Health, Surveillance Department, Guyana.

Risk Prioritisation of Zoonoses in Guyana

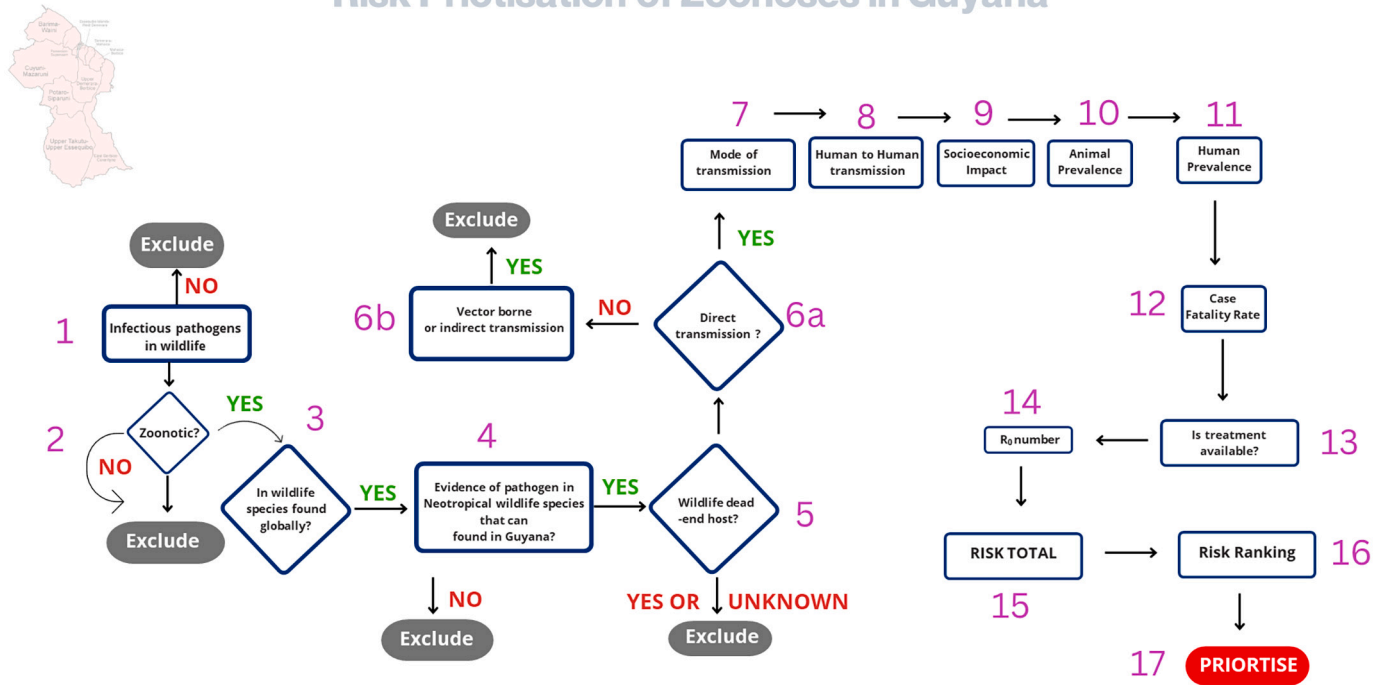


Fig. 3. Decision tree with the inclusion and exclusion criteria applied to the pathogen hazards in wildlife found in Guyana during the hazard identification phase.

associated with the wildlife species endemic to Guyana or the region? (For this criterion, any evidence was considered, including both natural and experimental infections.), (iii) Is there evidence that the pathogen may be associated with the wildlife species endemic to Guyana or the region (versus a dead-end host)? and (iv) Can the pathogen be directly transmitted to humans? (Fig. 3 and Table 2) [11]. The threat of the zoonotic agent to specific at-risk sub-populations in Guyana such as pregnant mothers, children, indigenous persons and the disabled was assessed and rated by national expertise. Each voting member was allowed to rank the

criteria in their preferred order to address their sector’s priorities and needs. Individual rankings were combined and a ranked list of the criteria was created based on the scores provided by everyone. For each of the criteria used, a sequential numerical weight was assigned and the analytical hierarchy process assigned the most important criteria with the highest weight and the least important criteria with the lowest weight. A decision tree was built by using the first ranked criterion as the first node, the second ranked criterion as the second node, and so on (Fig. 3).

