

Ateneo de Manila University

**Archium Ateneo**

---

Biology Faculty Publications

Biology Department

---

1-31-2022

## **Zoonotic Pathogens From Illegally Traded Wildlife Justify Adopting the One Health Perspective in Disease Response**

Marianne Allison G. Lee

Vinyl Joseph S. Valeza

Jonathan Patrick H. Yan

Ronald Allan L. Cruz

Follow this and additional works at: <https://archium.ateneo.edu/biology-faculty-pubs>



Part of the [Animal Sciences Commons](#), [Biology Commons](#), [Diseases Commons](#), [Environmental Policy Commons](#), [International Trade Law Commons](#), and the [Public Health Commons](#)

---

# Zoonotic pathogens from illegally traded wildlife justify adopting the One Health perspective in disease response

Lee, Marianne Allison G.\*<sup>1</sup>, Valeza, Vinyl Joseph S.<sup>1,2</sup>, Yan, Jonathan Patrick H.<sup>1</sup>, Cruz, Ronald Allan L.<sup>1</sup>

<sup>1</sup>Ateneo Wildlife Trade Research and Advocacy Group, Department of Biology, School of Science and Engineering, Ateneo de Manila University, Katipunan Avenue, Loyola Heights, Quezon City 1108, Philippines

<sup>2</sup>College of Medicine, Pamantasan ng Lungsod ng Maynila, Gen. Luna cor. Muralla St., Intramuros Manila 1002, Philippines

## ABSTRACT

Recent studies have described a direct relationship between the illegal wildlife trade (IWT) and the prevalence of zoonotic pathogens in human populations. In the Philippines, the Philippine Integrated Disease Surveillance and Response (PIDSRS) framework outlines the monitoring, response, and management of disease outbreaks, but needs to be updated in the wake of zoonoses from IWT. Here, we identified zoonotic pathogens that may be introduced to human populations through the IWT, pinpointed potential outbreak hotspots, and provided recommendations on how to improve the Philippines' public health response while considering One Health. Using seizure data from the Biodiversity Management Bureau (DENR-BMB) covering the period from 2010 to 2016, we found that birds (32.3% of volume) and reptiles (63.3% of volume) were the most frequently seized by law enforcement in terms of incidence

and volume. About 54% of seized wildlife could potentially host zoonotic pathogens with bacteria (78.3%), protozoa (34.8%), and viruses (27.5%) being the most represented pathogen groups. Three cities in Metro Manila together accounted for 30% of all seizures in the country followed by Palawan province which accounted for about 28% of seizures. Of the twelve epidemic prone diseases identified in the PIDSRS, five diseases were found to have causative agents that could potentially be hosted by the traded wildlife. These findings will not only enhance the approach to surveillance in the PIDSRS but will also aid in identifying opportunities to improve policies on agriculture and food security, public health and disease surveillance, and biodiversity conservation.

## INTRODUCTION

The Philippines is one of the world's mega diversity countries, which altogether hold two-thirds of the Earth's biological diversity (Posa et al. 2008; DENR-BMB 2014). The country is

\*Corresponding author

Email Address: marianne.lee@obf.ateneo.edu

Date received: March 08, 2021

Date revised: December 17, 2021

Date accepted: January 19, 2022

## KEYWORDS

zoonoses; wildlife trade; biodiversity loss; public health; One Health

characterized by high endemism; nearly half of its vertebrates and 45% to 60% of its vascular plants are unique to the islands (Posa et al. 2008). However, the Philippines is currently facing some of the greatest losses of biodiversity. Overexploitation through the illegal wildlife trade (IWT) is one of the principal pressures to Philippine biodiversity. The country is a known source, transit point, and destination for trafficked wildlife, and it is estimated that the total value of IWT is as much as PHP 50 billion per year (Enano 2019). One consequence of the IWT is the introduction of zoonotic disease agents into human populations. While zoonotic diseases have been around for a long time, their recent emergence has greatly impacted public health because of their penetration across more biogeographic barriers, wider host or vector ranges, and the expanding host species reservoir (Wang and Cramer 2014). Zoonotic diseases make up an estimated 70% of emerging infectious diseases (EIDs) and the increasing human population allows for pathogens to have several entry points into the population, including trade and consumption of animals (Woolhouse et al. 2005; Karesh et al. 2012). The consumption of wildlife in Wuhan, China has been implicated as the origin of SARS coronavirus 2 (SARS-CoV-2), the causative agent of the COVID-19 pandemic. Bats and pangolins have been particularly highlighted as vectors (Lam et al. 2020; Xu et al. 2020). The possibility that the virus originated from and was transmitted through wildlife trade and consumption led to a reexamining of national and international-level wildlife trade policies and the links between biodiversity and health.

As activities like the IWT increase the interactions between humans and wildlife and create more opportunities for the spread of disease, the need for a One Health approach in public health response becomes even more imperative. The One Health approach brings together partners in the health and environment sectors to examine changes in the interactions between humans, wildlife, and the environment. It links biodiversity to food security, nutrition, shelter, sanitation, mental health and well-being, and infectious diseases. It also identifies ways to manage this landscape through the development and implementation of policies and programs that ensure optimal health outcomes for all (WHO 2017; CDC 2018). Consistent patterns have shown that biodiversity loss tends to increase pathogen transmission and disease incidence. Keesing and Ostfeld (2021) provide an updated review of the literature on the link between biodiversity and zoonotic diseases, emphasizing the need for studying the richness and abundance of particular taxa that are likely carriers of zoonotic disease, such as rodents, bats, primates, and artiodactyls among mammals.

Several legislations exist in the Philippines to address zoonoses. In 2011, the Philippine Inter-Agency Committee on Zoonoses (PhilCZ) was established through Administrative Order (AO) No. 2011-10, which stipulates that the PhilCZ will develop a national strategy on the prevention, control, and elimination of zoonoses and establish a functional mechanism for the effective prevention, control, and elimination of zoonotic diseases. In 2017, the Department of Health (DOH) launched the Emerging and Re-emerging Infectious Disease program and through it has sought to manage specific zoonoses like the Zika Virus, Ebola Virus, and A(H5N6) in tandem with other government agencies in the country like the Department of Agriculture (DA) and the Department of Environment and Natural Resources (DENR). The program applies the One Health approach in that it considers the social determinants of health and environmental changes as contributing factors to the emergence or resurgence of infectious diseases. For disease surveillance and disease outbreak management, the Philippines is guided primarily by the Philippine Integrated Disease Surveillance and Response (PIDSR) framework, which began implementation in 2008. Aside from identifying priority diseases, it also outlines the roles

of local and national government entities in disease surveillance and management. However, gaps in disease surveillance persist resulting in outbreaks like the 2014 Henipavirus outbreak in Sultan Kudarat that was suspected, based on the ecology of henipaviruses, to have originated from fruit bats found in the concerned villages (Ching et al. 2015) and the recurring Ebola Virus outbreak—the most recent of which was detected in 2015 in monkeys bound for export (Peñas et al. 2019).

As IWT continues to facilitate the emergence and penetration of zoonotic diseases into human populations, it is necessary to know what other diseases of zoonotic origin could cause outbreaks in the country. As a known source, transit point, and destination for IWT, the Philippines would highly benefit from an updated PIDSR. This study determined 1) what pathogens from traded wildlife can possibly lead to zoonoses in the Philippines, 2) the animal hosts of these zoonotic disease agents, and 3) possible disease hotspots. These findings can lead to recommendations on the improvement of the PIDSR, particularly surveillance.

## MATERIALS AND METHODS

To identify the zoonotic disease agents that may be introduced to populations through the IWT, wildlife seizure data from the DENR-Biodiversity Management Bureau (DENR-BMB) were obtained. The data provided by the DENR-BMB was in the form of a tabular dataset in Microsoft Excel and was a consolidation of seizure reports from the DENR regional offices. The information in the datasets, which covered the period from January 2010 to June 2016, included common names of wildlife, species taxonomy, place of seizure including the region, quantity confiscated, apprehending office, and the date of seizure. From this, a new dataset was constructed showing the taxonomic classes of the confiscated wildlife and their associated zoonotic pathogens in addition to the aforementioned information in the DENR-BMB datasets. Only partial data for 2016 was available when the request was made for the seizure records.

The keywords “[taxon name]”, “zoonotic”, “zoonoses”, “pathogen”, and “disease” were used to identify the associated pathogens of the seized wildlife. A pathogen was included in the new dataset if it met all of the following criteria: 1) the pathogen must have been found on the traded animal host or the host was found to have had antibodies against the pathogen as a result of a previous infection, 2) the pathogen must have had documented transmission to humans from an animal host but not necessarily from a DENR-BMB listed seized wildlife, and 3) the pathogen must be able to cause a significant illness that may or may not lead to death (Pavlin et al. 2009). The zoonotic nature of the pathogens was then confirmed through a literature search on Google Scholar, the databases of the Center for Disease Control (CDC), and the appendix of zoonotic pathogens by Taylor et al. (2001) in Risk Factors for Human Disease Emergence.

## RESULTS AND DISCUSSION

### Trends in Wildlife Seizures

Between January 2010 and June 2016, the DENR-BMB recorded 187 wildlife seizures in the Philippines. Seizures halved between 2011 and 2013, followed an upward trend between 2013 and 2015, and decreased again in 2016 most likely due to the partial data available for that year (Fig. 1).

A total of 6,810 terrestrial and aquatic animals across 127 species were seized, with most species being either birds (47.7%) or reptiles (34.4%). Birds were more frequently seized (59.8% of incidents) than all other taxa, while reptiles accounted

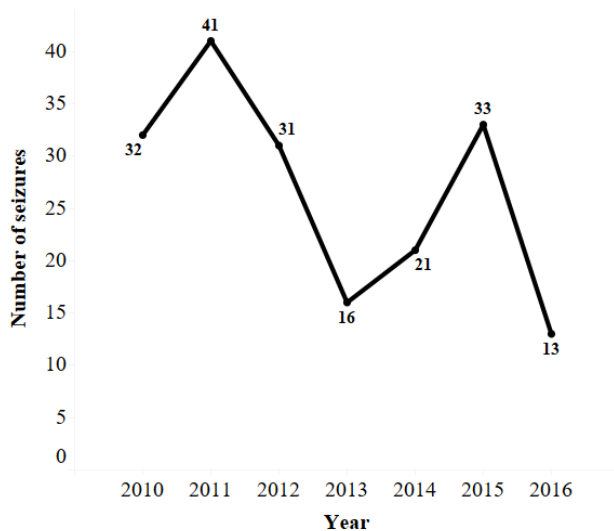


Figure 1: Trend in wildlife seizures in the Philippines between January 2010 and June 2016.

for 63.3% of the volume of seized wildlife (Fig. 2). This is consistent with the trends derived from data on trade in Cartimar Market in Pasay from 2008 to 2019 (Cruz and Lagunzad 2021). Parrots (Psittacidae) are particularly heavily traded, especially in the tropics, where the trade has been happening for over a thousand years (Weston and Memon 2009; Pires 2012).

