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Identifying Gaps in the Zoonotic Disease Burden of Central America

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2017

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Abstract

Identifying Gaps in the Zoonotic Disease Burden of Central America

By Megan Taylor

Background: CDC's One Health Zoonotic Disease Prioritization (OHZDP) Process brings together representatives from human, animal, and environmental health sectors to prioritize zoonotic diseases of greatest concern and to develop next steps to address these priorities. To prepare for these prioritizations, CDC's One Health Office maintains a global zoonotic disease burden database and is developing regional zoonotic disease burden databases to support locations conducting OHZDP workshops to have readily available data on zoonotic diseases and identify gaps in zoonotic disease burden in their region.

Objectives: The goal of this project was to develop a regional zoonotic disease burden database for Central America for use during CDC's OHZDP Process and to identify gaps in the zoonotic disease burden across Central America.

Methods: A list of zoonotic diseases was created by collating zoonotic disease lists from previous OHZDP workshops, along with reviewing recent zoonotic disease literature for Central America in PubMed and Scopus. CDC's One Health Office's Excel™-based global zoonotic disease burden database was adapted for Central America. A structured data and literature review were conducted for zoonotic disease impacts on humans and animals in the region. Information collected, including data gaps, was assessed, and summarized and profiles for each country in the region were developed.

Results: The database included data on 45 zoonotic diseases in Central America. Data was identified for 387 of 2,160 cells (18%). Most data were found from GIDEON, PAHO, ProMed and GHDx. Human prevalence and incidence data made up most of the database, along with human mortality data.

Discussion: Due to the lack of data identified publicly, it was difficult to assess the zoonotic disease burden across the Central America region. Human surveillance data for some zoonotic diseases are being published publicly on a routine basis; however, there was limited information publicly available on the animal health side. To effectively prepare for OHZDP workshops in the region, it is imperative to collaborate with human, animal, and environmental health ministries to incorporate additional data into these databases for a more complete assessment of zoonotic disease burden in the region.

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Chapter 1: Introduction

Zoonotic Disease Overview

Zoonotic diseases are caused by pathogens that spread between animals and humans. There is a wide variety of pathogens that cause zoonotic diseases including bacteria, viruses, fungi, and parasites [1]. More than half of human pathogens are zoonotic in origin[2]. Zoonoses contribute to human illnesses ranging from mild to severe and even fatal[3]. As globalization and the use of non-human animal products for food, agriculture, and trade increase, the human population is more vulnerable to the spread of zoonotic diseases.

Zoonotic diseases can be transmitted through direct or indirect contact. Direct contact often occurs through animal bites such as with rabies virus but can also occur through exposure to respiratory droplets in the case of avian influenza[3]. An example of indirect transmission is vector borne zoonoses like the Zika virus that can be spread through the bite of an infected mosquito. Zoonoses can also be transmitted to people through contaminated food or water. Foodborne zoonotic pathogens are usually introduced to humans due to improper handling of animals through lack of hygiene or eating undercooked meats[3]. Most zoonotic diseases are caused by bacteria and both Gram-negative and Gram-positive bacteria can contribute to zoonotic infections[3]. In terms of viral zoonoses, RNA viruses are often more responsible for zoonotic infections, but DNA viruses are also the cause of some zoonotic diseases[4].

Various animal species, including domestic and wild animals, have the potential to spread zoonotic diseases. In one study, it was found that on average 14%-62% of pet owners allow their dogs and cats on their beds, which is one risk factor that may further the emergence of zoonotic diseases[5.] As the popularity of owning exotic pets along with common pets has increased, so has the risk of zoonotic infection[3]. The emergence of new zoonotic diseases as well as the re-

emergence of previous zoonoses, can also be due to the increased proximity of humans to animals, including wildlife; wild animals are a major source of pathogens that can cause emerging and re-emerging zoonotic diseases[6]. It has been estimated that 60.3% of emerging diseases are zoonotic and of those, 71.8% are from wildlife[7]. Infectious diseases can be easily transmitted from wild animals because they are so closely linked to humans, domestic animals, and the environment[8]. The loss of biodiversity and increase in globalization due to land-use change can contribute to the emergence of new zoonotic diseases[9-11].

Zoonotic Disease Impact

It is evident that zoonoses present a huge global disease burden. While additional efforts to quantify the burden of zoonotic diseases are needed, this burden has been evaluated through measurements such as disease incidence, prevalence, morbidity, mortality and economic cost[12]. People who become ill from zoonotic disease infections may have to take time off from work which could prevent them from providing for their families leading to economic impacts[3]. Many bacterial zoonoses, like bartonellosis and campylobacteriosis, can result in chronic conditions which can increase medical expenditures[13]. There are also large economic losses that result from failure to control zoonotic diseases. In an analysis of six zoonotic disease outbreaks from 1997 to 2009, the estimated total cost was $80 billion. It was determined that had the outbreaks been prevented, the evaded costs would have been about $6.7 billion per year[14]. The economic losses from zoonotic diseases often disproportionately affect developing countries. In the case of Echinococcosis, the yearly economic burden in developing countries is a loss of $2 billion in livestock and 1.5 million human healthy life-years[14].