Table 2

Final criteria and associated questions used in the ranking process of zoonotic diseases using the One Health Zoonotic Disease Prioritization (OHZDP) tool during the workshop for Guyana, 2022.

Ranking	Prioritization Criteria	Question	Answer (score)
7	At risk sub-populations	What are the at-risk sub-populations?	1 to 5 (lowest to highest)
2	Human to human transmission	Is the disease transmissible from human to human?	1 to 5 (lowest to highest)
5	Socioeconomic impact	What is the socioeconomic impact for Guyana?	1 to 5 (lowest to highest)
8	Animal Prevalence	What is the disease prevalence in animals?	1 to 5 (lowest to highest)
5	Human Prevalence	What is the disease prevalence in humans?	1 to 5 (lowest to highest)
1	Case fatality rate	What is the case fatality rate of the disease?	1 to 5 (lowest to highest)
4	Is treatment available	Are there existing treatments for this disease?	1 to 5 (no treatment to available treatment)
3	R ₀ Number	What is the Reproductive number of the disease?	1 to 5 (lowest to highest)
Risk Total Score			

N.B For each disease, responses to each question were inputted into the OHZDP tool. Based on the different modes of transmission from wildlife to humans the relevant risk factor was assigned (Respiratory – 5, Fecal-oral – 4, bodily fluids – 3, blood-borne – 2, Skin-to-skin – 1) according to published literature report. For the next six (6) criteria an evaluation for each was established based on collective national expertise and experience and likewise graded on a scale of 1 to 5. The reproduction number, R₀, was evaluated and assessed (R₀ < 1 = 1, R₀ 1–3 = 2, R₀ 4–6 = 3, R₀ 7–9 = 4 and R₀ ≥ 10 = 5) based on published literature reports for each zoonotic infection. In disease prioritization, the R₀ value is important because it quantifies the infectiousness of a pathogen and its ability to cause disease and spread within a population.

2.5. Disease scoring and final ranking

Working via facilitation OHZDP workshop participants went through each of the 50 diseases on the list and answered each categorical question using data generated through the literature review. Where data was not available for Guyana specifically, expert knowledge and data from the region or globally were used to inform the answers. For each disease, responses to each question were inputted into the OHZDP tool [10]. Based on the different modes of transmission from wildlife to humans the relevant risk factor was assigned (Respiratory – 5, Fecal-oral – 4, bodily fluids – 3, blood-borne – 2, Skin-to-skin – 1) according to published literature reports [12,13]. For the next six (6) criteria an evaluation for each was established based on collective national expertise and experience and likewise graded on a scale of 1 to 5. The reproduction number, R₀, was evaluated and assessed (R₀ < 1 = 1, R₀ 1–3 = 2, R₀ 4–6 = 3, R₀ 7–9 = 4 and R₀ ≥ 10 = 5) based on published literature reports for each zoonotic infection [14–22]. In disease prioritization, the R₀ value is important because it quantifies the infectiousness of a pathogen and its ability to cause disease and spread within a population. In other words, R₀ is the expected number of cases directly generated by one case in a population where all individuals are susceptible to infection. The tool automatically calculated the weighted score for each criterion for each disease. Next, the cumulative risk score was calculated for each zoonotic infection and each disease was ranked based on the cumulative risk score. A final ranked list of prioritized zoonoses for Guyana was compiled in wide consultation with varied stakeholders with individuals meeting and culminating in a final One Health zoonotic prioritization workshop, presented and discussed after which consensus was sought and reached.

2.6. Next steps and action plans

Once the list of priority zoonotic diseases was finalized, it was presented to the national agencies and CIFOR. Subsequently, initial scheduling and plans for next steps and relevant approaches to mobilized actions to effectively tackle the confirmed priority zoonotic diseases for Guyana, with monitoring and surveillance capacity building using a multisectoral One Health approach, were to follow.