The hill myna *Gracula religiosa* (Linnaeus, 1758), blue-naped parrot *Tanygnathus lucionensis* (Linnaeus, 1766) were the species most frequently seized by law enforcement, at 6% and 5% of all incidents, respectively. Meanwhile, the Tokay gecko *Gekko gecko* (Linnaeus, 1758) (27.6% of volume) and the Southeast Asian box turtle *Cuora amboinensis* (Daudin, 1802) (16.8% of volume) were the species most frequently seized by law enforcement and constituted a significant share in the volume of seized wildlife (Table 1). Of these, *T. lucionensis* is particularly problematic; it is considered Critically Endangered by the

Philippine National Red List (Gonzalez et al. 2018, BCSP 2020). Also frequently seized was the Philippine pangolin *Manis culionensis* (de Elera, 1915), which is found only in the Palawan faunal region and is considered Critically Endangered by the International Union for the Conservation of Nature (IUCN). In the Philippine Red List, it is given the Endangered status (Gonzalez et al. 2018; BCSP 2020), which may need to be reassessed in the wake of the continued trade in this species, which is the most traded mammal in the country (Cruz and Lagunzad 2021). All trade in the species is prohibited by national and international laws as it is listed under Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Table 1: Species most frequently seized by law enforcement and with largest volumes of seizures in the Philippines.

Top 5 Species by Incidence	Number of Seizures	Top 5 Species by Volume	Quantity (individual specimens)
<i>Gracula religiosa</i>	20	<i>Gekko gecko</i>	1,883
<i>Tanygnathus lucionensis</i>	16	<i>Cuora amboinensis</i>	1,148
<i>Gekko gecko</i>	11	<i>Gracula religiosa</i>	741
<i>Manis culionensis</i>	11	<i>Tanygnathus lucionensis</i>	494
<i>Python bivittatus</i>	11	<i>Siebenrockiella leytenis</i>	440

Turtles are heavily targeted by IWT. Accounting for 6% of the volume of seized wildlife was the Philippine Forest turtle *Siebenrockiella leytenis* (Taylor, 1920). It is considered Critically Endangered in both the IUCN Red List and the National Red List. The most serious threat to it is illegal extraction from the wild for international trade (Sy et al. 2020).

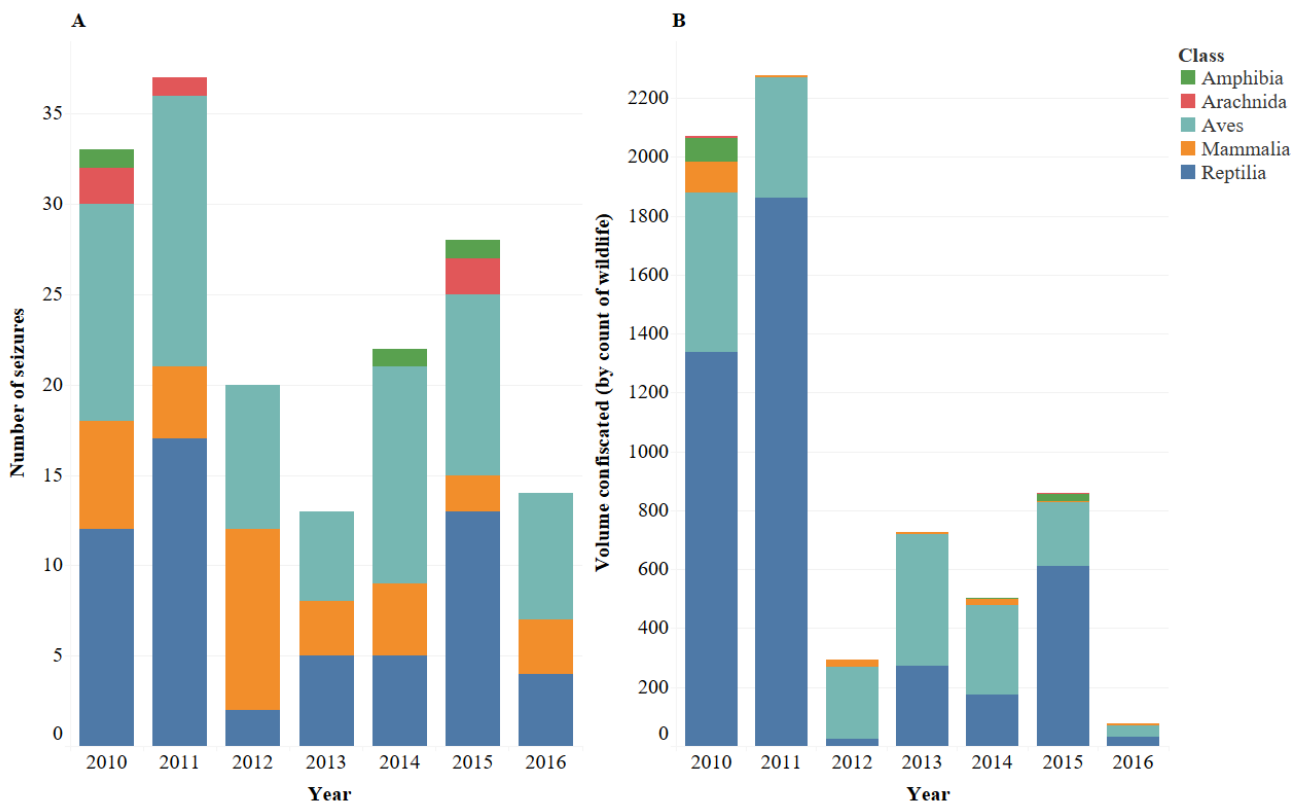


Figure 2: (A) More frequently seized wildlife by number of seizures and (B) the corresponding volumes seized by law enforcement.

**Table 2: The wildlife species illegally traded in the Philippines based on seizure data from 2010 to 2016 and their associated zoonotic pathogens as determined through the literature search.**

Scientific Name	Class	Associated Pathogens	Pathogen Type	Reference
<i>Accipiter trivirgatus</i>	Aves	<i>Aspergillus fumigatus</i>	Fungi	Jones MP and Orosz SE (2000)
<i>Acerodon jubatus</i>	Aves	<i>Coxiella burnetii</i>	Bacteria	Ioannou I et al. (2009)
	Aves	<i>Cryptosporidium parvum</i>	Protozoa	Reboredo-Fernandez A et al. (2015)
	Aves	West Nile Virus	Virus	Venter M and Swanepoel R (2010)
	Mammalia	Reston Ebola Virus	Virus	Jayme SI et al. (2015)
<i>Acridotheres cristatellus</i>	Aves	Influenza A Virus H5N1	Virus	Stallknecht DE and Brown JD (2008)
<i>Agapornis fischeri</i>	Aves	<i>Cryptosporidium spp.</i>	Protozoa	Zhang X et al. (2015)
<i>Agapornis fischeri</i>	Aves	<i>Chlamydomydia psittaci</i>	Bacteria	Suksai P et al. (2016)
<i>Ahaetulla prasina</i>	Reptilia	<i>Salmonella enterica</i>	Bacteria	Fasaei B and Tamai I (2018)
<i>Amazona oratrix</i>	Aves	<i>Aspergillus fumigatus</i>	Fungi	Boseret G et al. (2013)
	Aves	<i>Campylobacter jejuni</i>	Bacteria	Boseret G et al. (2013)
	Aves	<i>Chlamydomydia psittaci</i>	Bacteria	Boseret G et al. (2013)
	Aves	<i>Cryptococcus neoformans</i>	Fungi	Boseret G et al. (2013)
	Aves	<i>Cryptosporidium parvum</i>	Protozoa	Boseret G et al. (2013)
	Aves	<i>Giardia duodenalis</i>	Protozoa	Boseret G et al. (2013)
	Aves	Influenza A Virus H5N1	Virus	Boseret G et al. (2013)
	Aves	<i>Mycobacterium avium</i>	Bacteria	Jones MP and Orosz SE (2000)
	Aves	<i>Mycobacterium bovis</i>	Bacteria	
	Aves	<i>Mycobacterium genavense</i>	Bacteria	
	Aves	<i>Salmonella typhimurium</i>	Bacteria	
	Aves	West Nile Virus	Virus	
<i>Aonyx cinereus</i>	Mammalia	<i>Giardia duodenalis</i>	Protozoa	Beck R et al. (2011)
<i>Aratinga solstitialis</i>	Aves	<i>Campylobacter jejuni</i>	Bacteria	Boseret G et al. (2013)
	Aves	<i>Chlamydomydia psittaci</i>	Bacteria	Boseret G et al. (2013)
	Aves	<i>Cryptococcus neoformans</i>	Fungi	Boseret G et al. (2013)
	Aves	<i>Cryptosporidium parvum</i>	Protozoa	Boseret G et al. (2013)
	Aves	<i>Giardia duodenalis</i>	Protozoa	Boseret G et al. (2013)
	Aves	Influenza A Virus H5N1	Virus	Boseret G et al. (2013)
	Aves	<i>Mycobacterium avium</i>	Bacteria	Boseret G et al. (2013)
	Aves	<i>Mycobacterium bovis</i>	Bacteria	Boseret G et al. (2013)
	Aves	<i>Mycobacterium genavense</i>	Bacteria	Boseret G et al. (2013)
	Aves	<i>Salmonella typhimurium</i>	Bacteria	Boseret G et al. (2013)
	Aves	West Nile Virus	Virus	Boseret G et al. (2013)
<i>Arctictis binturong</i>	Mammalia	<i>Bacillus anthracis</i>	Bacteria	Hugh-Jones ME and De Vos V (2002)
	Mammalia	<i>Brugia malayi</i>	Helminth	Wicker LV et al. (2016)
	Mammalia	<i>Brugia pahangi</i>	Helminth	Edeson JFB and Wilson T (1964)
<i>Boa constrictor</i>	Reptilia	<i>Plesiomonas shigelloides</i>	Bacteria	Wicker LV et al. (2016)
<i>Boa constrictor</i>	Reptilia	<i>Cryptosporidium parvum</i>	Protozoa	Pedraza-Diaz S et al. (2009)
<i>Boiga dendrophila</i>	Reptilia	<i>Salmonella enterica</i>	Bacteria	Geue L and Löschner U (2002)
<i>Boiga dendrophila</i>	Reptilia	<i>Pseudomonas aeruginosa</i>	Bacteria	Colinon C et al. (2010); Foti M et al. (2013)
	Reptilia	<i>Aeromonas hydrophila</i>	Bacteria	Jho YS et al. (2011)
	Reptilia	<i>Enterococcus faecalis</i>	Bacteria	Jho YS et al. (2011)
	Reptilia	<i>Escherichia coli</i>	Bacteria	Jho YS et al. (2011)
	Reptilia	<i>Klebsiella pneumoniae</i>	Bacteria	Jho YS et al. (2011)
	Reptilia	<i>Morganella morganii</i>	Bacteria	Jho YS et al. (2011)
	Reptilia	<i>Proteus mirabilis</i>	Bacteria	
	Reptilia	<i>Proteus vulgaris</i>	Bacteria	
<i>Bubo philippensis</i>	Aves	<i>Serratia marcescens</i>	Bacteria	Jho YS et al. (2011)