Additionally, antimicrobial resistance is a major outcome of zoonotic diseases. Antimicrobials are used to treat diseases in both humans and animals, which can cause resistant

pathogens to arise. Resistant pathogens can then be spread between animals and people and in turn increase resistant infections[3,15]. Zoonotic diseases can also impact food security, since decreases in food supply due to the loss of livestock from zoonotic diseases influence human health and nutrition. This also has large financial consequences for farmers and can diminish international trade[3]. These financial consequences for farmers due to zoonotic disease outbreaks can also have large mental health impacts. During a 2003 avian flu epidemic in the Netherlands, one third of poultry farmers dealt with stress, fatigue, and depression and these conditions were more frequent among farmers than the general population[16]. A 2020 study found that frontline workers tasked with culling to control animal diseases in South Korea had high rates of depression and 74.5% showed evidence of post-traumatic stress disorder (PTSD)[17].

Overall zoonotic diseases have a substantially negative impact on the global economy. Currently, the COVID-19 pandemic has contributed to enormous economic losses across all industries including health, travel, education, sports, entertainment, hospitality and finance[18]. The production of goods has been suspended on a global scale from potential decreases in raw materials which has greatly affected supply-chains[19]. According to the World Bank, most countries are expected to face COVID-19 related recessions and many people will have to deal with severe poverty[20]. Preventing and controlling zoonotic disease threats is crucial due to their impacts on people, animals, and the environment.

One Health

During the 1800s, scientists noted the links between human and animal health. In 1964, Dr. Calvin Schwabe coined the term “One Medicine” to describe the similarities between human and animal medicine and the importance of cooperation between the fields to prevent diseases common to both disciplines. By 2007, the One Health approach was recommended at the

International Ministerial Conference on Avian and Pandemic Influenza for countries to prepare for pandemics[21]. One Health is defined by the Centers for Disease Control and Prevention (CDC) and the One Health Commission as "a collaborative, multisectoral, and trans-disciplinary approach - working at local, regional, national, and global levels - to achieve optimal health (and well-being) outcomes recognizing the interconnections between people, animals, plants and their shared environment"[22,23]. Cooperation among these different disciplines will allow for better utilization of resources in the response to emerging and re-emerging pathogens, quantifying the zoonotic disease burden, and initiating effective disease prevention strategies. Implementing the One Health approach on a global scale is necessary to support zoonotic disease detection and response efforts to prevent further outbreaks, epidemics, and pandemics[24].

CDC One Health Office

The U.S. Centers for Disease Control and Prevention's (CDC) One Health Office is located within the National Center for Emerging and Zoonotic Infectious Diseases in Atlanta, Georgia, was established in 2009. CDC's One Health Office was the first formal office dedicated to One Health within the U.S. Government, the purpose of the One Health Office is to increase domestic and global knowledge of the concept of One Health and to protect the health of humans, animals, and the environment. The office collaborates with health partners across One Health sectors at the international level as well as within the United States. One Health Office staff have a notable working relationship with international organizations like the World Health Organization (WHO), World Organisation for Animal Health (OIE), and the Food and Agriculture Organization of the United Nations (FAO)[25].

The One Health Office is active in zoonotic disease education through the Zoonoses Education Coalition (ZEC), which is a public-private partnership to facilitate the dissemination

of messages to the public to foster a better understanding of zoonotic disease risk and prevention when handling pets. After multiple outbreaks of influenza, the One Health Office played a role in the development of the Influenza and Zoonoses Education Among Youth in Agriculture program to promote zoonotic disease education in agricultural communities throughout rural areas of the United States. Additionally, the One Health Office develops guidance and recommendations for zoonotic disease prevention and control, in collaboration with many partners including the National Association of State Public Health Veterinarians (NASPHV).

The CDC One Health Office also works globally and domestically to develop tools and trainings to advance One Health. They also encourage the use of the One Health approach globally through its zoonotic disease prioritization process[26].

CDC One Health Zoonotic Disease Prioritization

The CDC One Health Office developed the One Health Zoonotic Disease Prioritization (OHZDP) Process in 2014 to support countries and regions to prioritize zoonotic diseases of greatest concern. The OHZDP process includes participants from human, animal, and environmental health sectors along with other representatives to promote collaboration among One Health partners in the specific region, country, or other areas. The aims of these workshops are to use a multisectoral approach to create a priority zoonotic disease list for the country or region and to determine the next steps to address those diseases[27].

The OHZDP workshops operate by identifying a group of voting members from across all One Health sectors so that there is equal representation in determining the prioritized zoonotic disease list. Representatives from the different One Health sectors serve as neutral, trained facilitators to assist in disease prioritization. Advisors from different organizations that participate in zoonotic disease work are brought in to lend their expertise to voting members as

well as to provide post-workshop support. Through including these specific people, the overall process is relevant to the local context. Additionally, the various steps that are involved in developing the priority zoonotic disease list include using local data to assess zoonotic disease burden. The OHZDP workshops result in a full formal report for the country or region[27].

Project Purpose

To support the preparation for these OHZDP workshops, CDC's One Health Office maintains a global zoonotic disease burden database and has initiated the development of regional zoonotic disease databases to support locations conducting OHZDP workshops and to identify gaps in zoonotic disease burden. The goal of this project was to develop a region-specific zoonotic disease burden database for Central America for the CDC One Health Office's OHZDP Process. This database will serve as a resource for countries within the region to make informed and data-driven decisions on zoonotic disease burden in Central America when prioritizing zoonotic diseases through the OHZDP Process.