3. Results

3.1. Participants

The OHZDP workshop for Guyana included twenty five (25) participants from multiple disciplines representing the Guyana Livestock Development Authority, Guyana Food Safety Authority, Ministry of Health (Vector Control Services, Epidemiology and Surveillance Unit, Analytical Science and Veterinary Public Health), North Rupununi District Development Board, South Rupununi District Council, Protected Areas Commission, Environmental Protection Agency, Guyana Wildlife Conservation Management Commission, Rupununi Livestock Producers Association and Ministry of Amerindian Affairs. The prioritization process was done in the presence of One Health technical advisors from the Center for International Forestry Research (CIFOR) and the Food and Agriculture Organization of the United Nations (FAO-UN) in Guyana. Technical assistance was available from the Centre for Biosecurity Studies (The University of the West Indies, Cave Hill Campus) in Barbados and the Programa de Estudio y Control de Enfermedades Tropicales (PECET) lab from the University of Antioquia in Colombia.

3.2. Confirmation of the list of zoonoses

Upon presentation of the initial list of fifty (50) zoonoses, deliberation followed on the exclusion of VBDs and the relevant importance of some zoonoses (Table 3). These zoonoses were endorsed as the list of zoonoses to be present for prioritization.

3.3. Final ranking of diseases

The final scores and ranking of diseases are presented in Table 4. In the ranking of zoonotic diseases, workshop participants decided to group zoonotic enteric viruses, bacteria and parasites as ‘gastroenteritis’, zoonotic respiratory viral pathogens (e.g. coronavirus, influenza (‘bird and swine flu’)) were combined into Coronavirus grouping, zoonotic poxviruses including Mpox were grouped as Orthopoxvirus, viral hemorrhagic fever viral pathogens including hantavirus, arenavirus etc. were grouped as VHF viruses and hepatic viruses such as hepatitis A-E were grouped under hepatitis.

Overall, eight zoonotic disease syndromes were identified as priority zoonotic agents in Guyana (Table 4). These include Coronavirus grouping, Viral haemorrhagic fever, hepatitis, tuberculosis, rabies, gastroenteritis, orthopoxvirus and leptospirosis, all of which are listed in the order of highest to lowest ranking (Table 4).

4. Discussion

A consensus of eight (8) priority zoonotic diseases was generated for Guyana during the OHZDP workshop, including coronavirus, viral haemorrhagic fever (VHF) viruses, hepatitis, tuberculosis, rabies, gastroenteritis (bacterial and viral origin), orthopoxvirus, and leptospirosis. These diseases were ranked based on their severity and potential impact on human and animal health. The prioritization of zoonotic diseases is crucial for effective preparedness and prevention strategies in Guyana. The lack of comprehensive data on zoonotic diseases in developing countries like Guyana highlights the importance of a One Health approach to address these health threats.

Table 3

Preliminary list of zoonoses used in the prioritization process of zoonotic diseases using the One Health Zoonotic Disease Prioritization (OHZDP) tool during the workshop for Guyana, 2022.

Disease	Bacterial zoonoses	Viral zoonoses	Parasitic zoonoses	Fungal zoonoses
	Gastroenteritis	Campylobacteriosis Salmonellosis <i>Clostridium perfringens</i> <i>Escherichia coli</i> Streptococcosis Shigellosis Yersinosis	Enteroviruses Parvoviruses Rotaviruses Noroviruses Hepatitis A, D, E	Giardiasis Cryptosporidiosis
Undifferentiated fever	Leptospirosis Typhoid fever	Same as ARD	Toxoplasmosis	n/a
Acute respiratory disease (ARD)	Tuberculosis	Influenzas Coronaviruses Hantavirus fever Arenavirus fevers Paramyxoviruses Adenoviruses	n/a	Histoplasmosis
Skin disease	Leprosy	Orthopoxvirus disease Papillomavirus disease	Chagas disease Myiasis Leishmaniasis Scabies Toxocarosis/toxocariasis	Dermatophytosis

N.B For each disease state reported by the Ministry of Health endemic zoonotic pathogens and their potential diseases were listed.

n/a - not applicable.