Scientific Name	Class	Associated Pathogens	Pathogen Type	Reference
<i>Cacatua alba</i>	Aves	<i>Staphylococcus aureus</i>	Bacteria	Jho YS et al. (2011)
<i>Bubo philippensis</i>	Aves	<i>Salmonella enterica</i>	Bacteria	Hydeskov HB et al. (2013)
<i>Cacatua alba</i>	Aves	<i>Chlamydomphila psittaci</i>	Bacteria	Perez JM (2012)
	Aves	<i>Chlamydomphila psittaci</i>	Bacteria	Boseret G et al. (2013)
	Aves	<i>Campylobacter jejuni</i>	Bacteria	Boseret G et al. (2013)
	Aves	<i>Chlamydomphila psittaci</i>	Bacteria	Boseret G et al. (2013)
	Aves	<i>Cryptococcus neoformans</i>	Fungi	Boseret G et al. (2013)
	Aves	<i>Cryptosporidium parvum</i>	Protozoa	Boseret G et al. (2013)
	Aves	<i>Escherichia coli</i>	Bacteria	Boseret G et al. (2013)
	Aves	<i>Giarda duodenalis</i>	Protozoa	
	Aves	Influenza A Virus H5N1	Virus	
	Aves	<i>Mycobacterium avium</i>	Bacteria	
	Aves	<i>Mycobacterium bovis</i>	Bacteria	
<i>Cacatua galerita</i>	Aves	<i>Mycobacterium genavense</i>	Bacteria	Boseret G et al. (2013)
	Aves	<i>Salmonella typhimurium</i>	Bacteria	Boseret G et al. (2013)
<i>Cacatua haematurophygia</i>	Aves	West Nile Virus	Virus	Flammer K Drewes LA (1988)
<i>Cacatua galerita</i>	Aves	<i>Chlamydomphila psittaci</i>	Bacteria	Maluping R et al. (2007)
<i>Cacatua sulphurea</i>	Aves	<i>Giarda duodenalis</i>	Protozoa	Mcdonnell P et al. (2003); Upcroft JA et al. (1997)
<i>Cacatua haematurophygia</i>	Aves	<i>Chlamydomphila psittaci</i>	Bacteria	Kaleta EF and Taday E (2003)
<i>Carettochelys insculpta</i>	Reptilia	<i>Escherichia coli</i>	Bacteria	Flammer K and Drewes LA (1988)
<i>Ceratophrys ornata</i>	Amphibia	<i>Chlamydomphila psittaci</i>	Bacteria	Kaleta EF and Taday E (2003)
<i>Chelonoidis carbonaria</i>	Reptilia	Newcastle Disease Virus	Virus	Kawamura M et al. (1987)
<i>Carettochelys insculpta</i>	Reptilia	<i>Paecilomyces lilacinus</i>	Fungi	Lafortune M et al. (2005)
<i>Chelonia mydas</i>	Reptilia	<i>Staphylococcus aureus</i>	Bacteria	Santoro M et al. (2006)
	Reptilia	<i>Bacillus cereus</i>	Bacteria	Santoro M et al. (2006)
	Reptilia	<i>Aeromonas hydrophila</i>	Bacteria	Santoro M et al. (2006)
<i>Corvus macrorhynchos</i>	Aves	<i>Enterobacter cloacae</i>	Bacteria	Santoro M et al. (2006)
	Aves	<i>Escherichia coli</i>	Bacteria	Santoro M et al. (2006)
	Aves	<i>Klebsiella pneumoniae</i>	Bacteria	Santoro M et al. (2006)
<i>Crocodylus johnstoni</i>	Reptilia	<i>Proteus mirabilis</i>	Bacteria	Santoro M et al. (2006)
<i>Cuora amboinensis</i>	Reptilia	<i>Proteus vulgaris</i>	Bacteria	Santoro M et al. (2006)
<i>Eclectus roratus</i>	Aves	<i>Pseudomonas aeruginosa</i>	Bacteria	Santoro M et al. (2006)
	Aves	<i>Serratia marcescens</i>	Bacteria	Santoro M et al. (2006)
	Aves	<i>Vibrio alginolyticus</i>	Bacteria	Santoro M et al. (2006)
<i>Chelonoidis carbonaria</i>	Reptilia	<i>Campylobacter fetus</i>	Bacteria	Wang CM et al. (2013)
<i>Chelus fimbriata</i>	Reptilia	<i>Aeromonas hydrophila</i>	Bacteria	George RH (1996)
<i>Geochelone elegans</i>	Reptilia	<i>Escherichia coli</i>	Bacteria	George RH (1996)
<i>Gonyosoma oxycephalum</i>	Reptilia	<i>Mycobacterium avium</i>	Bacteria	George RH (1996)
<i>Goura victoria</i>	Aves	<i>Vibrio alginolyticus</i>	Bacteria	George RH (1996)
<i>Corvus macrorhynchos</i>	Aves	<i>Clostridium perfringens</i>	Bacteria	Tanimura N et al. (2006)
<i>Crocodylus johnstoni</i>	Aves	<i>Coxiella burnetii</i>	Bacteria	Asaoka Y et al. (2003)
<i>Eclectus roratus</i>	Aves	<i>Coxiella burnetii</i>	Bacteria	To H et al. (1998)
<i>Gallicolumba luzonica</i>	Aves	Influenza A Virus H5N1	Virus	Roh YS et al. (2010)
<i>Gekko gekko</i>	Aves	<i>Mycobacterium szulgai</i>	Bacteria	Quist EM et al. (2011)
<i>Geochelone elegans</i>	Reptilia	<i>Mycobacterium szulgai</i>	Bacteria	Maluping R et al. (2007)
<i>Gonyosoma oxycephalum</i>	Aves	<i>Histoplasma capsulatum</i>	Fungi	Flammer K and Drewes LA (1988)
<i>Goura victoria</i>	Aves	<i>Chlamydomphila psittaci</i>	Bacteria	Maricopa County Department of Public Health (2003)
<i>Gracula religiosa</i>	Aves	<i>Escherichia coli</i>	Bacteria	Casey C (2007)
	Aves	<i>Escherichia coli</i>	Bacteria	Wang CM et al. (2013)
	Aves	West Nile Virus	Virus	Foti M et al. (2013)
	Reptilia	<i>Edwardsiella tarda</i>	Bacteria	De Camps S et al. (2008)
	Reptilia	<i>Campylobacter fetus</i>	Bacteria	Jones MP and Orosz SE (2000)

Scientific Name	Class	Associated Pathogens	Pathogen Type	Reference
	Reptilia	<i>Pseudomonas aeruginosa</i>	Bacteria	
	Aves	<i>Toxoplasma gondii</i>	Protozoa	
	Aves	<i>Aspergillus fumigatus</i>	Fungi	
<i>Graptemys geographica</i>	Reptilia	<i>Campylobacter jejuni</i>	Bacteria	Boseret G et al. (2013)
	Reptilia	<i>Chlamydophila psittaci</i>	Bacteria	Boseret G et al. (2013)
	Reptilia	<i>Cryptococcus neoformans</i>	Fungi	Boseret G et al. (2013)
	Reptilia	<i>Cryptosporidium parvum</i>	Protozoa	
<i>Haliastur indus</i>	Aves	<i>Giarda duodenalis</i>	Protozoa	Boseret G et al. (2013)
<i>Hoplobatrachus rugulosus</i>	Amphibia	Influenza A Virus H5N1	Virus	Boseret G et al. (2013)
	Amphibia	<i>Mycobacterium avium</i>	Bacteria	Boseret G et al. (2013)
<i>Hydrosaurus pustulatus</i>	Reptilia	<i>Mycobacterium bovis</i>	Bacteria	Boseret G et al. (2013)
<i>Iguana iguana</i>	Reptilia	<i>Mycobacterium genavense</i>	Bacteria	Boseret G et al. (2013)
<i>Indotestudo elongata</i>	Reptilia	<i>Pasteurella multocida</i>	Bacteria	Petersen KD et al. (2001)
<i>Leucopsar rothschildi</i>	Aves	<i>Salmonella typhimurium</i>	Bacteria	Boseret G et al. (2013)
<i>Lonchura oryzivora</i>	Aves	West Nile Virus	Virus	Boseret G et al. (2013)
<i>Graptemys geographica</i>	Reptilia	<i>Aeromonas hydrophila</i>	Bacteria	George RH (1996)
<i>Lorius garrulus</i>	Aves	<i>Escherichia coli</i>	Bacteria	George RH (1996)
<i>Lorius lory</i>	Aves	<i>Mycobacterium avium</i>	Bacteria	George RH (1996)
<i>Haliastur indus</i>	Aves	<i>Vibrio alginolyticus</i>	Bacteria	George RH (1996)
	Aves	<i>Chlamydophila psittaci</i>	Bacteria	Maluping R et al. (2007)
<i>Hoplobatrachus rugulosus</i>	Amphibia	<i>Bacillus cereus</i>	Bacteria	Cho H et al. (2010)
<i>Hydrosaurus pustulatus</i>	Mammalia	<i>Spirometra erinaceieuropaei</i>	Helminth	Jongthawin J et al. (2014)
	Reptilia	<i>Campylobacter fetus</i>	Bacteria	Wang CM et al. (2015)
<i>Iguana iguana</i>	Reptilia	<i>Escherichia coli</i>	Bacteria	Sylvester WRB et al. (2014)
<i>Indotestudo elongata</i>	Reptilia	<i>Enterobacter cloacae</i>	Bacteria	Ahmed AM et al. (2007))
<i>Leucopsar rothschildi</i>	Aves	<i>Toxoplasma gondii</i>	Protozoa	De Camps S et al. (2008)
<i>Lonchura oryzivora</i>	Aves	Influenza A Virus H5N1	Virus	Brooks-Moizer F et al. (2008)
<i>Lorius garrulus</i>	Aves	<i>Toxoplasma gondii</i>	Protozoa	Laveran M (1900)
<i>Lorius lory</i>	Aves	<i>Toxoplasma gondii</i>	Protozoa	Shima A and Osborn K (1989)
	Aves	<i>Salmonella typhimurium</i>	Bacteria	Chahota R et al. (2006)
	Aves	<i>Chlamydophila psittaci</i>	Bacteria	Raso TF et al. (2004)
	Aves	<i>Cryptococcus neoformans</i>	Fungi	
<i>Morelia viridis</i>	Reptilia	West Nile Virus	Virus	Komar N (2003)
<i>Macropus rufogriseus</i>	Mammalia	<i>Angiostrongylus cantonensis</i>	Helminth	Bermudez R et al. (2009)
<i>Manis culionensis</i>	Aves	<i>Leptospira weilii</i>	Bacteria	Roberts MW et al. (2010)
<i>Melopsittacus undulatus</i>	Aves	<i>Toxoplasma gondii</i>	Protozoa	Procviv P and Carlisle MS (2001)
	Aves	<i>Toxoplasma gondii</i>	Protozoa	Mohapatra RK et al. (2016)
	Mammalia	<i>Brugia malayi</i>	Helminth	Chin SC et al. (2016)
	Aves	<i>Necator americanus</i>	Helminth	Boseret G et al. (2013)
	Aves	<i>Chlamydophila psittaci</i>	Bacteria	Boseret G et al. (2013)
	Aves	<i>Cryptococcus neoformans</i>	Fungi	Boseret G et al. (2013)
	Aves	<i>Encephalitozoon cuniculi</i>	Fungi	Boseret G et al. (2013)
	Aves	<i>Escherichia coli</i>	Bacteria	
	Aves	Influenza A Virus H5N1	Virus	
	Aves	<i>Toxoplasma gondii</i>	Protozoa	
<i>Morelia viridis</i>	Reptilia	<i>Salmonella enterica</i>	Bacteria	Geue L and Löschner U (2002)
<i>Nymphicus hollandicus</i>	Aves	<i>Campylobacter jejuni</i>	Bacteria	Boseret G et al. (2013)
<i>Panthera tigris</i>	Mammalia	<i>Chlamydophila psittaci</i>	Bacteria	Boseret G et al. (2013)
	Mammalia	<i>Cryptococcus neoformans</i>	Fungi	Boseret G et al. (2013)
	Mammalia	<i>Cryptosporidium parvum</i>	Protozoa	Boseret G et al. (2013)
	Mammalia	<i>Cryptosporidium parvum</i>	Protozoa	Boseret G et al. (2013)
	Mammalia	<i>Encephalitozoon cuniculi</i>	Fungi	Boseret G et al. (2013)
	Mammalia	<i>Encephalitozoon cuniculi</i>	Fungi	Boseret G et al. (2013)