Chapter 2: Methods

In order to develop a region-specific zoonotic disease burden database for Central America, there were multiple components that needed to be considered before the data collection process could occur. The first step was to identify which zoonotic diseases were going to be included in the database. The next step was to identify which variables were going to be searched for each zoonotic disease. Once these two steps were concluded, the literature and data review processes were undertaken. Below are the methods for each step of the development of this Central America Zoonotic Disease Burden Database.

Zoonotic Disease Selection

A list of 45 zoonotic diseases was compiled using zoonotic disease lists considered for prioritization from previous OHZDP workshops[28]. Zoonotic diseases from these lists were cross checked for the Central America region by conducting literature searches in PubMed and Scopus. The initial search terms used included "zoonotic diseases AND Central America". Specified searches were also conducted and used the string: ((Disease Terms)) AND ((Central America)). The literature search criteria included English language publications from the last 10 years. Articles were scanned for zoonotic diseases most relevant to the region. The final list is described in Table 1.

Database Development

The CDC One Health Office for global zoonotic disease burden database, which is built in Microsoft Excel™, was adapted for the specific Central American region. The database was formatted to collect publicly available zoonotic disease data from the countries of Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama. Data for the following variables was included for each of the zoonotic diseases identified in these countries: human prevalence, human incidence, human mortality, animal prevalence, animal incidence, animal mortality, last documented human outbreak, and last documented animal outbreak. The database template that was used is provided in the Appendix (Table 1).

Data and Literature Review

Database cells were filled with appropriate zoonotic disease-specific information for humans and animals in the Central America region through data and literature reviews of public sources. Data was collected from October 15, 2021 through January 9, 2022. Information was gathered from the CDC, the Pan American Health Organization (PAHO), the World Health

Organization (WHO) as well as the following sources to identify as much data in as many variables as possible.

1. Global Health Data Exchange Global Burden of Disease Results Tool http://ghdx.healthdata.org/gbd-results-tool
2. World Organization for Animal Health World Health Information System https://wahis.oie.int/#/home
3. Food and Agriculture of the United States Global Animal Disease Information System https://empres-i.review.fao.org/#/
4. International Society for Infectious Diseases ProMEd https://promedmail.org/
5. Global Infectious Disease and Epidemiology Network https://app-gideononline-com.proxy.library.emory.edu/start

After reviewing the above sources, literature searches were conducted in PubMed, Scopus, the Virtual Health Library Regional Portal, and the World Organisation for Animal Health's Documentary Portal to fill in any remaining gaps. The Virtual Health Library Regional Portal was used to find potential sources in Spanish. Articles searched among these databases were limited to the last 10 years with no language filter. Initial search strings included ((Disease Terms)) AND ((Country or Region)) AND ((variables)). For example, ((Anthrax)) AND ((Costa Rica)) AND ((mortality)). Resulting articles were reviewed by conducting a title and abstract screen to determine relevancy of information. Information from these articles were included if they included information on any of the variables previously listed. If there was a lack of relevant results, more specific search strings were used. A list of sample search strings can be

found below. If after searching through the resources and the literature and no information was found for a certain variable it was defined as “no data identified” in the cell.

Sample Search Strings

((Disease terms)) AND ((Country)) AND ((human)) AND ((prevalence) or (incidence))

((Disease terms)) AND ((Country)) AND ((human)) AND ((mortality))

((Disease terms)) AND (Country)) AND ((animal) OR (domestic animal) OR (livestock) OR (cattle) OR (bovine) OR (poultry) OR (chicken) OR (sheep) OR (goat) OR (bovine) OR (caprine) OR (pig) OR (swine) OR (porcine) OR (horse) OR (equine) OR (dog) OR (canid) OR (canine) OR (cat) OR (feline) OR (felid) OR (companion animal) OR (pet)) OR ((wildlife) OR (wild animal) OR (feral) OR (exotic) OR (rodent) OR (bird) OR (avian) OR (fish) OR (bats) OR (primate)) AND ((incidence) OR (prevalence))

((Disease terms)) AND (Country)) AND ((animal) OR (domestic animal) OR (livestock) OR (cattle) OR (bovine) OR (poultry) OR (chicken) OR (sheep) OR (goat) OR (bovine) OR (caprine) OR (pig) OR (swine) OR (porcine) OR (horse) OR (equine) OR (dog) OR (canid) OR (canine) OR (cat) OR (feline) OR (felid) OR (companion animal) OR (pet)) OR ((wildlife) OR (wild animal) OR (feral) OR (exotic) OR (rodent) OR (bird) OR (avian) OR (fish) OR (bats) OR (primate)) AND ((mortality))

((Disease terms)) AND ((Country)) AND ((human)) AND ((outbreak) OR (epidemic))

((Disease terms)) AND (Country)) AND ((animal) OR (domestic animal) OR (livestock) OR (cattle) OR (bovine) OR (poultry) OR (chicken) OR (sheep) OR (goat) OR (bovine) OR (caprine) OR (pig) OR (swine) OR (porcine) OR (horse) OR (equine) OR (dog) OR (canid) OR (canine) OR (cat) OR (feline) OR (felid) OR (companion animal) OR (pet)) OR ((wildlife) OR (wild animal) OR (feral) OR (exotic) OR (rodent) OR (bird) OR (avian) OR (fish) OR (bats) OR (primate)) AND ((outbreak) OR (epidemic))

Citing Data Available

Throughout the literature review process, data from both gray and published literature were included in the database. Data points were cited using American Psychological Association (APA) style. In-text format was used in individual cells while full citations were included in a separate column. If duplicate articles were found across sources, they were cited from the source in which they were first identified. It was necessary to cite and reference each data value so that future users of the database can identify what is most important for their local context.

