

THE ROLE OF CONSERVATION IN PUBLIC HEALTH

By

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Abstract

This is a report of my field experience (240 hours) completed at the Soltis Center and Monteverde Institutions in Costa Rica during the summer of 2015. Under the supervision of Dr. Raymond Tarpley, the director of the Conservet Program, the course explores concepts related to conservation and facilitates collaboration amongst veterinary students, veterinarians, biologists, and ecologists to identify levels of health dysfunction in the ecosystem and establish methods of intervention to protect public health.

The Conservet Program included lecture-based discussions with local professionals about the biodiversity in Costa Rica, disease ecology, drivers of global health dysfunction, and conservation strategies. The course also provided opportunities for fieldwork data collection from two different eco-zones of rain forest and local farms to explore the complexity of environmental function. The fieldwork focused on birds, bats, rodents, local livestock, fish, and mosquitoes as sentinels for disease and ecosystem health. Diseases investigated include Dengue, Chikungunya, Chagas Disease, West Nile Virus, and Avian Influenza. With a focus on conservation, this program allowed me to develop a greater understanding of public health from studying the interface between human, animal, and environmental health.

This report describes my field experience in Costa Rica and discusses the relevance of conservation efforts as it affects public health. The key to understanding emerging infectious diseases is to understand the protective effects of nature intact, and recognize the consequences of destroying it. This report will also discuss the MPH core competency courses and how they relate to my field experience.

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Chapter 1 - Costa Rican Ecology

For a country roughly the same size as the state of West Virginia, Costa Rica is home to 5% of the world's biodiversity, encompassing more than the North American countries combined (Institute for Global Health and Health Policy, 2013). With two coasts and a mountainous system, numerous varied eco-zones exist in Costa Rica that house over 500,000 identified species from the beaches to the rainforests. The mountains offer a high altitude change throughout the central part of the country creating these eco-zones with different ranges of precipitation and temperature. Each zone is characterized according to the latitudinal belt of its location, humidity level, and elevation (National Biodiversity Institute, 2016). With only 51,100 km² of total land and 5% of the world's biodiversity, Costa Rica is often cited as having the highest species per area unit in the world. For this reason, the government of Costa Rica has declared roughly 25% of the country's territory as protected areas and has created many national parks surrounding over 60 volcanoes (Institute for Global Health and Health Policy, 2013).

Costa Ricans take great pride in their country as it is truly beautiful and peaceful. The Pacific Coast is home to the Spanish speaking "Ticos" (Costa Ricans) while the Caribbean side is home to a more English-speaking, Jamaican influenced African-Caribbean culture (Institute for Global Health and Health Policy, 2013). Costa Rica was the first country to constitutionally abolish the use of a national army (National Biodiversity Institute, 2016). This allowed a considerable amount of the national budget to go towards education and conservation. The additional funding is now available to protect such a wealth of biodiversity within their borders. There are countless benefits towards preserving these ecosystems that affect not only plant and animal life, but human life as well.

Diversity among Rainforests

Upon abolishing the national army, more funding has been available for Costa Rica to utilize in efforts to protect its biological diversity. Numerous incentive programs have been developed to sustainably manage the forests in this country, which currently cover 46.8% of land area; however, at one point 99% of Costa Rica was forested. During the 1970s and early 1980s, vast stretches of rainforest were destroyed and converted to farmland, cattle pastures, and urban development (Butler, 2006). Today, deforestation rates have declined considerably, yet it's still an active problem in the form of illegal timber harvesting and land loss in unprotected areas. Approximately two-thirds of the remaining rainforests are protected today, rivaling any other international conservation effort across the globe. In turn, eco-tourism has become one of the most important sources of revenue for Costa Rica (National Biodiversity Institute, 2016). In addition to the revenue incentive, preserving the rainforests of Costa Rica carries moral and ecological value as it is home to many unique types of rainforests, unknown to much of the world.