Scientific Name	Class	Associated Pathogens	Pathogen Type	Reference
	Mammalia	<i>Giarda duodenalis</i>	Protozoa	Boseret G et al. (2013)
	Mammalia	<i>Mycobacterium avium</i>	Bacteria	Boseret G et al. (2013)
	Mammalia	<i>Mycobacterium bovis</i>	Bacteria	Yilmaz R and Yumusak N (2015)
	Mammalia	<i>Mycobacterium genavense</i>	Bacteria	
	Mammalia	<i>Salmonella typhimurium</i>	Bacteria	
	Mammalia	West Nile Virus	Virus	
	Mammalia	<i>Bacillus anthracis</i>	Bacteria	
<i>Pantherophis guttatus</i>	Reptilia	<i>Brugia pahangi</i>	Helminth	Edeson JFB and Wilson T (1964)
<i>Paradoxurus hermaphroditus</i>	Mammalia	<i>Clostridium perfringens</i>	Bacteria	Zeira O et al. (2012)
	Mammalia	<i>Dirofilaria immitis</i>	Helminth	Acharjyo LN (2004)
	Mammalia	<i>Escherichia coli</i>	Bacteria	Carvalho FR et al. (2010)
	Mammalia	<i>Gnathostoma spinigerum</i>	Helminth	Shrivastav AB et al. (2011)
	Mammalia	<i>Microsporium canis</i>	Fungi	Sykes JM and Ramsay EC (2007)
<i>Pelodiscus sinensis</i>	Reptilia	<i>Mycobacterium avium</i>	Bacteria	Cho HS et al. (2006)
<i>Paradoxurus hermaphroditus</i>	Reptilia	<i>Mycobacterium bovis</i>	Bacteria	Cousins D (2004)
	Reptilia	<i>Strongyloides stercoralis</i>	Helminth	Fagiolini M et al. (2010)
	Reptilia	<i>Toxocara cati</i>	Helminth	Fagiolini M et al. (2010)
	Reptilia	<i>Toxoplasma gondii</i>	Protozoa	Thiangtum K et al. (2006)
	Reptilia	<i>Yersinia enterocolitica</i>	Bacteria	Mingrone MG and Fantasia M (1988)
	Mammalia	<i>Brugia malayi</i>	Helminth	Edeson JFB and Wilson T (1964)
	Reptilia	<i>Brugia pahangi</i>	Helminth	Edeson JFB and Wilson T (1964)
<i>Petaurus breviceps</i>	Mammalia	<i>Giarda duodenalis</i>	Protozoa	Oronan R et al. (2013)
	Mammalia	<i>Leptospira interrogans</i>	Bacteria	Wicker LV et al. (2016)
<i>Pithecopaga jefferyi</i>	Aves	<i>Toxoplasma gondii</i>	Protozoa	Wicker LV et al. (2016)
<i>Pelodiscus sinensis</i>	Reptilia	<i>Aeromonas hydrophila</i>	Bacteria	Sugita H and Deguchi Y (1983)
<i>Probosciger aterrimus</i>	Aves	<i>Citrobacter freundii</i>	Bacteria	Sugita H and Deguchi Y (1983)
<i>Psittacula eupatria</i>	Aves	<i>Edwardsiella tarda</i>	Bacteria	Xu T and Zhang XH (2014)
<i>Petaurus breviceps</i>	Aves	<i>Enterobacter aerogenes</i>	Bacteria	Sugita H and Deguchi Y (1983)
<i>Pithecopaga jefferyi</i>	Aves	<i>Enterobacter cloacae</i>	Bacteria	Sugita H and Deguchi Y (1983)
<i>Prionailurus bengalensis</i>	Aves	<i>Enterobacter cloacae</i>	Bacteria	Guangzhou HU et al. (2010)
<i>Probosciger aterrimus</i>	Aves	<i>Enterococcus hirae</i>	Bacteria	Sugita H and Deguchi Y (1983)
	Aves	<i>Klebsiella pneumoniae</i>	Bacteria	Oros J et al. (2003)
	Aves	<i>Mycobacterium kansasii</i>	Bacteria	Nichols M et al. (2014)
	Mammalia	<i>Listeria monocytogenes</i>	Bacteria	Barrows M (2006)
	Aves	<i>Toxoplasma gondii</i>	Protozoa	Keymer IF (1972)
	Aves	<i>Aspergillus fumigatus</i>	Fungi	Chen JC et al. (2015)
	Mammalia	<i>Toxoplasma gondii</i>	Protozoa	Oros J et al. (1998)
	Aves	<i>Chlamydomphila psittaci</i>	Bacteria	
<i>Psittacula eupatria</i>	Aves	<i>Campylobacter jejuni</i>	Bacteria	Boseret G et al. (2013)
	Aves	<i>Chlamydomphila psittaci</i>	Bacteria	Boseret G et al. (2013)
	Aves	<i>Cryptococcus neoformans</i>	Fungi	Boseret G et al. (2013)
	Aves	<i>Cryptosporidium parvum</i>	Protozoa	
<i>Psittacus erithacus</i>	Aves	<i>Giarda duodenalis</i>	Protozoa	Boseret G et al. (2013)
	Aves	Influenza A Virus H5N1	Virus	Boseret G et al. (2013)
	Aves	<i>Mycobacterium avium</i>	Bacteria	Boseret G et al. (2013)
	Aves	<i>Mycobacterium bovis</i>	Bacteria	
<i>Psittichas fulgidus</i>	Aves	<i>Mycobacterium genavense</i>	Bacteria	Boseret G et al. (2013)
<i>Pyrrhura molinae</i>	Aves	<i>Salmonella typhimurium</i>	Bacteria	Boseret G et al. (2013)
<i>Psittacula krameri</i>	Aves	West Nile Virus	Virus	Boseret G et al. (2013)
<i>Psittacus erithacus</i>	Aves	West Nile Virus	Virus	Mancianti F et al. (2001)



Scientific Name	Class	Associated Pathogens	Pathogen Type	Reference
<i>Psitttrichas fulgidus</i>	Aves	<i>Candida albicans</i>	Fungi	Maluping R et al. (2007)
	Aves	<i>Chlamydophila psittaci</i>	Bacteria	Raso TF et al. (2004)
	Aves	<i>Cryptococcus neoformans</i>	Fungi	Hinney B et al. (2016); Kašičková D et al. (2009)
	Aves	<i>Encephalitozoon cuniculi</i>	Fungi	Jones MP and Orosz SE (2000)
	Aves	<i>Aspergillus fumigatus</i>	Fungi	Raso TF et al. (2004)
	Aves	<i>Cryptococcus neoformans</i>	Fungi	Lee SY et al. (2011)
	Aves	<i>Encephalitozoon cuniculi</i>	Fungi	Flammer K and Drewes LA (1988)
	Aves	<i>Escherichia coli</i>	Bacteria	Long P et al. (1983)
	Aves	<i>Nocardia asteroides</i>	Bacteria	
<i>Pyrrhura molinae</i>	Aves	<i>Campylobacter jejuni</i>	Bacteria	Boseret G et al. (2013)
<i>Python regius</i>	Reptilia	<i>Chlamydophila psittaci</i>	Bacteria	Boseret G et al. (2013)
<i>Python reticulatus</i>	Reptilia	<i>Cryptococcus neoformans</i>	Fungi	Boseret G et al. (2013)
<i>Spilopelia chinensis</i>	Aves	<i>Cryptosporidium parvum</i>	Protozoa	Boseret G et al. (2013)
	Aves	<i>Giardia duodenalis</i>	Protozoa	Boseret G et al. (2013)
	Aves	Influenza A Virus H5N1	Virus	Boseret G et al. (2013)
	Aves	<i>Mycobacterium avium</i>	Bacteria	Boseret G et al. (2013)
<i>Spilornis cheela</i>	Aves	<i>Mycobacterium bovis</i>	Bacteria	Boseret G et al. (2013)
<i>Streptopelia tranquebarica</i>	Aves	<i>Mycobacterium genavense</i>	Bacteria	Boseret G et al. (2013)
	Aves	<i>Salmonella typhimurium</i>	Bacteria	Boseret G et al. (2013)
<i>Sula leucogaster</i>	Aves	West Nile Virus	Virus	Boseret G et al. (2013)
<i>Python bivittatus</i>	Reptilia	Arenavirus	Virus	Latney LV and Wellehan J (2013)
<i>Python regius</i>	Reptilia	<i>Chlamydia pneumoniae</i>	Bacteria	Cope I et al. (2014)
<i>Python reticulatus</i>	Reptilia	<i>Chlamydia pneumoniae</i>	Bacteria	Samaniego C et al. (2015)
<i>Spilopelia chinensis</i>	Reptilia	<i>Chlamydia pneumoniae</i>	Bacteria	Gilbert M et al. (2012)
	Aves	<i>Chlamydophila psittaci</i>	Bacteria	
<i>Trichoglossus moluccanus</i>	Aves	Influenza A Virus H5N1	Virus	Phong SF et al. (2006)
	Aves	<i>Toxoplasma gondii</i>	Protozoa	Chen JC et al. (2015)
<i>Tropidophorus grayi</i>	Reptilia	West Nile Virus	Virus	Pedersen K et al. (2016)
<i>Spilornis cheela</i>	Aves	<i>Toxoplasma gondii</i>	Protozoa	Chen JC et al. (2015)
<i>Streptopelia tranquebarica</i>	Aves	Far eastern Tick-borne encephalitis virus	Virus	Stallknecht DE and Brown JD (2008)
	Mammalia	Influenza A Virus H5N1	Virus	Xing Y et al. (2017)

Among marine species, green sea turtles *Chelonia mydas* (Linnaeus, 1758) and hawksbill turtles *Eretmochelys imbricata* (Linnaeus, 1766) were implicated in the greatest number of seizures at 11 and 10 seizures, respectively. The operations led to the retrieval of 194 green sea turtles and 877 hawksbill turtles. In the National Red List, *C. mydas* and *E. imbricata* are considered Endangered and Critically Endangered, respectively (Gonzalez et al. 2018, BCSP 2020).

With the exception of *C. mydas*, all of the aforementioned species are recognized by the DENR-BMB as the most traded species in the Philippines (ADB 2019).

### Zoonotic Pathogens in Traded Wildlife

There were 65 zoonotic pathogens with which the traded wildlife was found to be associated (Table 2). About 54% of traded wildlife species were found to be associated with zoonotic pathogens, with birds accounting for over half of wildlife positive for zoonotic disease agents. Bacteria (78.3%), protozoa (34.8%), and viruses (27.5%) were the largest pathogen groups represented, with *Chlamydophila psittaci* (9.2%), *Toxoplasma gondii* (6.0%), and Influenza A(H5N1) (5.5%) being the most frequently associated with the seized wildlife (Table 2). *C. psittaci* and the A(H5N1) virus primarily infect birds (Sims et al. 2005; Knittler and Sachse 2015). It was

expected that pathogens of avian and reptilian origin would figure largely in the dataset as birds and reptiles were the most seized wildlife in terms of both incidence and volume. Also concerning is that *C. psittaci* and *T. gondii* are not in the PIDSR list of endemic-prone diseases despite the high potential of transmission from traded wildlife. Psittacosis outbreaks caused by *C. psittaci* have occurred several times in the past, such as one that occurred among poultry slaughter plant workers in two US states in 2018 (National Center for Immunization and Respiratory Diseases 2018). Though the symptoms of toxoplasmosis are mild, approximately 30% of humans are infected with *T. gondii* and it is likely that clinical disease is more common than reported (Dubey 2021). Water contaminated by *T. gondii* oocysts is a known source of toxoplasmosis and may possibly be the route of infection in the wildlife trade, aside from consumption of the meat.