Country Vignettes

After the database was finalized, data and their information sources were reviewed and summarized across each disease, variable, and country. General trends for the entire database were indicated. Country specific profiles were developed highlighting gaps in data and the number of articles found through literature searches.

Chapter 3: Results

Zoonotic Diseases Included for Central America

The Central America Zoonotic Disease Burden Database included 45 zoonotic diseases (Table 1). This zoonotic disease list included 17 bacterial diseases, 14 viral diseases, 10 parasitic diseases, 3 fungal diseases, and 1 caused by prions.

Table 1: Zoonotic Disease List

Zoonotic Disease	**Etiologic Agent**
Bacteria	
Anthrax	*Bacillus anthracis*
Bartonellosis	*Bartonella spp.*
Borreliosis	*Borellia spp.*
Brucellosis	*Brucella abortus, Brucella melitensis, Brucella suis*
Campylobacteriosis	*Campylobacter jejuni, Campylobacter psittaci*
Colibacillosis	*Escherichia coli*
Ehrlichiosis	*Ehrlichia spp.*
Leptospirosis	*Leptospira spp.*
Listeriosis	*Listeria monocytogenes*
Q fever	*Coxiella burnetii*
Rickettsiosis	*Rickettsia africae, Rickettsia aeschlimanni, Rickettsia conori*
Salmonellosis	*Salmonella spp.*
Typhus (endemic)	*Rickettsia typhi*
Typhus (epidemic)	*Rickettsia prowazekii*
Typhus (scrub)	*Orientia tsutsugamushi*
Yersiniosis	*Yersinia enterocolitica*
Zoonotic Tuberculosis	*Mycobacterium bovis*
Viruses	
Avian Influenza	Influenza A virus
Chikungunya	Chikungunya virus
Dengue	Dengue virus
Eastern Equine Encephalitis	Eastern equine encephalitis virus
Hantavirus	Hantavirus
Hepatitis E	Hepatitis E virus
Rabies	Rabies virus
COVID-19	SARS-CoV-2
Swine influenza	Influenza A virus
Venezuelan Equine Encephalitis	Venezuelan equine encephalitis virus
Western Equine Encephalitis	Western equine encephalitis virus
West Nile Fever	West Nile virus
Yellow Fever	Yellow fever virus
Zika	Zika virus
Parasites/Protozoa	

Chaga's Disease	*Trypanosoma cruzi*
Cryptosporidiosis	*Cryptosporidium spp.*
Cysticercosis	*Taenia saginatum, Taenia solium*
Echinococcosis	*Echinococcosis*
Fascioliasis	*Fasciola hepatica*
Giardiasis	*Giardia lamblia*
Leishmaniasis	*Leishmania spp.*
Toxocariasis	*Toxocara canis, Toxocara cati*
Toxoplasmosis	*Toxoplasma gondii*
Trichinosis	*Trichinella spp.*
Fungi	
Coccidioidomycosis	*Coccidioides spp.*
Cryptococcosis	*Cryptococcus neoformans, Cryptococcus gattii*
Histoplasmosis	*Histoplasma capsulatum*
Prions	
Bovine spongiform encephalopathy	Prions

Central America Zoonotic Disease Burden Database

Central America

There was a total of 2,160 cells within the database. Data were found for 387 (18%) cells across the database. In general, public data across the diseases and variables of interest were lacking. Zoonotic diseases that resulted in no data identified across all variables are described in country vignettes below and are summarized in Table 2. The majority of data identified came from GIDEON, PAHO, ProMEd and GHDx. The number of data points for each country by source are included in Appendix: Tables 2-8. Human prevalence and incidence data made up most of the database, along with human mortality data. Estimates for human prevalence, human incidence, and human mortality were found for hepatitis E, rabies, yellow fever, zika, Chaga's disease, cysticercosis, leishmaniasis, and dengue from GHDx for most countries. Zoonotic diseases that had the most recent and available human data included chikungunya, dengue, SARS-CoV-2, and zika. Animal mortality data was only found for 2 countries for different

zoonotic diseases and was at least 5 years old. Data collected for last documented outbreaks were sporadic and a majority was only present on the human side.

Belize

After searching the data available for Belize, no data were identified across all variables for the following zoonotic diseases: borreliosis, bovine spongiform encephalopathy, coccidioidomycosis, colibacillosis, cryptococcosis, cryptosporidiosis, echinococcosis, ehrlichiosis, fascioliasis, hantavirus, listeriosis, Q fever, typhus (endemic, epidemic, and scrub), and western equine encephalitis.

There were no zoonotic diseases that resulted in the identification of data across all variables for Belize.

There was a total of 3 articles found through PubMed that provided data appropriate for the variables of interest.

Costa Rica

After searching the data available for Costa Rica, no data were identified across all variables for the following zoonotic diseases: avian influenza, bovine spongiform encephalopathy, cryptococcosis, cryptosporidiosis, echinococcosis, Q fever, trichinosis, typhus (epidemic and scrub), western equine encephalitis, yersiniosis, and zoonotic tuberculosis.