Cloud Forests

Cloud forests are formed by a combination of wind and geography. Trade winds flow from the northeast across the Caribbean Sea, driving moist air into the Cordillera Tilaran. These mountains push air up, causing it to cool and expand – excess humidity coalesces forming tiny droplets, mist, and clouds (Janzen, Hallwachs, & Joyce, 2016). The mountain peaks enveloped with trade wind-derived clouds can capture enormous amounts of water, especially when covered with tropical cloud forests. Vegetation such as mosses, ferns, and bromeliads increase surface area for water absorption, preventing erosion and releasing water vapor into the atmosphere. These high altitude cloud forests that typically inhabit areas greater than 1100

meters elevation, are a hauntingly beautiful site to witness in Costa Rica. The cloud forests offer a home to unique species of plant and animal life, different from those inhabiting lowland tropical rainforests – such as shorter tree heights, abundance of moss, and consistently damp, cloudy conditions (Butler, 2006).

Rain Forests

Rainforests differ from cloud forests primarily in their elevation. Rainforests are typically lower in elevation at 90-1000 m, near sea-level and are subject to much higher temperatures. Rainforests receive at least 80 inches of rain per year (Janzen, Hallwachs, & Joyce, 2016). The trees are much higher in rainforests compared to cloud forests, forming canopies of high branches and leaves. Warmer temperatures welcome a greater diversity of species. The diversity of trees, plants, insects, and wildlife is unmatched by any other ecological zone. An estimated 200,000+ species of organisms inhabit the rainforests (Butler, 2006).

Current Protection Efforts

While a considerable amount of land is under national protection in Costa Rica, there are many challenges facing conservation efforts. Costa Rica has several conservation agencies present throughout the country, for example, Osa Conservation in the peninsular region, and Area de Conservacion in Guanacaste. Agencies such as these, have countless programs in place attempting to conserve habitats, in addition to reestablishing wildlife and plant populations throughout the country. These agencies provide jobs in the form of parataxonomists, guards, environmental educators, and ecotourism guides that not only employ the locals, but also provide a direct link between conservation and economic development (Osa Conservation, 2016). However, government inconsistencies with environmental policies have led to inappropriate distribution of funds meant to support conservation. For example, a portion of the taxes collected

in Costa Rica are intended to go towards conservation; however, oftentimes the amounts are varied and inappropriately distributed. These conservation agencies are often undermined and left seeking funding outside of the country (McShane and Wells, 2004).

In spite of corruption and inefficiency, Costa Rica does provide some model work of conservation strategies that can be implemented internationally. For example, “Polluter Pays” principles in urban sectors of the country financially support conservation in the rural sector (McShane and Wells, 2004). Creation of protected areas with endowments for management pay market price for land and then provide direct employment of the locals in all activities linked to conservation for that protected area. Such strategies provide incentive for the locals to collaborate towards a common goal of conservation. Not only do the conservation projects provide jobs creating a monetary incentive, but the positions involve the people in projects that create an emotional incentive and sense of pride to protect their country’s resources (Osa Conservation, 2016).

Biological Corridors

National parks are vital to biodiversity conservation; however, often they are not sufficient in surface area to sustain viable wildlife populations and ecosystems. In order to increase surface area and connect the dots of protected land, biological corridors have become a topic of interest to those involved in conservation. Biological corridors are meant to connect two protected areas of forest in order to preserve structure of the ecosystem and avoid isolation of species (Osa Conservation, 2016). By linking protected areas, surface area is increased substantially to maintain greater genetic diversity among species, which in turn, prevents loss of biodiversity. Isolated protected areas are at a disadvantage to an extent, regardless of their protection from habitat destruction. Over time, species become less and less genetically diverse –

they are exposed to a limited population and inbreeding inevitably occurs (McShane and Wells, 2004). This can be detrimental to species in the event of disease outbreaks and environmental adversity, as it results in the majority of the population becoming susceptible to the same things.

Corridors are becoming more and more important with climate change. Species are able to alter their distribution to areas more suited to their specific requirements as the weather changes and resources deplete. Corridors remove the barriers that would have existed from isolated protected areas, allowing species to adapt in their surroundings (Osa Conservation, 2016). The corridors also restore natural vegetation of areas previously destroyed by agricultural expansion and urbanization (Anderson and Jenkins, 2006).