The PIDSR identified twelve epidemic-prone diseases, of which five were found to have causative agents that were zoonotic in nature and were also harbored by the traded wildlife based on the results of the literature search (Table 3). Of these, Influenza A H5N1 viruses are the most problematic, being found in 12 traded species confiscated from 34 operations, mostly (13) conducted in Metro Manila. Six of these seizures were in Manila, but three were in Pasay City, likely (though not certainly) in

Cartimar given its reputation for IWT. Palawan is also a common site for the trade of the host species. These species include *G. religiosa*, one of the most traded species in the Philippines (ADB 2019). Though there are two cases of seizure of this species in Metro Manila (including Pasay City), it is largely a Palawan-based trade (six operations).

**Table 3: Cross-referencing the causative agents of epidemic prone diseases in the PIDSRS with the pathogens found associated with the wildlife seized in the Philippines.**

Epidemic Prone Diseases	Causative Agents*	Associated with Seized Wildlife?
Acute Viral Hepatitis	Hepatitis A	No
	Hepatitis B	No
	Hepatitis C	No
Anthrax	<i>Bacillus anthracis</i>	Yes
	<i>Escherichia coli</i>	Yes
Bacterial Meningitis	Group B Streptococcus	No
	<i>Neisseria meningitidis</i>	No
	<i>Haemophilus influenzae</i>	No
	<i>Listeria monocytogenes</i>	Yes
	<i>Streptococcus pneumoniae</i>	No
	<i>Vibrio cholerae</i>	No
Cholera	—	—
Dengue	—	—
Human Avian Influenza	Influenza A H5 Viruses	Yes
	Influenza A H7 Viruses	No
	Influenza A H9 Viruses	No
Influenza-like Illness	—	—
Leptospirosis	<i>Leptospiriosis</i> sp.	Yes
Meningococcal Disease	<i>Neisseria meningitidis</i>	No
Paralytic Shellfish Poisoning	—	—
Severe Acute Respiratory Syndrome (SARS)	SARS-CoV	No
Typhoid and Paratyphoid Fever	—	—

\* Determined through the CDC

“—”: The causative agents for these epidemic prone diseases cannot be identified.

*E. coli*, a causative agent of bacterial meningitis, has been documented in 11 of the traded species, including several species of Psittacidae (parrots), the most highly traded bird family. Most of the seizures (11 of 22) of the hosts have been in Metro Manila, most commonly (5) in Quezon City but twice in Pasay City. The other three are less commonly encountered in seized animals, but all of them as well as *E. coli* are also identified by Allen et al. (2017) as emerging infectious diseases (EID) from wildlife.

Previous studies have shown that wildlife in markets can cause the transmission of disease to humans. In 2016, Greator and colleagues conducted market surveys in Lao PDR and identified traded mammals that had the potential to host 36 zoonotic pathogens. In 1995, De Schrijver reported on how a team of customs officials in Belgium developed psittacosis after coming into contact with parakeets that were infected with *C. psittaci*. The parakeets had been illegally imported into the country by a sailor from India. The customs officials were admitted to the hospital for atypical pneumonia (De Schrijver 1995). As a key trade hotspot, the situation in the Philippines is similar: contact with illegally traded wildlife that have the potential to host zoonotic pathogens increase one’s risk of getting sick with disease that may or not may be debilitating.

The information on zoonotic pathogens that humans can possibly derive from traded wildlife is dependent on the data available from the DENR-BMB, which is only from 2010 onward. Given the illicit nature of the activity, seizure records are the only major source of data available on IWT (Rosen and

Smith 2010). This certainly imposes a limitation in the determination of reservoirs for zoonoses, particularly among taxa whose trade is not adequately reported, and highlights the need to improve surveillance of diseases that can infect humans. Many of the species reported in the seizure records, especially marine turtles and birds, have been traded since before the Spanish colonial period (Cruz and Lagunza 2021).

### Seizure Hotspots

Three cities in Metro Manila together accounted for 30% of all wildlife seizures in the country: Pasay City (13.9%), Manila (10.2%), and Quezon City (7.4%) (Table 4). Cartimar Market, a fixture in Pasay City, is a retail center that sells various items from clothes and shoes to pets and sometimes protected or endangered wildlife. Over 10% of all seizures in the country occurred here. Of the five causative agents that were found to be associated with the seized wildlife based on the literature search, Influenza A(H5N1) and *Escherichia coli* may have had the greatest number of occurrences. All five causative agents of epidemic prone diseases may have been harbored by wildlife that were seized in Metro Manila suggesting that Metro Manila is not only a seizure hotspot but also potentially a disease outbreak hotspot.

**Table 4: Top 10 cities or municipalities by number of seizures.**

Province	City/Municipality	Number of Seizures	% Share in Total Seizures
Metro Manila	Pasay City	15	13.9
Metro Manila	Manila	11	10.2
Metro Manila	Quezon City	8	7.4
Palawan	Puerto Princesa	6	5.6
Palawan	Taytay	5	4.6
Palawan	Rizal	4	3.7
Palawan	Quezon	4	3.7
Palawan	Narra	4	3.7
Palawan	El Nido	3	2.8
Palawan	Aborlan	3	2.8

The same can be said for Palawan province that saw the occurrence of three of the five causative agents (Influenza A(H5N1), *E. coli*, and *Bacillus anthracis*) (Table 5). Palawan province also accounted for 27.8% of all seizures in the Philippines, with cities and municipalities like Puerto Princesa City (5.6%), Taytay (4.6%), and Narra (3.7%) accounting for the most operations. General Santos City accounted for 29.8% of the volume of seized wildlife followed by Pasay City (10.6% of the total volume), and the municipalities of Rizal (8.0%) and Narra (7.0%) in Palawan. While General Santos City accounted for the largest volume of seized wildlife, it was only implicated in two seizure incidents with one operation leading to the seizure of over 1,600 Tokay geckos.

The identification of Metro Manila and Palawan as hotspots is important not only in the context of curbing IWT but also in identifying potential origins of zoonoses. The significant trade in implicated hosts of epidemic-prone pathogens in these areas, which are centers of trade and tourism, is concerning and should be taken into account in epidemic monitoring. In the context of the One Health framework, these should be considered as hotspots not only by the DENR-BMB but also by the DOH and other health-related institutions. Additionally, Metro Manila is also a common seizure site for *C. psittaci* and *T. gondii*, the most common zoonoses identified from traded wildlife but neither of which is identified by the PIDSRS as pathogens of concern. It might be a critical preemptive step for the potential of these pathogens to become epidemics to be studied, especially because of the high rate of emergence of infectious diseases in

recent years (Allen et al. 2017). Allen et al. (2017) identify the Philippines as being a high-risk area for EID from wildlife.

## CONCLUSION

The consideration of the impacts of wildlife trade on public health invites a rethinking of disease surveillance activities in the Philippines that rely primarily on the reporting of local health units and routine collection and analysis of data from DENR and the DOH among other agencies (Manual of Procedures for the Philippine Integrated Disease Surveillance and Response 2014). This approach to surveillance can be enhanced with baselines on what zoonotic agents may be introduced to populations through trade as opposed to responding to diseases that may potentially cause outbreaks as they come. Pathogens of avian origin such as *C. psittaci* and A(H5N1) were the most frequently associated with seized wildlife. Some of the seized wildlife that were found to be associated with some zoonotic pathogens were also wildlife of conservation concern—like the Philippine pangolin *M. culionensis* and the Luzon bleeding heart *Gallicolumba luzonica* (Scopoli, 1786). Five of the pathogens associated with epidemic-prone diseases are found in traded wildlife, including *G. religiosa*, one of the most heavily traded in the Philippines. There was a concentration of seizures in the provinces of Metro Manila and Palawan, but more importantly most of the causative agents of the identified epidemic prone diseases in the PIDSRS may have also occurred here, making them hotspots not only for IWT but also potentially for EID outbreaks. This emphasizes the need for a One Health perspective in the understanding of IWT and zoonotic outbreaks as the consequences of the IWT will contribute to economic and public health problems through its

impacts to local wildlife, livestock, and human health (Bezerra-Santos et al. 2021).

Knowing the disease agents, animal hosts, and possible disease outbreak hotspots leads to the following recommendations with the One Health approach in mind:

1. The PIDSRS could be updated. The last known assessment of the framework was in 2015 when Gallardo et al. published their evaluation of the surveillance systems of Eastern Visayas 16 months after the region was hit by Typhoon Haiyan. They found that, post-Haiyan, no outbreaks were reported because of the irregular reporting by the surveillance units. As the Philippines grapples with the COVID-19 pandemic and its effects, the PIDSRS will move surveillance units to identify opportunities to improve disease surveillance activities, particularly for diseases that are zoonotic in origin. The additional disease agents, animal hosts, and possible disease outbreak hotspots that were identified through the literature review and analysis of DENR-BMB seizure data will prove helpful as a baseline in this regard, particularly from a preemptive standpoint.
2. Identify priority species for conservation and improve wildlife law enforcement. Among the animal species identified by the DENR-BMB as the most traded, four (Southeast Asian box turtle, hawksbill turtle, Tokay gecko, and Palawan pangolin) have been identified as carriers of pathogens. Identifying target species for

**Table 5: Causative agents of epidemic prone diseases in the PIDSRS and their occurrence in confiscated wildlife and seizure locations.**

Associated Pathogens	Confiscated Wildlife Species	Province	City/ Municipality
<i>Bacillus anthracis</i>	<i>Arctictis binturong</i>	Palawan	Quezon
	<i>Panthera tigris</i>	Metro Manila	Quezon City
<i>Escherichia coli</i>	<i>Boiga dendrophila</i>	Misamis Oriental	Laguindingan
	<i>Boiga dendrophila</i>	Palawan	El Nido
	<i>Cacatua alba</i>	Davao del Sur	Davao City
	<i>Cacatua alba</i>	Metro Manila	Manila
	<i>Cacatua alba</i>	Rizal	Cainta
	<i>Cacatua haematurophygia</i>	Metro Manila	Manila
	<i>Cacatua haematurophygia</i>	Palawan	Rizal
	<i>Cacatua haematurophygia</i>	Palawan	Puerto Princesa City
	<i>Cacatua haematurophygia</i>	Palawan	Narra
	<i>Cacatua haematurophygia</i>	Palawan	El Nido
	<i>Chelus fimbriata</i>	Metro Manila	Quezon City
	<i>Eclectus roratus</i>	Davao del Sur	Davao City
	<i>Eclectus roratus</i>	Metro Manila	Pasay City
	<i>Graptemys geographica</i>	Metro Manila	Quezon City
	<i>Iguana iguana</i>	Metro Manila	Quezon City
<i>Iguana iguana</i>	Metro Manila	Pasay City	
<i>Melopsittacus undulatus</i>	Metro Manila	Quezon City	