Rabies was the only disease that included data across all variables for Costa Rica.

There was a total of 12 articles found through PubMed that provided data appropriate for the variables of interest.

El Salvador

After searching the data available for El Salvador, no data were identified across all variables for the following zoonotic diseases: bartonellosis, borreliosis, bovine spongiform

encephalopathy, campylobacteriosis, coccidioidomycosis, colibacillosis, cryptococcosis, cryptosporidiosis, echinococcosis, ehrlichiosis, fascioliasis, hantavirus, Q fever, rickettsiosis, toxocariasis, trichinosis, typhus (endemic, epidemic, and scrub), Venezuelan equine encephalitis, western equine encephalitis, yersiniosis, and zoonotic tuberculosis.

There were no zoonotic diseases that resulted in the identification of data across all variables for El Salvador.

There was a total of 3 articles found through PubMed that provided data appropriate for the variables of interest.

Guatemala

After searching the data available for Guatemala, no data were identified across all variables for the following zoonotic diseases: borreliosis, bovine spongiform encephalopathy coccidioidomycosis, Eastern equine encephalitis, echinococcosis, ehrlichiosis, fascioliasis, hantavirus, listeriosis, Q fever, toxocariasis, trichinosis, typus (endemic and scrub),
West Nile fever, western equine encephalitis, yersiniosis, and zoonotic tuberculosis, in searches for Guatemala.

There were no zoonotic diseases that resulted in the identification of data across all variables for Guatemala.

There was a total of 9 articles found through PubMed that provided data appropriate for the variables of interest.

Honduras

After searching the data available for Honduras, no data were identified across all variables for the following zoonotic diseases: avian influenza, bartonellosis, borreliosis, bovine spongiform encephalopathy, campylobacteriosis, coccidioidomycosis, colibacillosis, eastern

equine encephalitis, echinococcosis, ehrlichiosis, fascioliasis, hantavirus, listeriosis, Q fever, rickettsiosis, toxoplasmosis, trichinosis, typhus (endemic, epidemic and scrub), West Nile fever, western equine encephalitis, and yersiniosis.

There were no zoonotic diseases that resulted in the identification of data across all variables for Honduras.

There was a total of 7 articles found through PubMed that provided data appropriate for the variables of interest.

Nicaragua

After searching the data available for Nicaragua, no data were identified across all variables for the following zoonotic diseases: avian influenza, bartonellosis, borreliosis, bovine spongiform encephalopathy campylobacteriosis, coccidioidomycosis, colibacillosis, cryptococcosis, eastern equine encephalitis, echinococcosis, fascioliasis, hantavirus, toxocariasis, trichinosis, typhus (endemic, epidemic and scrub), West Nile fever, western equine encephalitis, yersiniosis, and zoonotic tuberculosis.

There were no zoonotic diseases that resulted in the identification of data across all variables for Nicaragua.

There was a total of 14 articles found through PubMed that provided data appropriate for the variables of interest.

Panama

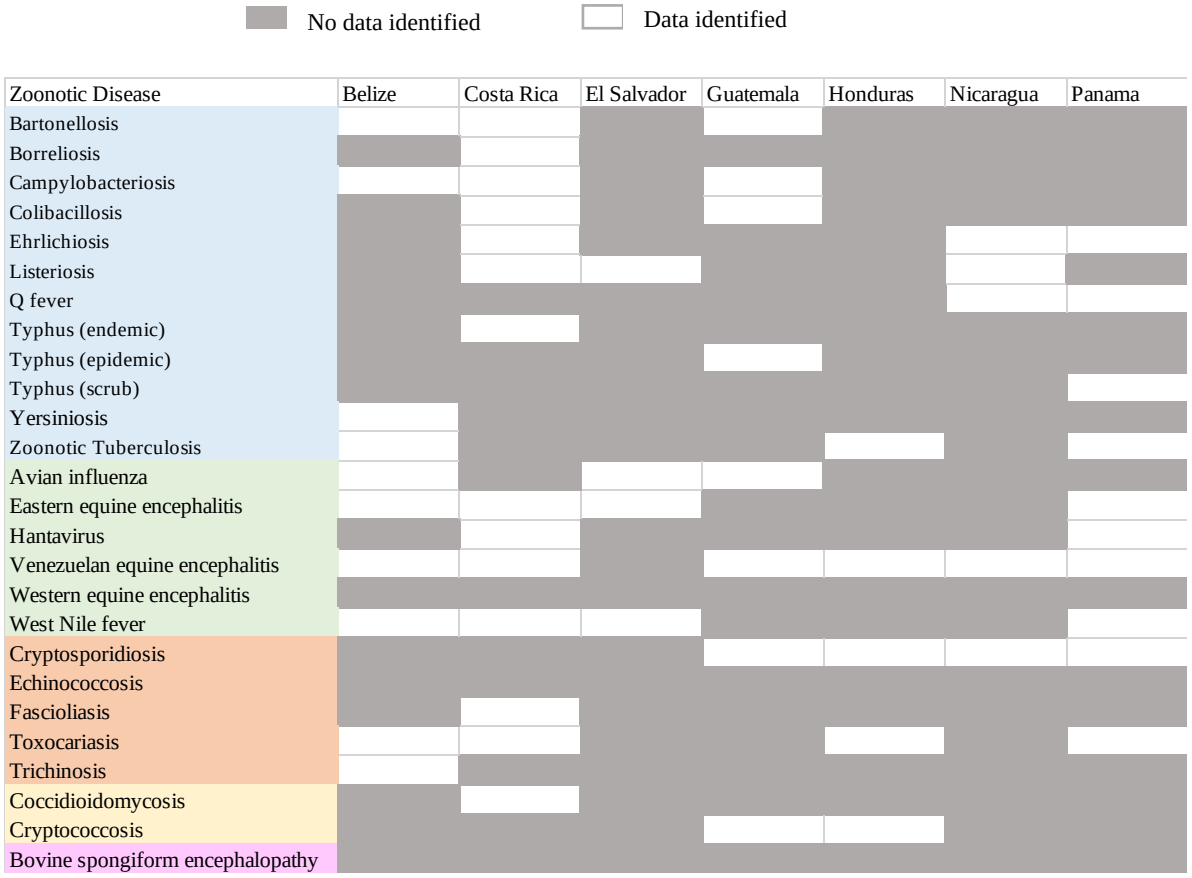
After searching the data available for Panama, no data were identified across all variables for the following zoonotic diseases: avian influenza, bartonellosis, borreliosis, bovine spongiform encephalopathy, campylobacteriosis, coccidioidomycosis, colibacillosis,