Overall, the efforts put forth by Costa Ricans to protect their richly diverse country rival that of any other country around the world. These conservation efforts not only restore and preserve plant and animal life, but have the capacity to benefit human health.

Chapter 2 - Field Experience

In order to complete my field experience, I traveled to the Soltis Center near La Fortuna, Costa Rica. The Soltis Center is a facility constructed by Texas A&M University to be used as a field research station to support sustainable use and conservation of tropical biodiversity in Central America. Situated on the Caribbean side of the Cordillera de Tilaran mountain range, the Soltis Center is in the middle of primary and secondary rainforest (Institute for Global Health and Health Policy, 2013). The last portion of my experience was completed at the Monteverde Institute. Monteverde is located on the Pacific side of the mountains, hardly 16 kilometers west of the Soltis Center, but located in an entirely different eco-zone. The Pacific side is much drier and colder, with higher elevation and different species of plant and animals than observed on the Caribbean side. Comparisons of species, disease incidence, and climate were made between the two eco-zones in order to better comprehend the wealth of biodiversity in Costa Rica.

I traveled to Costa Rica as a member of the Conservet course. Conservet is a program for veterinary and ecology students with an interest in the interface between animal, human, and environmental wellness. This course places the team of students in the center of a unique ecosystem providing lecture-structured discussions and field studies that characterize the complexity of environmental functions and ecological health. The informal lectures were provided as an opportunity to learn more about Costa Rica, the biodiversity present, conservation strategies, and prevalence of diseases in the area. Eight veterinary students from all over the United States participated in the course in addition to two veterinarians, one veterinarian from the Buffalo Zoo, and our director, Dr. Tarpley, who provided an interesting background with DVM, PhD, and MPH credentials. Throughout the course, we met with many different biologists

and ecologists in the area and conducted field research involving birds, bats, mosquitoes, and livestock.

When it wasn't raining in the daylight hours, we used mist netting to trap birds that we would use for sample collection. Mist nets are comprised of a mesh, cloth pattern that can be stretched between two trees, poles, etc. When a bird or bat flies into the net, it becomes tangled and captured in a pocket. Upon trapping the birds, we were then able to identify species, gender, age, measure morphometrics, and swab the birds to test for Avian Influenza (AI). Altogether, we captured 13 different species of birds around the Soltis Center and 9 species at Monteverde ranging from woodcreepers, to motmots, and even a toucan. Tables 2.1 and 2.2 list the species of birds captured at both sites, respectively. We swabbed the choanae and cloaca of the birds and sent the swabs to the Servicio Nacional de Sanidad y Calidad Agroalimentaria (SENASA). SENASA is the Costa Rican agency responsible for surveillance, regulation, and certification of plant and animal products in addition to prevention, eradication, and control of diseases that affect them (Institute for Global Health and Health Policy, 2013). SENASA expressed an interest in processing the swabs for us in order to monitor the potential spread of AI in Central America. There was great concern that the migratory water fowl of the US would return to areas of Central America over the winter months, bringing with them, the highly pathogenic strain of avian influenza (HPAI) that broke in the United States in 2015. If HPAI spreads into Central America, immense bird populations of the tropics would be devastated. We completed the same mist netting and sample collection in Monteverde, comparing and contrasting the different species of birds present among different eco-zones. Several opportunities arose along the way to collect samples from small neighboring farms in the area. The local farmers were very welcoming and

allowed us to examine and swab their chickens for AI as well. Fortunately, the wild and domestic populations of birds we sampled were negative for AI.