Table 4

Prioritization of zoonoses in Guyana with relevant prioritization criteria, total risk scores and ranking of each disease.

Prioritization Criteria	Ranking of Priority Zoonotic Diseases							
	Tuberculosis	Leptospirosis	Gastroenteritis	Rabies	Coronavirus	Orthopoxvirus	VHF viruses	Hepatitis
At risk sub-populations	2	3	3	1	5	2	2	2
Human to human transmission	4	2	2	1	5	1	4	2
Socioeconomic impact	3	2	3	2	5	2	3	3
Animal Prevalence	1	2	3	2	2	2	3	2
Human Prevalence	3	1	2	1	2	1	3	3
Case fatality rate	2	2	1	5	3	1	5	4
Is treatment available	1	1	1	4	3	5	5	3
R ₀ Number	2	1	2	1	3	2	3	2
Total Risk Score	18	14	17	17	28	16	28	21
RANKING	4	8	5	5	1	7	1	3

N.B The list of priority zoonotic diseases as agreed by the multisectoral group of national and international experts during the OHZDP workshop were coronavirus (including other respiratory viral pathogens e.g. avian/swine influenza virus), viral hemorrhagic fever (VHF) viruses (e.g. hantavirus, arenavirus, etc.), hepatitis (hepatitis A - G viruses), tuberculosis, rabies, gastroenteritis (bacterial and viral pathogens), orthopoxvirus (e.g. Monkey pox virus) and leptospirosis.

4.1. One health platform

This is the first reported attempt at One Health zoonotic disease prioritization in the Caribbean and in CARICOM territories. This One Health platform aims to integrate expertise from various sectors including animal, human, and environmental health to tackle zoonotic diseases collectively. By establishing a collaborative framework, Guyana can enhance surveillance, data collection, and decision-making processes to mitigate the risks posed by endemic and emerging zoonoses. The prioritization of zoonotic threats based on criteria such as case fatality rate and epidemic potential allows for a targeted approach to disease control and prevention.

In developing countries (e.g., Guyana), the problem of zoonotic diseases is often underestimated due to weak surveillance, poor awareness and a paucity of data. Traditional methods like the CDC method [10] would be challenging to implement in this country-specific context. The development of the criteria was influenced by known and future risks of social, political, economic and security impacts on human and animal health than by existing disease burden data. A One Health platform would create a positive change where more critical data is collected and utilized in a data-driven decision-making process to protect against animal, environmental and human health threats in Guyana.

4.2. Zoonotic disease transmission

Understanding the pathways of zoonotic disease transmission is essential for effective prevention strategies. In Guyana, practices such as hunting and consumption of wild meat pose significant risks for zoonotic spillover. Research on the role of wildlife in disease transmission and the impact of human behaviour on zoonotic outbreaks is crucial for developing targeted interventions. The One Health platform in Guyana facilitates cross-border collaboration to address migration-related risks and enhance preparedness against zoonotic threats. At present, there is an urgent need to extensively analyze practices that are linked to the transmission of zoonotic pathogens. An illustration of a possible pathway of pathogen exposure via hunted wildlife, can be observed among the native Waiwai Amerindian who face exposure hazards via cuts injuries during butchering of wild animals [23]. Participant observation revealed that hunting is integral to Waiwai identity and the Waiwai exhibit a cultural aversion to domestic meats. These findings provide valuable insights into the interplay of hunting, wild meat consumption and potential pathways of zoonotic transmission from wild meat in the Amazonia [23]. However, the drivers of transmission risk for zoonotic diseases from the hunting and consumption of wild meat in Amazonia remain understudied [24]. This lack of research is alarming

given that the region is a hot spot for zoonotic disease emergence [5], and a variety of zoonotic pathogens have been identified among important Amazonian subsistence species [25–27]. The OHZDP permits better facilitation of such research to fill in knowledge gaps to yield more effective surveillance and management of zoonotic risks.