cryptococcosis, echinococcosis, fascioliasis, listeriosis, trichinosis, typhus (endemic and epidemic), western equine encephalitis, and yersiniosis.

There were no zoonotic diseases that resulted in the identification of data across all variables for Panama.

There was a total of 15 articles found through PubMed that provided data appropriate for the variables of interest.

Table 2: List of zoonotic diseases with no available data across all variables by country



Literature Searches

There were 54 articles that were included in the database from PubMed. PubMed was the initial search engine used. Some of those articles contained data points for multiple countries, diseases, or variables. After performing literature searches through other search engines, duplicate or no new relevant articles were found. Duplicates were marked as being drawn from PubMed. While also conducting literature searches, repeat articles were found that were referenced in GIDEON and ProMed. Those were counted as being sourced from GIDEON or ProMed rather than PubMed.

Utilizing specified search strings resulted in notable narrowing of appropriate articles. For example, a search of (Costa Rica) in PubMed yielded 5,202 resulting articles limited to the last 10 years. A search of (leptospirosis) in PubMed gave 3,123 articles limited to the last 10 years. Solely searching (human prevalence) limited to the last 10 years gave 1,393,084 articles. Searching ((Costa Rica) and (leptospirosis)) resulted in 10 articles limited to the last 10 years. A search of ((Costa Rica) and (leptospirosis) and (human prevalence)) gave 7 results. Three of those 7 articles had information relevant to this zoonotic disease burden database. The same search string used in Scopus resulted in 3 articles, 2 of which were repeated from PubMed and 1 that was provided in GIDEON. In searching the Virtual Health Library Regional Portal with the same search string, 6 articles were found. All 6 of those articles were repeated in PubMed.

Chapter 4: Discussion

The aim of this project was to create a zoonotic disease burden database for Central America that can be utilized to support the CDC's One Health Office OHZDP workshops to assess the burden of zoonotic diseases in Central America. While a database was produced, the scarcity of publicly available data for the region created a major limitation and made it difficult

to properly assess the actual zoonotic disease burden within the region. For zoonotic diseases and variables where no data were identified, it cannot be determined whether the zoonotic disease is not circulating in the region or country, if surveillance is not being conducted for those zoonotic diseases, or if the data is just not publicly available.

Another important limitation is that the data search did not include a comprehensive search of all Spanish language publications. Spanish is the official language for all seven countries in Central America region. Not all relevant surveys, case reports, clusters, or outbreaks related to One Health and published in Spanish in national and/or regional journals were available to our efforts to compile this database.

However, there are some relevant inferences that can be made about the zoonotic disease data identified for Central America. It is evident that routine surveillance on the human side for chikungunya, dengue, SARS-CoV-2, and zika does occur in the Central American region. The database does not provide information about completeness of surveillance for these diseases in each country. Reports are published through PAHO on a weekly basis for chikungunya, dengue, and zika[29-31]. Currently, SARS-CoV-2 data is being reported daily [32]. The number of cases, incidence rates, number of deaths, and last documented outbreaks in humans were found in each country for those zoonotic diseases from these PAHO reports.

In terms of the quality of data found for other zoonotic diseases, concrete statistical values were limited. Human prevalence and incidence data mostly included seroprevalence surveys of specific populations rather than general prevalence or incidence rates for the country. While these seroprevalences of specific populations were included in the database when available, this data is not generalizable to the overall population because it is necessary to consider the context of the study population[33]. For example, in Panama the seroprevalence of

spotted fever group rickettsiosis was found to be 29-31% in people from rural areas[34]. If a similar seroprevalence survey was undertaken for people from a more urban environment, it would likely be lower due to the anticipated less frequent exposure to tick bites. When human mortality data was identified, it was usually presented as number of deaths as opposed to a mortality or fatality rate. In order for this to be used within an OHZDP workshop, data need to be consistently collected across zoonotic diseases. When these types of data are found for use during the OHZDP workshops, participants would then need to conduct separate calculations to enable comparisons across diseases in a standardized manner. The animal prevalence and incidence data contained a range of estimated prevalence, seroprevalence, or case counts for different animal species across countries depending on methods of study.