Associated Pathogens	Confiscated Wildlife Species	Province	City/ Municipality
Influenza A Virus H5N1	<i>Melopsittacus undulatus</i>	Metro Manila	Manila
	<i>Panthera tigris</i>	Metro Manila	Quezon City
	<i>Psittacus erithacus</i>	Metro Manila	Manila
	<i>Psittacus erithacus</i>	Rizal	Cainta
	<i>Sula leucogaster</i>	Palawan	Rizal
	<i>Acridotheres cristatellus</i>	Davao del Norte	Carmen
	<i>Acridotheres cristatellus</i>	Laguna	Calamba
	<i>Acridotheres cristatellus</i>	Metro Manila	Quezon City
	<i>Acridotheres cristatellus</i>	Metro Manila	Manila
	<i>Acridotheres cristatellus</i>	Nueva Ecija	Cabanatuan City
	<i>Amazona oratrix</i>	Metro Manila	Manila
	<i>Aratinga solstitialis</i>	Cavite	Dasmarinas City
	<i>Aratinga solstitialis</i>	Metro Manila	Pasay City
	<i>Aratinga solstitialis</i>	Rizal	Cainta
	<i>Cacatua alba</i>	Davao del Sur	Davao City
	<i>Cacatua alba</i>	Metro Manila	Manila
	<i>Cacatua alba</i>	Rizal	Cainta
	<i>Corvus macrorhynchos</i>	Metro Manila	Quezon City
	<i>Corvus macrorhynchos</i>	Rizal	Cainta
	<i>Gracula religiosa</i>	Batangas	San Luis
	<i>Gracula religiosa</i>	Batangas	Batangas City
	<i>Gracula religiosa</i>	Davao del Norte	Carmen
	<i>Gracula religiosa</i>	Metro Manila	Pasay City
	<i>Gracula religiosa</i>	Metro Manila	Manila
	<i>Gracula religiosa</i>	Palawan	Rizal
	<i>Gracula religiosa</i>	Palawan	Quezon
	<i>Gracula religiosa</i>	Palawan	Puerto Princesa City
	<i>Gracula religiosa</i>	Palawan	Narra
	<i>Gracula religiosa</i>	Palawan	El Nido
	<i>Gracula religiosa</i>	Palawan	Aborlan
	<i>Gracula religiosa</i>	Quezon	Lucena City
	<i>Lonchura oryzivora</i>	Metro Manila	Quezon City
<i>Melopsittacus undulatus</i>	Metro Manila	Quezon City	
<i>Melopsittacus undulatus</i>	Metro Manila	Manila	
<i>Psittacula eupatria</i>	Cavite	Dasmarinas City	
<i>Pyrrhura molinae</i>	Metro Manila	Manila	
<i>Spilopelia chinensis</i>	Camarines Sur	Libmanan	

Associated Pathogens	Confiscated Wildlife Species	Province	City/ Municipality
	<i>Spilopelia chinensis</i>	Davao del Norte	Carmen
	<i>Streptopelia tranquebarica</i>	Metro Manila	Pasay City
<i>Leptospira</i> sp.	<i>Paradoxurus hermaphroditus</i>	Cavite	Dasmarinas City
	<i>Paradoxurus hermaphroditus</i>	Metro Manila	Pasay City
	<i>Macropus rufogriseus</i>	Sarangani	Glan
	<i>Macropus rufogriseus</i>	Surigao del Norte	Surigao City
<i>Listeria monocytogenes</i>	<i>Petaurus breviceps</i>	Davao del Sur	Davao City
	<i>Petaurus breviceps</i>	Metro Manila	Quezon City
	<i>Petaurus breviceps</i>	Metro Manila	Pasay City

conservation will also require stricter implementation of wildlife laws—ensuring that pet shops and other wildlife facilities have the necessary permits to operate and are compliant with health and safety regulations. Funding and support for wildlife law enforcement and rangers is also necessary to ensure that poaching activities are immediately detected and stopped, and general access to wild habitats is lessened.

- Strengthen the role of the Bureau of Animal Industry (BAI) in the regulation of wild animal consumption and fund research to provide baseline data on wildlife food markets. As the primary government agency tasked with conducting livestock disease research, regulating and inspecting the import, export, and movement of livestock, and enforcing food safety standards, the Bureau will play a central role in reinvigorated strategies that address the increasing interface between human communities and wildlife, particularly in the form of wildlife consumption. It should synergize its efforts with the DENR-BMB and the DOH. At present, research on wildlife food markets in the Philippines is sparse. Their role in the Philippine wildlife trade and potential to be origins of disease outbreaks remains largely unclear or unknown.
- Include One Health in biology and public health curricula. In the general curriculum of biology and public health programs in Philippine universities, which are traditionally taken as preparatory programs for careers in biological research and medicine, there is no explicit integration of the interface between human health and environment health. Certain fundamental courses can be enriched with modules that highlight this connection, particularly through examples of zoonoses from wildlife and their increasing spread the more that human activity encroaches on natural habitats. Special electives can be developed that combine concepts, theories, and applications from these and allied courses in environmental and health sciences. Public health courses like environmental health and health service management can also be so enhanced.

Building on the commendable work that the government has done, the Philippines will greatly benefit from enhanced and strategies that revisit the tight links between public health and environmental health to ensure that no one gets left behind.

## ACKNOWLEDGMENTS

The authors would like to extend their appreciation to the DENR-BMB for their assistance and sharing their datasets.

## CONTRIBUTIONS OF INDIVIDUAL AUTHORS

Conception: MAGL, VJSV, JPHY, RALC; Analysis: MAGL, VJSV, JPHY, RALC; Writing and Reviewing: MAGL, VJSV, RALC; all authors agreed to the submission of this manuscript.

## CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

## REFERENCES

- Acharjyo LN. Helminthiasis in captive wild carnivores and its control in India. *Zoos' Print J* 2004; 19(7):1540-1543.
- [ADB] Asian Development Bank. 2019. Addressing illegal wildlife trade in the Philippines. Metro Manila (Philippines): ADB.
- Ahmed AM, Motoi Y, Sato M, Maruyama A, Watanabe H, Fukumoto Y, Shimamoto T. Zoo animals as reservoirs of gram-negative bacteria harboring integrons and antimicrobial resistance genes. *Appl Environ Microbiol* 2007; 73(20):6686-6690.
- Allen T, Murray KA, Zambrana-Torrel C, Morse SS, Rondinini C, Di Marco M, Breit N, Olival KJ, Daszak P. Global hotspots and correlates of emerging zoonotic diseases. *Nat Commun* 2017; 8. <https://doi.org/10.1038/s41467-017-00923-8> (accessed 17 December 2021).
- Asaoka Y, Yanai T, Hirayama H, Une Y, Saito E, Sakai H, Goryo M, Fukushi H, Masegi T. Fatal necrotic enteritis associated with *Clostridium perfringens* in wild crows (*Corvus macrorhynchos*). *Avian Pathol* 2004; 33(1):19-24.
- Barrows M. Toxoplasmosis in a colony of sugar gliders (*Petaurus breviceps*). *Vet Clin N Am - Exot Anim Pract* 2006; 9(3):617-623.
- [BCSP] Biodiversity Conservation Society of the Philippines. 2020. Philippine Red List of threatened wild fauna, Part I - Vertebrates. Philippines: DENR-BMB.

- Beck R, Sprong H, Bata I, Lucinger S, Pozio E, Cacciò SM. Prevalence and molecular typing of *Giardia* spp. in captive mammals at the zoo of Zagreb, Croatia. *Vet Parasitol* 2011; 175(1-2):40-46.
- Bermúdez R, Failde LD, Losada AP, Nieto JM, Quiroga MI. Toxoplasmosis in Bennett's wallabies (*Macropus rufogriseus*) in Spain. *Vet Parasitol* 2009; 160(1-2):155-158.
- Bezerra-Santos MA, Mendoza-Roldan JA, Thompson RC, Dantas-Torres F, Otranto D. Illegal Wildlife Trade: A Gateway to Zoonotic Infectious Diseases. *Trends Parasitol* 2021; 37(3):181-184.
- Boseret G, Losson B, Mainil JG, Thiry E, Saegerman C. Zoonoses in pet birds: review and perspectives. *Vet Res* 2013; 44(1):1-7.
- Brooks-Moizer F, Robertson SI, Edmunds K, Bell D. Avian influenza H5N1 and the wild bird trade in Hanoi, Vietnam. *Ecol Soc* 2009; 14(1).
- Brown JD, Stallknecht DE, Swayne DE. Experimental infection of swans and geese with highly pathogenic avian influenza virus (H5N1) of Asian lineage. *Emerg Infect Dis* 2008; 14(1):136.
- Carvalho FR, DebRoy C, Baeza E, Hinckley L, Gilbert K, Choi SJ, Risatti G, Smyth JA. Necrotizing pneumonia and pleuritis associated with extraintestinal pathogenic *Escherichia coli* in a tiger (*Panthera tigris*) cub. *J Vet Diagn Invest* 2010; 22(1):136-140.
- Castro-Silva MA, Manoel FC, Krueger J, Barreiros MA, Branco JO. Identificação de bactérias potencialmente patogênicas a humanos presentes em *Sula leucogaster* (Suliformes: Sulidae), no litoral de Santa Catarina, Brasil *Rev Bras Ornitol* 2011; 19(4):520-524.
- CDC. One Health Basics. <https://www.cdc.gov/onehealth/basics/index.html>, 2018. (accessed 30 May 2020).
- Chahota R, Ogawa H, Mitsuhashi Y, Ohya K, Yamaguchi T, Fukushi H. Genetic diversity and epizootiology of *Chlamydophila psittaci* prevalent among the captive and feral avian species based on VD2 region of ompA gene. *Microbiol Immunol* 2006; 50(9):663-678.
- Chen JC, Tsai YJ, Wu YL. Seroprevalence of *Toxoplasma gondii* antibodies in wild birds in Taiwan. *Res Vet Sci* 2015; 102:184-188.
- Chin SC, Lien CY, Chan Y, Chen CL, Yang YC, Yeh LS. Hematologic and serum biochemical parameters of apparently healthy rescued Formosan pangolins (*Manis pentadactyla pentadactyla*). *J Zoo Wildl Med* 2015; 68-76.
- Ching PKG, de los Reyes VC, Sucaldito MN, Tayag E, Columna-Vingno AB, Malbas Jr. FD, Bolo Jr. GC, Sejvar JJ, Eagles D, Playford G, Dueger E, Kaku Y, Morikawa S, Kuroda M, Marsh GA, McCullough S, Foxwell AR. Outbreak of Henipavirus Infection, Philippines, 2014. *Emerg Infect Dis* 2015; 21(2):328-331.
- Cho H, Liu L, Liu K, Zhu Y, Dziong M, Lu L, Yang X. Phenotypic characterization and phylogenetic analysis of a virulent *Bacillus cereus* strain from the Tiger frog, *Hoplobatrachus rugulosus* Wiegmann. *Afr J Microbiol Res* 2010; 4(24):2780-2786.
- Cho HS, Kim YH, Park NY. Disseminated mycobacteriosis due to *Mycobacterium avium* in captive Bengal tiger (*Panthera tigris*). *J Vet Diagn Invest* 2006; 18(3):312-314.
- Colinon C, Jocktane D, Brothier E, Rossolini GM, Cournoyer B, Nazaret S. Genetic analyses of *Pseudomonas aeruginosa* isolated from healthy captive snakes: evidence of high inter- and intrasite dissemination and occurrence of antibiotic resistance genes. *Environ Microbiol* 2010; 12(3):716-729.
- Cope I, Wheelhouse N, Pocknell A, Dagleish M, Summers B. An unusual presentation of *Chlamydia pneumoniae* infection in a Royal Python (*Python regius*). *Vet Rec Case Rep* 2014; 2(1):e000086.
- Cousins D. *Mycobacterium bovis*: an extraordinary pathogen. *Microbiol Aust* 2004; 25(4):15-17.
- Cruz RAL, Lagunzad CGB. The big picture: Consolidating national government and CITES records of animal trade in the Philippines from 1975 to 2019. *Philipp Sci Lett* 2021; 14:79-100.
- De Camps S, Dubey JP, Saville WJ. Seroepidemiology of *Toxoplasma gondii* in zoo animals in selected zoos in the midwestern United States. *J Parasitol* 2008; 94(3):648-653.
- De Schrijver K. A psittacosis outbreak in Belgium customs officers. *Euro Surveill* 1995; 0(0):173.
- DENR-BMB. Paje: DENR won't tolerate illegal wildlife trade. <http://www.dnr.gov.ph/news-and-features/latest-news/1907-paje-dnr-wont-tolerate-illegal-wildlife-trade.html>, 2014. (accessed 18 March 2016).
- Dubey JP. Outbreaks of clinical toxoplasmosis in humans: five decades of personal experience, perspectives and lessons learned. *Parasit Vectors* 2021; 14(1).
- Duron O, Jourdain E, McCoy KD. Diversity and global distribution of the *Coxiella* intracellular bacterium in seabird ticks. *Ticks Tick Borne Dis* 2014; 5(5):557-563.
- Edeson JF, Wilson T. The epidemiology of filariasis due to *Wuchereria bancrofti* and *Brugia malayi*. *Annu Rev Entomol* 1964; 9(1):245-268.
- Enano J. PH losing P50B a year to Illegal Wildlife Trade. <https://newsinfo.inquirer.net/1155025/ph-losing-p50b-a-year-to-illegal-wildlife-trade>, 2019. (accessed 30 May 2020).
- Fagiolini M, Lia RP, Laricchiuta P, Cavicchio P, Mannella R, Cafarchia C, Otranto D, Finotello R, Perrucci S. Gastrointestinal parasites in mammals of two Italian zoological gardens. *J Zoo Wildl Med* 2010; 41(4):662-670.
- Fasaei BN, Tamai IA. Detection of *Salmonella* spp. from zoo animals in Iran, determination of serovars, antibiotic susceptibility and genotyping by RAPD-PCR. *J Hell Vet Medical Soc* 2017; 68(3):377-384.
- Flammer K, Drewes LA. Species-related differences in the incidence of gram-negative bacteria isolated from the cloaca of clinically normal psittacine birds. *Avian Dis* 1988; 1:79-83.