Avian Influenza

The influenza viruses are segmented, negative sense, single-strand RNA viruses under the family, *Orthomyxoviridae*. There are 5 genera within *Orthomyxoviridae*, including Influenza A, B, and C – Influenza A is the only type known to infect birds (Capua and Alexander, 2008). Two surface proteins, hemagglutinin and neuraminidase, are recognized as antigens that re-align into different combinations, resulting in different strains of the virus. With this variability and segmentation of the virus, it becomes possible for two main groups of influenza to affect birds – low pathogenic avian influenza (LPAI), and highly pathogenic avian influenza (HPAI) (Capua & Alexander, 2008). AI has become a hot topic of surveillance worldwide within the last ten years, most notably devastating United States poultry operations in 2015 (USDA, 2016). The general consensus with AI is that there are large reservoirs of LPAI in wild birds, waterfowl in particular, and that these viruses are able to spread to domestic poultry, occasionally mutating to become very virulent HPAI viruses. The US outbreak resulted in the destruction of millions of birds – wreaking havoc on the poultry industry, and the financial and emotional state of poultry producers (USDA, 2016). AI is also a threat to public health due to its rapidly mutating, segmented architecture. The ability of the influenza virus to recombine, or rearrange itself, creates a threat of potential mutation into a strain that can infect humans, thus there is much interest in surveillance and control of this virus among the avian species (Capua & Alexander, 2008).

Bats

In addition to birds, bats were also trapped in the evenings using a similar mist net. The nets were set up at dusk in the jungle surrounding the Soltis Center. We checked the nets periodically, collecting the bats that flew into the nets with thick, leather gloves. Altogether, 9 different species of bats were captured including the vampire bat. Table 2.3 provides a complete list of all species. We brought them back to our lab in cloth bags and identified species, measured morphometrics, examined for ectoparasites, and collected blood samples. This opportunity provided us with the chance to not only collect biological samples from bats, but to become comfortable in handling them and recognizing what a valuable ecological species they really are. I have to admit, I was terrified of the tiny, flying mammals, but after handling them, I gained a greater understanding of this amazingly specialized species. To the public eye, bats have a horrifying reputation as blood-sucking, disease carrying, flying terrors. However, few realize bats are actually considered a crucial keystone species, as they are primary insect predators, seed dispersers, and pollinators of countless plants and crops. They also provide an interesting immunology research target because they live in highly gregarious social structures.

In addition to the chickens, birds, and bats, we were also able to collect blood and feces from dogs, horses, and cattle from neighboring farms. We collected blood in order to look for the presence of West Nile Virus, Chikungunya, Viral Encephalitis, and Equine Infectious Anemia. The blood samples were sent off to a lab at the National University of Costa Rica (UNA) and were unremarkable in regards to pathogen presence.

West Nile Virus

West Nile Virus was first detected in the Western Hemisphere in 1999, upon its diagnosis in the Bronx Zoo of New York. Since then, the virus has spread widely across the country, into

Canada and down through Mexico. Among the species diagnosed as positives are migratory birds, ravens, horses, mosquitoes, and humans. However, as the virus has spread south in Mexico and Latin America, the number of reported human cases are smaller and smaller. Several hypotheses try to address this issue. One being that a different virus strain is circulating in Latin America. Another, is that the limited financial resources in these countries is a barrier to comprehensive testing and coverage. An additional hypothesis exists suggesting the presence of pre-existing neutralizing antibodies from another Flavivirus in these areas is responsible for partial protection against WNV, these other Flaviviruses being Dengue Virus or Encephalitis Virus (Elizondo-Quiroga, 2013).

Dengue

Dengue is a mosquito-borne viral disease that has spread rapidly throughout the tropics with local variations influenced by rainfall, temperature, and rapid urbanization. Dengue was first recognized in the clinical presentation of hemorrhagic fever in the Philippines and Thailand in the 1950s. Today, it has become a leading cause of hospitalization and death among children in Asian and Latin American countries. The World Health Organization estimates approximately 390 million Dengue infections every year. Prior to 1970, only 9 countries had experienced Dengue epidemics; however, now the disease is endemic in more than 100 countries among Africa, the Americas, the Mediterranean, Southeast Asia, and the Western Pacific (World Health Organization, 2015). Dengue is spread primarily by the *Aedes aegypti* and *Aedes albopictus* mosquitoes – these mosquitoes have a wide range of temperature tolerance and have the ability to hibernate in adverse conditions (World Health Organization, 2015). With climate change and habitat destruction, these species have adapted in an especially hardy manner, bringing with them the Dengue virus.