The irregularity of the data identified for this database is concerning when these data points should ideally be standardized for the OHZDP workshops. Without further information about the status of these zoonotic diseases in Central America, it would be difficult to rely on this database for the OHZDP consultative end evidence-based decision-making processes. On a larger scale, this database identified important gaps in the publication of surveillance data on animals with zoonotic diseases in the region. The paucity of publicly available data for the animal populations in the region suggests the absence of active surveillance for zoonotic diseases in animals among the various countries in the region. This lack of important information could lead to a failure to identify zoonotic disease outbreaks among animals which could eventually spread into the human population.

Another aspect highlighted by this database is the scarcity of data for the neglected tropical zoonoses included in our disease list. There are currently twenty different neglected tropical diseases recognized by the World Health Organization. Those evaluated in this database

included Chaga's disease, coccidioidomycosis, chikungunya, cryptococcosis, cysticercosis, dengue, echinococcosis, fascioliasis, histoplasmosis, leishmaniasis and rabies. The majority of these diseases yielded little to no data. Neglected zoonoses disproportionately affect impoverished communities whose proximity to animals and lack of access to adequate healthcare leaves them particularly vulnerable to these diseases[35]. Continuing to ignore the surveillance of these zoonotic diseases in both human and animal populations can further contribute to health inequity in impoverished populations.

Ultimately, it is important to address the findings from this database in the context of the current SARS-CoV-2 pandemic. It is well known that influenza A viruses have the potential to cause pandemics. While there is influenza surveillance ongoing in Central America with weekly influenza case counts available through FluNet, this site does not include information on human mortality or any animal variables. As stated earlier, the absence of zoonotic disease data for animal variables could result in missing influenza outbreaks that can affect the human population. The current influenza data maintained in FluNet is beneficial but leaves gaps among variables. These gaps can be detrimental to zoonotic disease detection, monitoring, and response in the countries in the region as well as other parts of the world. Human disease-specific mortality data is necessary to understand the severity of a disease within a population and to inform appropriate public health interventions. There is evidence to suggest that co-infection of influenza and SARS-CoV-2 can result in higher mortality[36]. In order to effectively monitor this in Central America, baseline human mortality data for influenza is needed. Co-infection of coccidioidomycosis and SARS-CoV-2 has also been of concern. It is reasonable to speculate that those who have pulmonary coccidiomycosis are predisposed to severe SARS-CoV-2 resulting from more extensive lung damage by the convergence of these two separate pathogens[37].

Another concern is that SARS-CoV-2 may reactivate coccidioidomycosis infection in some patients[37]. A recommended treatment for SARS-CoV-2 infection, dexamethasone, has been found to increase the risk of severe coccidioidomycosis and other pulmonary infections[37]. It is important for physicians to have a sense of awareness resulting from this information when diagnosing and treating patients who are also at risk of coccidioidomycosis. The minimal data available for coccidioidomycosis throughout countries in Central America is unsettling because it limits the ability to properly evaluate the current state of coccidioidomycosis infection in the region. Since SARS-CoV-2 is postulated to potentially to amplify pulmonary coccidioidomycosis, data across the selected variables are particularly necessary to identify coccidioidomycosis outbreaks so that informed prevention and mitigation measures can be put in place.

Recommendations

The findings of this search and creation of the database should be made available to facilitate OHZDP workshops in Central American countries, and respective health and agriculture ministries to help identify any other relevant data that have not been made publicly available. It is possible that gaps in the database are solely because surveillance data for these zoonotic diseases are not publicly available. By reaching out to individual health and agriculture ministries, other data can be identified and validated for the creation of a more complete database that will enable a better zoonotic disease prioritization process. In addition, future efforts to compile available One Health information for the central American region should include searches of Spanish language publications.

If, after these consultations are held, we confirm the absence of surveillance for these zoonotic diseases, Central American health and agriculture ministries can be exhorted to

routinely collect and analyze zoonotic disease surveillance data. PAHO can provide guidance and leadership, in collaboration with subject matter experts from CDC's One Health Office, the Council of State and Territorial Epidemiologists, FAO, and other key stakeholders. In general, we have uncovered the important surveillance gaps that should be addressed to improve zoonotic disease surveillance and interventions in animals and humans across the region. Ongoing surveillance should continue for chikungunya, dengue, SARS-CoV-2, and zika on the humans but should be expanded to animals as well. During the ongoing COVID-19 pandemic, there should be enhanced monitoring of influenza, coccidiomycosis, and other airborne zoonotic diseases in this region to identify and mitigate potential outbreaks.

The Future of One Health in Central America

Overall, the database indicates that Central American countries are taking steps to maintain surveillance for some zoonotic diseases. Implementing a One Health approach would necessitate increases and improvements in country-specific and regional zoonotic disease monitoring and application of appropriate prevention strategies to decrease the incidence, morbidity, and mortality associated with these diseases. Honduras and El Salvador have already begun collaborating with CDC's One Health Office on the interest in conducting an OHZDP processes which is promising for the outlook of One Health in the region[38]. As more countries in the Central America region recognize the value of One Health and make it a priority, the health of populations will improve.