4.3. OHZDP tool criteria and priority zoonoses

The resultant disease criteria from this OHZDP workshop in Guyana were supported by previous studies that presented similar criteria [28]. The top-ranking criterion was the case fatality rate or severity of disease in humans and this was reflected in OHZDP exercises in other countries [29–32]. This reflected the robustness and strength of the OHZDP tool and process, even in light of its flexibility. The impact of disease, epidemic potential (R_0) and transmission were other notable criteria found in other studies [29–32]. Of the eight (8) priority diseases during the workshop in Guyana were ranked top five (5) zoonoses using the CDC tool in 7 different countries (Thailand, Kenya, Ethiopia, Azerbaijan, Cameroon, South Africa, Democratic Republic of the Congo) and West African countries including rabies, tuberculosis, zoonotic influenza (listed under coronavirus) and VHF viruses [33]. Though endemic in Guyana, rabies is a notifiable illness in the Caribbean yet there are only 4 studies, with the most recent research conducted >35 years ago [34–36]. The vampire bat and the mongoose serve as the principal reservoir hosts for Caribbean sylvatic rabies. The vampire bat is the primary reservoir host in Trinidad and Tobago, Guyana, Suriname, Belize, and French Guiana [37]. The mongoose is the primary reservoir host in Grenada, Puerto Rico, and Cuba [37]. In São Paulo state of Brazil, rabies is found primarily in cattle and horses transmitted by vampire bats [38] confirming the interaction of these species in maintaining viral circulation. Brazil shares an extensive land border with Guyana and persons residing in region 9, Lethem in Guyana, travel across this border for medical treatment and services (Fig. 1). The inclusion of rabies as a national priority zoonotic disease should increase the pursuit of future rabies studies in Guyana to yield better data collection and assist cross-border surveillance.

Whereas with tuberculosis, another notifiable disease that is endemic in Guyana, more recent research has been conducted [39–41]. Tuberculosis has staged a resurgence as a cause of illness in the region, often as a co-infection with HIV, and is generally associated with outcomes of poverty, such as overcrowding, poor sanitation and low health expenditure per capita [101,102]. Gastroenteritis is a condition caused by bacterial and viral pathogens. There is a paucity of peer-reviewed studies on gastroenteritis research in Guyana [42]. One study in Amazonian children showed human bocavirus as a cause of both acute respiratory infections (ARI) and gastroenteritis [43]. Given the rate of movement across the Brazil/Guyana border, discussions ensued about vigilance on disease activity in Brazil to understand potential zoonotic threats that could spill over into Guyana from Brazil. This issue of migration was identified as a pivotal area where the One Health platform would benefit Guyana via cross-border collaboration in increasing preparedness and prevention against zoonotic threats. Of the selected priority zoonoses, the majority were endemic zoonotic diseases (rabies, tuberculosis and leptospirosis). The remaining are emerging zoonotic threats within the region, including coronavirus (zoonotic influenza, and other zoonotic viral respiratory diseases), VHF fevers, and hepatitis. The existence of migratory birds, backyard and commercial poultry systems, and differences in surveillance systems all contribute to Guyana and the Caribbean region's vulnerability to avian influenza (AI) [44,45].

4.4. Regional vulnerabilities

The Caribbean region, including Guyana, faces vulnerabilities to zoonotic diseases such as avian influenza due to factors like migratory birds and poultry systems. The limited understanding of zoonotic disease transmission practices in Guyana underscores the need for

comprehensive research and surveillance. By prioritizing zoonotic threats and fostering regional cooperation, countries can strengthen their capacity to respond to outbreaks and protect public health.

In Guyana, there is a very limited understanding of the practices and behaviors that constitute pathways of zoonotic disease transmission in the country. The role of wildlife in the transmission of zoonotic pathogens and the incidence of human diseases in the country necessitates extensive research to better understand the dynamics and factors involved. The SWM program has developed food safety methods to improve the quality of wild meat, reduce zoonotic risks and raise awareness about the zoonotic threat associated with contact with wild meat or wildlife in Guyana. This should allow better zoonotic risk management at the national level.