- Foti M, Giacopello C, Fisichella V, Latella G. Multidrug-resistant *Pseudomonas aeruginosa* isolates from captive reptiles. *J Exot Pet Med* 2013; 22(3):270-274.
- Gallardo FDL, de los Reyes VC, Sucaldito MN, Ligon-Imperio L, Peñas J, Rebato N, Tayag E, 2015. An assessment of the case notification system 16 months after Typhoon Haiyan in Region 8, the Philippines. *Western Pac Surveill Response J* 2015; 6(1):71-75.
- George RH. 14 Health Problems and Diseases of Sea Turtles. In *The Biology of Sea Turtles, Volume I* 2017. CRC Press LLC, Boca Raton, FL.
- Geue L, Löschner U. *Salmonella enterica* in reptiles of German and Austrian origin. *Vet Microbiol* 2002; 84(1-2):79-91.
- Gilbert M, Sokha C, Joyner PH, Thomson RL, Poole C. Characterizing the trade of wild birds for merit release in Phnom Penh, Cambodia and associated risks to health and ecology. *Biol Conserv* 2012; 153:10-16.
- Gonzalez JCT, Layusa CAA, Afuang LE, Duya MRM, Heaney LR, Balete DS, Tabaranza DGE, Española CP, van de Ven WA, Diesmos AC, Causaren RM, Diesmos MLL, Lagat RTL, Realubit NDC, Sy EY, Lit Jr IL, Naredo JCB, Lastica-Ternura EA, Pasicolan SA, Tagtag AM, De Leon JL, Lim TMS, Ong PS. Review and update of the 2004 National List of Threatened Terrestrial Fauna of the Philippines. *Sylvatrop* 2018; 28(1):73-144.
- Greatorex Z, Olson S, Singhalath S, Silithammavong S, Khammavong K, Fine A, Weisman W, Douangngeun B, Theppangna W, Keats L, Gilbert M, Karesh WB, Hansel T, Zimicki S, O'Rourke S, Joly DO, Mazet JAK. Wildlife Trade and Human Health in Lao PDR: An Assessment of the Zoonotic Disease Risk in Markets. *PLOS One* 2016; 1-17.
- Hinney B, Sak B, Joachim A, Kvač M. More than a rabbit's tale—*Encephalitozoon* spp. in wild mammals and birds. *Int J Parasitol Parasites Wildl* 2016; 5(1):76-87.
- Hu G, Li D, Su X, Li T, He J. Phylogenetic diversity of external and internal bacteria associated with soft-shelled turtle (*Trionyx sinensis*). *J Fish Sci* 2010; 29(7):393-398.
- Hugh-Jones ME, De Vos V. Anthrax and wildlife. *OIE Rev Sci Tech* 2002; 21(1):359-384.
- Hydaskov HB, Guardabassi L, Aalbaek B, Olsen KE, Nielsen SS, Bertelsen MF. *Salmonella* prevalence among reptiles in a zoo education setting. *Zoonoses Public Health* 2013; 60(4):291-295.
- Ioannou I, Chochlakakis D, Kasinis N, Anayiotos P, Lyssandrou A, Papadopoulos B, Tselentis Y, Psaroulaki, A. Carriage of *Rickettsia* spp., *Coxiella burnetii* and *Anaplasma* spp. by endemic and migratory wild birds and their ectoparasites in Cyprus. *Clin Microbiol Infect* 2009; 15:158-160.
- Jayne SI, Field HE, de Jong C, Olival KJ, Marsh G, Tagtag AM, Hughes T, Bucad AC, Barr J, Azul RR, Retes LM. Molecular evidence of Ebola Reston virus infection in Philippine bats. *Virology* 2015; 12(1):1-8.
- Jho YS, Park DH, Lee JH, Lyoo YS. Aerobic bacteria from oral cavities and cloaca of snakes in a petting zoo. *Korean J Vet Res* 2011; 51(3):243-247.
- Jones MP, Orosz SE. The diagnosis of aspergillosis in birds. *Semin Avian Exot Pet Med* 2000; 9(2):52-58.
- Jongthawin J, Intapan PM, Sanpool O, Sadaow L, Laymanivong S, Thanchomnang T, Maleewong W. Molecular evidence of *Spirometra erinaceieuropaei* infection in snakes *Ptyas korros* from Lao PDR and Thailand and frogs *Hoplobatrachus rugulosus* from Myanmar. *Southeast Asian J Trop Med Public Health* 2014; 45(6):1271.
- Kaleta EF, Taday EM. Avian host range of *Chlamydophila* spp. based on isolation, antigen detection and serology. *Avian Pathol* 2003; 32(5):435-462.
- Karesh WB, Dobson A, Lloyd-Smith JO, Lubroth J, Dixon MA, Bennett M, Aldrich S, Harrington T, Formenty P, Loh EH, MacHalaba CC, Thomas MJ, Heymann DL. Ecology of zoonoses: Natural and unnatural histories. *Lancet* 2012; 380(9857):1936-1945.
- Kašičková D, Sak B, Kvač M, Ditrich O. Sources of potentially infectious human microsporidia: molecular characterisation of microsporidia isolates from exotic birds in the Czech Republic, prevalence study and importance of birds in epidemiology of the human microsporidial infections. *Vet Parasitol* 2009; 165(1-2):125-130.
- Kawamura M, Nerome K, Kodama H, Izawa H, Mikami T. Serological and pathological studies of Newcastle disease viruses isolated from caged birds from southeast Asia. *Avian Dis* 1987; 564-569.
- Keesing F, Ostfeld RS. Impacts of biodiversity and biodiversity loss on zoonotic diseases. *Proc Natl Acad Sci USA* 2021; 118:e2023540118.
- Keymer IF. Diseases of birds of prey. *Vet Rec* 1972; 90(21):579-594.
- Knittler MR, Sachse K. *Chlamydia psittaci*: update on an underestimated zoonotic agent. *Pathog Dis* 2015; 73(1):1-15.
- Komar N. West Nile virus: epidemiology and ecology in North America. *Adv Virus Res* 2003; 61:185-234.
- Lafortune M, Wellehan JF, Terrell SP, Jacobson ER, Heard D, Kimbrough JW. Shell and systemic hyalohyphomycosis in Fly River turtles, *Carettochelys insculpta*, caused by *Paecilomyces lilacinus*. *J Herpetol Med Surg* 2005; 15(2):15-19.
- Lam TTY, Jia N, Zhang YW, Shum MHH, Jiang JF, Zhu HC, Tong YG, Shi YX, Ni XB, Liao YS, Li WJ, Jiang BG, Wei W, Yuan TT, Zheng K, Cui XM, Li J, Pei GQ, Qiang X, Cheung WYM, Li LF, Sun FF, Qin S, Huang JC, Leung GM, Holmes EC, Hu YL, Guan Y, Cao WC. Identifying SARS-CoV-2-related coronaviruses in Malayan pangolins. *Nature* 2020; 583:282-285.
- Latney LV, Wellehan J. Selected emerging infectious diseases of squamata. *Vet Clin North Am Exot Anim Pract* 2013; 16:319-338.
- Laveran M. An sujet de I hematzoaize andoglobaliaze de padda oryzirod. *C'ompterendu Soc Biol*, 1900; 25:14-20.
- Lee SY, Lee SS, Lyoo YS, Park HM. DNA detection and genotypic identification of potentially human-pathogenic microsporidia from asymptomatic pet parrots in South Korea