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Appendix

Table 1: Zoonotic Disease Database Template

	Epidemic/Pandemic Potential							
		Central America						
Questions	Human prevalence and/or incidence in the **Region**	Human prevalence and/or incidence in **Belize**	Human prevalence and/or incidence in **Costa Rica**	Human prevalence and/or incidence in **El Salvador**	Human prevalence and/or incidence in **Guatemala**	Human prevalence and/or incidence in **Honduras**	Human prevalence and/or incidence in **Nicaragua**	Human prevalence and/or incidence in **Panama**
Answers								
Bacteria								
Anthrax								
Bartonellosis								
Borreliosis								
Brucellosis								
Campylobacteriosis								
Colibacillosis								
Ehrlichiosis								
Leptospirosis								
Listeriosis								
Q fever								
Rickettsiosis								
Salmonellosis								
Typhus (endemic)								
Typhus (epidemic)								
Typhus (scrub)								
Yersiniosis								
Zoonotic Tuberculosis								
Viruses								
Avian Influenza								
Chikungunya								
Dengue								
Eastern Equine Encephalitis								
Hantavirus								
Hepatitis E								
Rabies								
SARS-CoV-2								
Swine Influenza								
Venezuelan Equine Encephalitis								
Western Equine Encephalitis								
West Nile Fever								
Yellow Fever								
Zika								
Parasites/Protozoa								
Chagas Disease								
Cryptosporidiosis								
Cysticercosis								
Echinococcosis								
Fasciolasis								
Giardiasis								
Leishmaniasis								
Toxocariasis								
Toxoplasmosis								
Trichinosis								
Fungi								
Coccidioidomycosis								
Cryptococcosis								
Histoplasmosis								
Prions								
Bovine Spongiform Encephalopathy								

Tables 2-5: Data value counts by source

Belize

	Human Prevalence-Incidence	Human Mortality	Animal Prevalence-Incidence	Animal Mortality	Last Documented Human Outbreak	Last Documented Animal Outbreak	Total
GIDEON	7	1	1	0	9	9	27
ProMed	0	0	1	0	0	6	7
GHDx	12	8	0	0	0	0	20
PAHO	6	4	0	0	2	0	12
Literature Searches	4	0	1	0	0	0	5
No data identified	30	34	42	45	36	35	222

Costa Rica

	Human Prevalence-Incidence	Human Mortality	Animal Prevalence-Incidence	Animal Mortality	Last Documented Human Outbreak	Last Documented Animal Outbreak	Total
GIDEON	16	8	19	0	7	3	53
ProMed	0	0	0	0	5	3	8
GHDx	12	8	0	0	0	0	20
PAHO	7	4	0	0	2	0	13
Literature Searches	7	1	7	2	1	0	18
No data identified	22	30	24	44	34	42	196

El Salvador

	Human Prevalence-Incidence	Human Mortality	Animal Prevalence-Incidence	Animal Mortality	Last Documented Human Outbreak	Last Documented Animal Outbreak	Total
GIDEON	12	3	3	0	7	1	26
ProMed	0	0	0	0	3	2	5
GHDx	12	8	0	0	0	0	20
PAHO	6	4	0	0	2	0	12
Literature Searches	3	0	0	0	0	0	3
No data identified	27	33	42	45	37	42	226

Guatemala

	Human Prevalence-Incidence	Human Mortality	Animal Prevalence-Incidence	Animal Mortality	Last Documented Human Outbreak	Last Documented Animal Outbreak	Total
GIDEON	12	2	7	0	9	1	31
ProMed	0	0	0	0	2	1	3
GHDx	13	8	0	0	0	0	21
PAHO	6	4	0	0	2	0	12
Literature Searches	8	1	3	0	0	0	12
No data identified	25	33	36	45	36	43	218

Tables 6-8: Data value counts by source

Honduras

	Human Prevalence-Incidence	Human Mortality	Animal Prevalence-Incidence	Animal Mortality	Last Documented Human Outbreak	Last Documented Animal Outbreak	Total
GIDEON	9	2	1	0	6	3	21
ProMed	0	0	0	1	1	4	6
GHDx	13	8	0	0	0	0	21
PAHO	6	4	0	0	2	0	12
Literature Searches	6	1	0	0	0	0	7
No data identified	28	33	44	44	39	40	228

Nicaragua

	Human Prevalence-Incidence	Human Mortality	Animal Prevalence-Incidence	Animal Mortality	Last Documented Human Outbreak	Last Documented Animal Outbreak	Total
GIDEON	11	3	9	0	6	2	31
ProMed	0	0	0	0	2	0	2
GHDx	13	8	0	0	0	0	21
PAHO	6	4	0	0	2	0	12
Literature Searches	11	0	2	0	0	2	15
No data identified	26	33	36	45	38	41	219

Panama

	Human Prevalence-Incidence	Human Mortality	Animal Prevalence-Incidence	Animal Mortality	Last Documented Human Outbreak	Last Documented Animal Outbreak	Total
GIDEON	15	3	9	0	11	4	42
ProMed	0	0	0	0	4	5	9
GHDx	14	8	0	0	0	0	22
PAHO	5	4	0	0	2	0	11
Literature Searches	7	2	3	0	2	1	15
No data identified	23	33	35	45	32	38	206