4.5. Limitations

There are limitations to this study, including the lack of national-level data regarding specific zoonotic diseases. This may have led to bias in the list of priority zoonoses toward public health and the Ministry of Health given the availability of data. These limitations, while acknowledged, were circumvented by engagement with academics, national, regional and international agencies to reflect on regional and global data. This study remains a transparent process to validate the prioritization of key zoonotic threats and determine their relative position with each other in the specific country context of Guyana.

4.6. Conclusion

The prioritization of eight (8) zoonotic diseases in Guyana through a One Health approach marks a significant step toward enhancing preparedness and prevention strategies. This is the first such effort for Guyana and additionally the Caribbean and CARICOM region. By identifying key zoonotic threats and promoting multisectoral collaboration, Guyana can better address the complex challenges posed by endemic and emerging diseases. Continued research, surveillance, and data-driven decision-making are essential for safeguarding human and animal health in the region.

Funding

The OHZDP workshop was funded as an activity which is part of the SWM Programme in Guyana, an Initiative of the Organization of African, Caribbean, and the Pacific States, which is funded by the European Union with co-funding from the French Development Agency (AFD).

CRedit authorship contribution statement

Kirk O. Douglas: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Govindra Punu:** Conceptualization, Data curation, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing. **Nathalie Van Vliet:** Funding acquisition, Project administration, Resources, Supervision, Validation, Writing – review & editing.

Declaration of competing interest

The authors declare that there are no known financial interest/personal relationships which may be considered as potential competing interest.

Data availability

The authors confirm that the data supporting the findings of this study are available within the article and/or its supplementary materials.

Acknowledgements

We are particularly thankful to the focal points of the SWM-One Health platform who participated in the zoonotic disease prioritization workshop and the Guyana Wildlife Conservation and Management Commission for their institutional support. This activity is part of the SWM Programme, an Initiative of the Organization of African, Caribbean, and the Pacific States, which is funded by the European Union with co-funding from the French Development Agency (AFD), implemented through a consortium partnership that includes the Centre for International Forestry Research (CIFOR), the Food and Agriculture Organization of the United Nations (FAO), Wildlife Conservation Society (WCS) and the French Agricultural Research Centre for International Development (CIRAD).