- as a risk factor for zoonotic emergence. *Appl Environ Microbiol* 2011; 77(23):8442-8444.
- Long P, Choi G, Silberman M. Nocardiosis in two Pesquet's parrots (*Psittrichas fulgidus*). *Avian Dis* 1983; 855-859.
- Maluping RP, Oronan RB, Toledo SU. Detection of *Chlamydophila psittaci* antibodies from captive birds at the Ninoy Aquino Parks and Wildlife Nature Center, Quezon city, Philippines. *Ann Agric Environ Med* 2007; 14(1).
- Mancianti F, Nardoni S, Ceccherelli R. Occurrence of yeasts in psittacines droppings from captive birds in Italy. *Mycopathologia* 2002; 153(3):121-124.
- Manual of Procedures for the Philippine Integrated Disease Surveillance and Response 2014, Third Edition. Manila: National Epidemiology Center, Department of Health, 2014.
- Maricopa County Department of Public Health. West Nile Virus in Maricopa County Background, Surveillance and Plan of Action. [https://prism.lib.asu.edu/flysystem/fedora/c16/110030/West\\_Nile\\_Virus\\_in\\_Maricopa\\_County...Plan\\_of\\_Action.pdf](https://prism.lib.asu.edu/flysystem/fedora/c16/110030/West_Nile_Virus_in_Maricopa_County...Plan_of_Action.pdf), 2003. (accessed 16 May 2016).
- McDonnell PA, Scott KE, Teoh DA, Olson ME, Upcroft JA, Upcroft P, Buret AG. *Giardia duodenalis* trophozoites isolated from a parrot (*Cacatua galerita*) colonize the small intestinal tracts of domestic kittens and lambs. *Vet Parasitol* 2003; 111(1):31-46.
- Mingrone MG, Fantasia M. Characteristics of *Yersinia* spp. isolated from wild and zoo animals. *J Wildl Dis* 1988; 24(1):25-29.
- Mohapatra RK, Panda S, Nair MV, Acharjyo LN. Check list of parasites and bacteria recorded from pangolins (*Manis* sp.). *J Parasit Dis* 2016; 40(4):1109-1115.
- National Center for Immunization and Respiratory Diseases. Multistate Psittacosis Outbreak among Poultry Plant Workers, 2018. Centers of Disease Control 2018. <https://www.cdc.gov/pneumonia/atypical/psittacosis/surveillance-reporting/outbreaks/2018-poultry-multistate-investigation.html> (accessed 17 December 2021).
- Nichols M, Takacs N, Ragsdale J, Levenson D, Marquez C, Roache K, Tarr CL. *Listeria monocytogenes* Infection in a Sugar Glider (*Petaurus breviceps*)—New Mexico, 2011. *Zoonoses Public Health* 2015; 62(4):254-257.
- Oronan RB, Licuan DA, Licuan DA, Santos JP, Lastica EA. Detection of antibodies against *Toxoplasma gondii* and *Chlamydophila felis* in Malayan Civets (*Viverra zibetha*), Palawan Bearcats (*Arctictis binturong whitei*) and Asian Palm Civets (*Paradoxurus hermaphroditus*) at a wildlife facility in Quezon City, Phils. *Philipp J Vet Anim Sci* 2014; 39(2).
- Oros J, Acosta B, Gaskin JM, Deniz S, Jensen HE. *Mycobacterium kansasii* infection in a Chinese soft shell turtle. *Vet Rec* 2003; 152(15):474-476.
- Oros J, Rodriguez JL, Fernandez A, Herraes P, de los Monteros AE, Jacobson ER. Simultaneous occurrence of *Salmonella arizonae* in a sulfur crested cockatoo (*Cacatua galerita galerita*) and iguanas. *Avian Dis* 1998; 818-823.
- Pavlin BI, Schloegel LM, Daszak P. Risk of Importing Zoonotic Diseases through Wildlife Trade, United States. *Emerg Infect Dis* 2009; 15(11):1721-1726.
- Pedersen K, Marks DR, Wang E, Eastwood G, Weaver SC, Goldstein SM, Sinnott DR, DeLiberto TJ. Widespread detection of antibodies to eastern equine encephalitis, West Nile, St. Louis encephalitis, and Turlock viruses in various species of wild birds from across the United States. *Am J Trop Med Hyg* 2016; 95(1):206.
- Pedraza-Díaz S, Ortega-Mora LM, Carrión BA, Navarro V, Gómez-Bautista M. Molecular characterisation of *Cryptosporidium* isolates from pet reptiles. *Vet Parasitol* 2009; 160(3-4):204-210.
- Peñas JA, Miranda ME, de los Reyes VC, Sucaldito MN, Magpantay RL. Risk assessment of Ebola Reston virus in humans in the Philippines. *Western Pac Surveill Response J* 2019; 10(3):1-8.
- Perez JM. Assessment of the hematocrit, erythrocyte and thrombocyte count and the detection of *Chlamydophila psittaci* antibodies in the blood serum of captive Philippine Eagle-owls (*Bubo philippensis*) using ELISA Kits for felines and avians. Undergraduate Theses 2012.
- Petersen KD, Christensen JP, Permin A, Bisgaard M. Virulence of *Pasteurella multocida* subsp. *multocida* isolated from outbreaks of fowl cholera in wild birds for domestic poultry and game birds. *Avian Pathol* 2001; 30(1):27-31.
- Phong SF, Aini I, Salim N, Al-Ajeeli KS. Detection and Identification of *Chlamydophila psittaci* from Wild Spotted Doves. *J Vet Malaysia* 2006; 18(2):23-27.
- Pires SF. The illegal parrot trade: A literature review. *Glob Crime* 2012; 13:176-190.
- Posa MRC, Diesmos AC, Sodhi NS, Brooks TM. Hope for threatened tropical biodiversity: Lessons from the Philippines. *Bioscience* 2008; 58(3).
- Prociv P, Carlisle MS. The spread of *Angiostrongylus cantonensis* in Australia. *Southeast Asian J Trop Med Public Health* 2001; 32:126-128.
- Quist EM, Belcher C, Levine G, Johnson M, Heatley JJ, Kiupel M, Giri D. Disseminated histoplasmosis with concurrent oral candidiasis in an Eclectus parrot (*Eclectus roratus*). *Avian Pathol* 2011; 40(2):207-211.
- Raso TF, Werther K, Miranda ET, Mendes-Giannini MJ. Cryptococcosis outbreak in psittacine birds in Brazil. *Med Mycol* 2004; 42(4):355-362.
- Reboredo-Fernandez A, Ares-Mazas E, Caccio SM, Gomez-Couso H. Occurrence of *Giardia* and *Cryptosporidium* in wild birds in Galicia (Northwest Spain). *Parasitology* 2015; 142(7):917-925.
- Roberts MW, Smythe L, Dohnt M, Symonds M, Slack A. Serologic-based investigation of leptospirosis in a population of free-ranging eastern grey kangaroos (*Macropus giganteus*) indicating the presence of *Leptospira weilii* serovar Topaz. *J Wildl Dis* 2010; 46(2):564-579.
- Roh YS, Park H, Cho A, Islam MR, Chekarova I, Ejaz SE, Lim CW, Kim B. Granulomatous pneumonia in a captive



- freshwater crocodile (*Crocodylus johnstoni*) caused by *Mycobacterium szulgai*. *J Zoo Wildl Med* 2010; 41(3):550-554.
- Samaniego CA, Lastica-Ternura EA, Acorda JA, Pajas AM, Lola MS. Macroscopic And Microscopic Findings in the Liver, Gallbladder, Spleen and Kidneys of Captive Reticulated Pythons (*Python reticulatus*, Schneider, 1801)(Reptilia: Pythonidae) with Pneumonia. *Philipp J Vet Anim Sci* 2015; 41(1).
- Santoro M, Hernández G, Caballero M, García F. Aerobic bacterial flora of nesting green turtles (*Chelonia mydas*) from Tortuguero National Park, Costa Rica. *J Zoo Wildl Med* 2006; 37(4):549-552.
- Shin SP, Kim JH, Gomez DK, Choresca Jr CH, Han JE, Park SC. Isolation and characterization of *Morganella morganii* from Asian water monitor *Varanus salvator*. *J Vet Clin* 2009; 26(4):391-394.
- Shima AL, Osborn KG. An epornitic of *Salmonella typhimurium* in a collection of lorries and lorikeets. *J Zoo Wildl Med* 1989; 373-376.
- Shrivastav AB, Singh KP, Bhat MA, Mishra A. Occurrence of *Gnathostoma spinigerum* in free range tigress. *J Parasit Dis* 2011; 35(1):75-76.
- Sims LD, Domenech J, Benigno C, Kahn S, Kamata A, Lubroth J, Martin V, Roeder P. Origin and evolution of highly pathogenic H5N1 avian influenza in Asia. *Vet Rec* 2005; 157(6):159-164.
- Sugita H, Deguchi Y. Microflora in the gastrointestinal tract of soft-shelled turtle *Trionyx sinensis*. *Bull Jpn Soc Sci Fish* 1983; 49(2):197-201.
- Suksai P, Lorsunyaluck B, Dittawong P, Sanyathitiseree P, Lertwatcharasarakul P. Genetic detection and identification of *Chlamydophila psittaci* in captive Psittacine birds in Thailand. *Wetchan Sattawaphaet* 2016; 46(1):67.
- Sy EY, Schoppe S, Diesmos MLL, Lim TMS, Diesmos AC. Endangered by trade: Seizure analysis of the critically endangered Philippine forest turtle *Siebenrockiella leytensis* from 2004–2018. *Philipp J Syst Biol* 2020; 14:1-8.
- Sykes IV JM, Ramsay EC. Attempted treatment of tigers (*Panthera tigris*) infected with *Microsporium canis*. *J Zoo Wildl Med* 2007; 252-257.
- Sylvester WR, Amadi V, Hegamin-Younger C, Pinckney R, Macpherson CN, McKibben JS, Bruhl-Day R, John-Sylvester KD, Hariharan H. Occurrence of antibiotic resistant *Escherichia coli* in green iguanas (*Iguana iguana*) in Grenada, West Indies. *Int J Vet Med Res Rep* 2014; 2014:1-8.
- Tanimura N, Tsukamoto K, Okamatsu M, Mase M, Imada T, Nakamura K, Kubo M, Yamaguchi S, Irishio W, Hayashi M, Nakai T. Pathology of fatal highly pathogenic H5N1 avian influenza virus infection in large-billed crows (*Corvus macrorhynchos*) during the 2004 outbreak in Japan. *Vet Pathol* 2006; 43(4):500-509.
- Taylor LH, Latham SM, Woolhouse MEJ. Risk factors for human disease emergence. *Philos Trans R Soc B Biol Sci* 2001; 356(1411):983-989.
- Thiangtum K, Nimsuphun B, Pinyopanuwat N, Chimnoi W, Tunwattana W, Tongthainan D, Jittapalpong S, Rukkamsuk T, Maruyama S. Seroprevalence of *Toxoplasma gondii* in captive felids in Thailand. *Vet Parasitol* 2006; 136(3-4):351-355.
- To H, Sakai R, Shiota K, Kano C, Abe S, Sugimoto T, Takehara K, Morita C, Takashima I, Maruyama T, Yamaguchi T. Coxiellosis in domestic and wild birds from Japan. *J Wildl Dis* 1998; 34(2):310-316.
- Uproft JA, McDonnell PA, Gallagher AN, Chen N, Uproft P. Lethal *Giardia* from a wild-caught sulphur-crested cockatoo (*Cacatua galerita*) established in vitro chronically infects mice. *Parasitology* 1997; 114(5):407-12.
- Venter M, Swanepoel R. West Nile virus lineage 2 as a cause of zoonotic neurological disease in humans and horses in southern Africa. *Vector Borne Zoonotic Dis* 2010; 10(7):659-664.
- Wang CM, Shia WY, Jhou YJ, Shyu CL. Occurrence and molecular characterization of reptilian *Campylobacter fetus* strains isolated in Taiwan. *Vet Microbiol* 2013; 164(1-2):67-76.
- Wang LF, Crameri G. Emerging zoonotic viral diseases. *OIE Rev Sci Tech* 2014; 33(2):569-581.
- Weston MK, Memon MA. The illegal parrot trade in Latin America and its consequences to parrot nutrition, health and conservation. *Bird Populations* 2009; 9:76-83.
- White FH. *Edwardsiella tarda*. In *Diseases of amphibians and reptiles* 1984 (pp. 83-92). Springer, Boston, MA.
- [WHO] World Health Organization. One Health. <https://www.who.int/news-room/q-a-detail/one-health>, 2017. (accessed 30 May 2020).
- Wicker LV, Canfield PJ, Higgins DP. Potential pathogens reported in species of the family Viverridae and their implications for human and animal health. *Zoonoses Public Health* 2017; 64(2):75-93.
- Woolhouse MEJ, Haydon DT, Antia R, 2005. Emerging pathogens: The epidemiology and evolution of species jumps. *Trends Ecol Evol* 2005; 20(5):238-244.
- Xing Y, Schmitt HJ, Arguedas A, Yang J. Tick-borne encephalitis in China: a review of epidemiology and vaccines. *Vaccine* 2017; 35(9):1227-1237.
- Xu J, Chen Y, Chen H, Cao B. 2019 novel coronavirus outbreak: a quiz or final exam? *Front Med* 2020; 14(2):225-228.
- Xu T, Zhang XH. *Edwardsiella tarda*: an intriguing problem in aquaculture. *Aquaculture* 2014; 431:129-135.
- Yilmaz R, Yumuşak N. An Athrax Outbreak in Wild Felidae Kept in a Local Zoo. In Presented at VII. Veterinary Pathology Congress 08th-10th September 2015 May 1 (Vol. 1, p. 1).
- Zeira O, Briola C, Konar M, Dumas MP, Wrzosek MA, Papa V. Suspected neurotoxicity due to *Clostridium perfringens* type B in a tiger (*Panthera tigris*). *J Zoo Wildl Med* 2012; 43(3):666-669.