Chikungunya

Chikungunya is another a viral disease transmitted by mosquitoes. The disease occurs in African and Asia, and in recent years has spread to Europe and the Americans just like Dengue. The proximity of mosquito breeding sites to human habitation is a significant risk factor for Chikungunya. The disease shares many similar signs to Dengue, including fever, severe joint pain, body aches and nausea. This disease is also transmitted by the mosquito species *Aedes aegypti* and *Aedes albopictus*. With habitat destruction, *Aedes* have spread to rural and urban areas, establishing breeding grounds in any form of standing water (World Health Organization, 2015).

Viral Encephalitis

There are several viruses that cause encephalitis – an infection of the brain. Among our livestock sampling, we did test for presence of these viruses and found none. These viruses include Western Equine Encephalitis Virus (WEEV), Eastern Equine Encephalitis Virus (EEEV), and Venezuelan Equine Encephalitis Virus (VEEV). WEEV, EEEV, and VEEV have widespread distributions in North, Central, and South Americas extending into Canada. The encephalitis viruses are spread by mosquitoes and are known to infect humans, horses, birds, and rodents. Depending on the climate, natural transmission of these viruses is maintained throughout the year, can overwinter in some host species, and be reintroduced annually by migratory birds (Zacks and Paessler, 2010).

Chagas Disease

There are over 100 species of Triatominae, subfamily of Reduviidae , and these insects were another species of interest to us. More commonly known as kissing bug or the assassin bug, these blood-sucking insects are known to carry the parasite *Trypanosoma cruzi*, causing Chagas

Disease. If the insects feed on an infected mammalian host, they ingest trypomastigotes that transform to an infective state within 3-4 weeks in the hindgut of the insect. The trypomastigotes are then deposited in feces that contaminate oral and nasal mucous membranes and conjunctiva of the eyes. The trypomastigotes enter host cells and begin their life cycle in the host, ultimately resulting in a blood-borne trypomastigote that ruptures from its host cell and goes on to infect adjacent cells and disseminate through lymphatics and the blood stream (Hemmige, Tanowitz, & Sethi, 2012). Chagas can be difficult to diagnose in humans because of vague clinical presentation including fever, fatigue, body aches, diarrhea, and vomiting. Chagas can also cause severe heart disease in dogs (TAMU, 2015). Since the 1990s, much initiative has been taken to control the vector of Chagas disease and a sharp decline in infection rate followed (Hemmige, Tanowitz, & Sethi, 2012). We were fortunate enough to have collected kissing bugs from neighboring homesteads in Monteverde. Fecal smears were performed in order to examine microscopically. Several samples were found to be positive with trypanosomes. Table 2.3 below is a summary of the different farm species we collected samples from, and what diagnostics were used to look for diseases of interest.

Table 2.1 Bird Species Captured at the Solits Center

Order	Species	Common Name	Description
Apodiformes	<i>Amazilia saucerrottei</i>	Steely-vented Hummingbird	Found in openings and edges of forests; consumes flower nectar
	<i>Phaethornis striigularis</i>	Stripe-throated Hermit Hummingbird	Found in woodlands and foothills; consumes flower nectar
Coraciformes	<i>Baryphthengus martii</i>	Rufous Motmot	Found in humid lowlands and rainforests; nests in burrows; consumes insects, lizards, fish, and crabs