References

- [1] K.E. Jones, et al., Global trends in emerging infectious diseases, *Nature* 451 (7181) (2008) 990–993.
- [2] P.B. Jahrling, A.M. Marty, T.W. Geisbert, Viral hemorrhagic fevers, in: *Medical Aspects of Biological Warfare*, Office of the Surgeon General, United States Army, and Borden Institute, Walter Reed Army Medical Center, Washington, DC, 2007, pp. 271–310.
- [3] S. Wacheck, M. Fredriksson-Ahoma, M. König, A. Stolle, R. Stephan, Wild boars as an important reservoir for foodborne pathogens, *Foodborne Pathog. Dis.* 7 (3) (2010) 307–312.
- [4] T. Allen, et al., Global hotspots and correlates of emerging zoonotic diseases, *Nat. Commun.* 8 (1) (2017) 1124.
- [5] B.A. Han, A.M. Kramer, J.M. Drake, Global patterns of zoonotic disease in mammals, *Trends Parasitol.* 32 (7) (2016) 565–577.
- [6] L. Swift, P.R. Hunter, A.C. Lees, D.J. Bell, Wildlife trade and the emergence of infectious diseases, *EcoHealth* 4 (2007) 25–30.
- [7] A. Puran, E. Paemelae, R. Ali, Wildmeat consumption on the coast of Guyana, in: *28th International Congress for Conservation Biology (Cartagena, Colombia)*, 2017.
- [8] N. van Vliet, A. Puran, O. David, R. Nasi, From the forest to the coast: the wild meat trade chain on the Coast of Guyana, *Ethnobiol. Conserv.* 11 (2022).
- [9] N.D. Wolfe, et al., Naturally acquired simian retrovirus infections in central African hunters, *Lancet* 363 (9413) (2004) 932–937.
- [10] C.L. Rist, C.S. Arriola, C. Rubin, Prioritizing zoonoses: a proposed one health tool for collaborative decision-making, *PLoS One* 9 (10) (2014) e109986.
- [11] K.M. McIntyre, C. Setzkorn, P.J. Hepworth, S. Morand, A.P. Morse, M. Baylis, A quantitative prioritisation of human and domestic animal pathogens in Europe, *PLoS One* 9 (8) (2014) e103529.
- [12] V. Ng, J.M. Sargeant, A quantitative approach to the prioritization of zoonotic diseases in North America: a health professionals' perspective, *PLoS One* 8 (8) (2013) e72172.
- [13] C. Ihekweazu, et al., Prioritization of zoonotic diseases of public health significance in Nigeria using the one-health approach, *One Health* 13 (2021) 100257.
- [14] J. Zhang, Z. Jin, G.-Q. Sun, X.-D. Sun, S. Ruan, Modeling seasonal rabies epidemics in China, *Bull. Math. Biol.* 74 (5) (2012) 1226–1251.
- [15] W. Yates, A. Rehmulla, D. McIntosh, Porcine rabies in western Canada, *Can. Vet. J.* 24 (5) (1983) 162.
- [16] C.C. De Mattos, C.A. De Mattos, E. Loza-Rubio, A. Aguilar-Setiá, L.A. Orciari, J. S. Smith, Molecular characterization of rabies virus isolates from Mexico: implications for transmission dynamics and human risk, *Am. J. Trop. Med. Hyg.* 61 (4) (1999) 587–597.
- [17] A. Belotto, L. Leanes, M. Schneider, H. Tamayo, E. Correa, Overview of rabies in the Americas, *Virus Res.* 111 (1) (2005) 5–12.
- [18] Y. Ali, K. Intisar, H. Wegdan, E. Ali, Epidemiology of rabies in Sudan, *J. Anim. Vet. Adv.* 5 (2006) 266–270.
- [19] Y. Ma, C. Horsburgh, L.F. White, H.E. Jenkins, Quantifying TB transmission: a systematic review of reproduction number and serial interval estimates for tuberculosis, *Epidemiol. Infect.* 146 (12) (2018) 1478–1494.
- [20] D. Baca-Carrasco, D. Olmos, I. Barradas, A mathematical model for human and animal leptospirosis, *J. Biol. Syst.* 23 (supp01) (2015) S55–S65.
- [21] N.R. Smoll, A. Khan, J. Walker, J. McMahon, M. Kirk, G. Khandaker, A norovirus gastroenteritis outbreak in an Australian child-care center: a household-level analysis, *PLoS One* 16 (11) (2021) e0259145.
- [22] Z. Mukandavire, S. Liao, J. Wang, H. Gaff, D.L. Smith, J.G. Morris Jr., Estimating the reproductive numbers for the 2008–2009 cholera outbreaks in Zimbabwe, *Proc. Natl. Acad. Sci.* 108 (21) (2011) 8767–8772.
- [23] M.S. Milstein, et al., An ethnographic approach to characterizing potential pathways of zoonotic disease transmission from wild meat in Guyana, *EcoHealth* 17 (2020) 424–436.
- [24] P. Mayor, H. Bizri, R.E. Bodmer, M. Bowler, Reproductive biology for the assessment of hunting sustainability of rainforest mammal populations through the participation of local communities, *Conserv. Biol.* 1 (2016) 1.
- [25] E. Voltarelli, S. Arraes, M. Lonardoni, U. Teodoro, T. Silveira, Serological survey for *Leishmania* sp. infection in wild animals from the municipality of Maringá, Paraná state, Brazil, *J. Venom. Anim. Toxins Trop. Dis.* 15 (2009) 732–744.
- [26] A.C. Yamakawa, et al., Serosurvey of *Toxoplasma gondii* and *Leptospira* spp. in free-range agoutis (*Dasyprocta azarae*) from an urban area of southern Brazil, *J. Wildl. Dis.* 56 (2) (2020) 472–474.
- [27] I. Ferreira, et al., Hepatitis E virus (HEV) infection in captive white-collared peccaries (*Pecari tajacu*) from Uruguay, *Transbound. Emerg. Dis.* 68 (3) (2021) 1040–1045.
- [28] V. Ng, J. Sargeant, Prioritizing zoonotic diseases: differences in perspectives between human and animal health professionals in North America, *Zoonoses Public Health* 63 (3) (2016) 196–211.
- [29] S. Muhemedi, J. Masumu, L. Lubula, P. Kabambi, E. Okitolonda, Prioritization of zoonotic diseases in the Democratic Republic of the Congo, 2016, *J. Zoonot. Dis. Publ. Health iMedPub* 2 (2018).
- [30] E.G. Pieracci, et al., Prioritizing zoonotic diseases in Ethiopia using a one health approach, *One Health* 2 (2016) 131–135.
- [31] P. Munyua, et al., Prioritization of zoonotic diseases in Kenya, 2015, *PLoS One* 11 (8) (2016) e0161576.
- [32] K.A. Kheirallah, et al., Prioritizing zoonotic diseases utilizing the one health approach: Jordan's experience, *One Health* 13 (2021) 100262.
- [33] X. Wang, et al., Using a one health approach to prioritize zoonotic diseases in China, 2019, *PLoS One* 16 (11) (2021) e0259706.
- [34] H. Reid, Outbreak of cattle rabies in the north west region of Guyana, *Vet. Rec.* 117 (24) (1985) 641.
- [35] B. Nehaul, Rabies transmitted by bats in British Guiana, *Am. J. Trop. Med. Hyg.* 4 (3) (1955) 550–553.
- [36] B. Nehaul, A.E. Dyrting, An outbreak of rabies in man in British Guiana, *Am. J. Trop. Med. Hyg.* 14 (2) (1965) 295–296.
- [37] J.F. Seetahal, et al., Rabies in the Caribbean: a situational analysis and historic review, *Trop. Med. Infect. Dis.* 3 (3) (2018) 89.
- [38] F. Mayen, Haematophagous bats in Brazil, their role in rabies transmission, impact on public health, livestock industry and alternatives to an indiscriminate reduction of bat population, *J. Veterinary Med. Ser. B* 50 (10) (2003) 469–472.
- [39] B. Alladin, et al., Tuberculosis and diabetes in Guyana, *Int. J. Infect. Dis.* 15 (12) (2011) e818–e821.
- [40] R. Kurup, K. Flemming, S. Daniram, S. Marks-James, R. Roberts Martin, Hematological and biochemistry profile and risk factors associated with pulmonary tuberculosis patients in Guyana, *Tuberc. Res. Treatm.* 2016 (2016).
- [41] E. Streit, S. Baboolal, P.E. Akpaka, J. Millet, N. Rastogi, Finer characterization of mycobacterium tuberculosis using spoligotyping and 15-loci MIRU-VNTRs reveals phylogeographical specificities of isolates circulating in Guyana and Suriname, *Infect. Genet. Evol.* 30 (2015) 114–119.
- [42] S. Persuad, P. Mohamed-Rambaran, A. Wilson, C. James, L. Indar, Determining the community prevalence of acute gastrointestinal illness and gaps in surveillance of acute gastroenteritis and foodborne diseases in Guyana, *J. Health Popul. Nutr.* 31 (4 Suppl 1) (2013) S57.
- [43] G.A.A. Leitão, et al., Human Bocavirus genotypes 1 and 2 detected in younger Amazonian children with acute gastroenteritis or respiratory infections, respectively, *Int. J. Infect. Dis.* 95 (2020) 32–37.
- [44] V. Gongora, et al., The Caribbean animal health network: new tools for harmonization and reinforcement of animal disease surveillance, *Ann. N. Y. Acad. Sci.* 1149 (1) (2008) 12–15.
- [45] M. Laurent, et al., Fighting Cocks Industry in the Caribbean: Awareness and Role of the Veterinary Services, 2012.