Passeriformes	<i>Arremonops conirostris</i>	Black-striped Sparrow	Found in lowlands and foothills; consumes insects
	<i>Capsiempis flaveola</i>	Yellow Tyrannulet	Found in thickets of shrubs and small trees; consume insects, arthropods, and berries
	<i>Coereba flaveola</i>	Bananaquit	Found in canopy and forest edges; consumes flower nectar and fruits
	<i>Glyphorhynchus spirurus</i>	Wedge-billed Woodcreeper	Found in woodlands and foothills; consumes arthropods and insects
	<i>Henicorhina leucosticte</i>	White-breasted Wood Wren	Found in low understories of wet forests and foothills; consumes insects and invertebrates
	<i>Mancus candei</i>	White-collared Manakin	Found in thickets and rainforests; consumes insects and fruits
	<i>Ramphocaenus melanurus</i>	Long-billed Gnatwren	Found in undergrowth and vines of dry forests; consumes insects and arthropods
	<i>Serinus burtoni</i>	Thick-billed Seedeater	Found in rainforests throughout South America and Africa; consumes seeds and insects
Piciformes	<i>Piculus simplex</i>	Rufous-winged Woodpecker	Found in forest canopies, moist lowland forests; consumes insects and invertebrates
Trochilliformes	<i>Amazilia tzacatl</i>	Rufous-tailed Hummingbird	Found in open country, river banks, woodlands and forest edges; consumes nectar from flowers

Table 2.2 Bird Species Captured at Monteverde

Order	Species	Common Name	Description
Apodiformes	<i>Phaethornis guy</i>	Green Hermit	Found in openings and edges of forests; consumes flower nectar
Coraciformes	<i>Motmotmus coeruliceps</i>	Blue-crowned Motmot	Found in humid lowlands and rainforests; nests in burrows; consumes insects, lizards, fish, and crabs
Passeriformes	<i>Dendrocolaptes sanctithomae</i>	Northern Barred Woodcreeper	Found in lowlands, trunks, and thick branches; consumes insects, arthropods, and small vertebrates
	<i>Melozone leucotis</i>	White-eared Ground Sparrow	Found in dark thickets, ravines, and patchy woodlands; consumes insects and arthropods
	<i>Saltator maximus</i>	Buff-throated Saltator	Found in thickets and dense vegetation; consumes insects, fruit, and nectar
	<i>Troglodytes aedon</i>	House Wren	Found in forests and open fields; consumes insects and arthropods
	<i>Turdus grayi</i>	Clay-colored Thrush	Found everywhere from forests to open fields; consumes fruit, insects, and invertebrates
Piciformes	<i>Aulacorhynchus prasinus caeruleogularis</i>	Blue-throated Toucanet	Found in upper levels of forest, in flocks; consumes fruits, insects, small vertebrates
Trochilloformes	<i>Campylopterus hemileucurus</i>	Violet Sabrewing	Found in understory and edges of forests; consumes flower nectar

Table 2.3 Bat Species Captured at the Soltis Center

Species	Common Name	Description
<i>Carollia perspicillata</i>	Seba's Short-Tailed Bat	Primarily frugivorous; Consume nectar, pollen, and insects
<i>Carollia sowelli</i>	Sowell's Short-Tailed Bat	Frugivorous; poorly understood species
<i>Carrollia castanea</i>	Chestnut Short-Tailed Bat Allen's Short-Tailed Bat	Frugivorous
<i>Dermanura watsoni</i>	Thomas' Fruit-Eating Bat Tent Bat	Found below 800 m. elevation; Frugivorous; Form tents under large leaves
<i>Desmodus rotundus</i>	Common Vampire Bat	Form very large colonies; Consume blood from livestock and horses
<i>Micronycteris microtis</i>	Common Big-eared Bat	Insectivorous
<i>Micronycteris minuta</i>	White Bellied Big-Eared Bat	Primarily insectivorous; also frugivorous
<i>Myotis riparius</i>	Vesper Bats Evening Bats Common Bats	Form large colonies; Insectivorous
<i>Pteronotus mesoamericanus</i>	Mustached Bat	Insectivorous

*Table descriptions retrieved from International Union for Conservation of Nature: Red List of Threatened Species (IUCN, 2016)



Figure A. Setting up the mist net.



Figure B. Processing birds collected.



Figure C. Processing bats collected.

FIGURES A - C

The photos to the left depict our field studies. Figure A illustrates the process of setting up the mist nets by stretching them between two poles or trees. The mist nets were used to capture birds and bats. Figure B represents our group processing the birds after collection. The specimens were weighed, measured, and examined in order to identify species.

Diagnostic samples were then collected. Figure C displays the thick, leather gloves used for handling the bats after capturing in mist nets. The bats were processed similarly to the birds in order to identify species and collect diagnostic samples.

Chapter 3 - Conservation and Sustainability in Costa Rica

Zoonoses are infectious diseases that are transmissible from animals to humans involving a wide range of causative agents including viruses, bacteria, parasites, fungi, and prions. Zoonoses make up 60% of all known infectious diseases, and 75% of emerging infectious agents are zoonotic (WHO, 2015). The rate of zoonotic disease emergence has increased markedly since the 1940s due to land-use alterations, urbanization, increased travel and trade, agricultural practices, encroachment into animal habitats, and increased awareness (Kulkarni, Berrang-Ford, Buck, Drebot, Lindsay, & Odgen 2015).

Ecologists use the term “climate envelope” or “abiotic niche” to describe the environmental tolerances that define geographic ranges of species. Within climate envelopes, species vary in abundance along with environmental gradients – such as temperature, precipitation, and vapor pressure – that together, correspond to optimal and less optimal conditions (Kulkarni *et al*, 2015). When a disease is present, these niches are occupied by pathogens, vectors, and hosts and their distribution is strongly influenced by abiotic conditions such as temperature, precipitation, wind currents, etc (Estrada-Pena, Ostfeld, Peterson, Poulin, & Fuente, 2014). Disease systems are associated with complex sets of host and vector species, each within a distinct ecological niche. As host species begin to overlap in spatial distribution, the potential for pathogen transmission can be enhanced or diluted. As the abiotic factors change, the behavior, social structure, and dispersal of populations of any species changes as well (Estrada-Pena *et al*, 2014). Such changes can modify the components of pathogen transmission and disease systems, thus elevating or depressing levels of infection in particular hosts. For transmission of a disease to occur, the necessary species of host, vectors, and pathogens must all be present. With changing climates, habitat destruction, and disappearance of species, more

potential interactions exist for transmission to occur outside of previous abiotic barriers (Kulkarni *et al*, 2015).

On a more global context, health dysfunction is a result of several drivers – climate change, loss of biodiversity, social conflict, poverty, and population growth (Estrada-Pena *et al*, 2014). The dysfunction of the ecosystem poses challenges and threats to public health as divergent factors continue to align to allow for disease emergence. All of the diseases mentioned in the previous chapter have documented increased prevalence associated with habitat destruction and climate change.

Climate Change

Climate change is the result of increased carbon dioxide levels in the atmosphere. According to the Intergovernmental Panel on Climate Change, recent decades have seen warming air and ocean temperatures, altered precipitation patterns, changes in frequency and intensity of extreme events such as droughts, floods, and storms, and rising sea levels (McIver, Kin, Woodward, Hales, Katscherian, Hashizume, Honda, Iddings, Naicker, Bambrick, McMichael, & Ebi, 2015). Life cycles and transmission routes of many infectious agents that affect plant, animal, and human life, are inextricably tied to climate. Thus climate change is a driver of global health dysfunction, as it affects health of all species.

Shifts in climate leads to changes of geographically linked ecosystems. Such alternations cause habitats to deviate; plant, insect, and animal life are disrupted as well. Density and distribution of animal reservoirs and arthropod vectors expand and enter new territories as climate change forces them to adapt – thus, bringing with them pathogens that have the ability to affect human health. One example being the successful emergence of Dengue and Chikungunya – as these diseases spread across the tropics and into the United States, it reached human

populations that were completely naïve to such pathogens, having no established immunity towards it, and no vaccine for protection (McIver *et al*, 2015).

Arboviruses in general – transmitted by ticks, mosquitoes, and other insects – gain greater geographical areas of incidence with changing climates. Their survival is sustained in larger regions as temperatures warm (Parkinson, Evengard, Semeza, Odgen, Borresen, Berner, Brubaker, Sjostedt, Evander, Hondula, Menne, Pshenichnaya, Gounder, Larose, Revich, Hueffer, & Albiñ, 2014). Climate change has the capacity to shift vector's geographic ranges in addition to shortening pathogen incubation time.

In addition, intense weather patterns create conditions conducive to outbreaks of infectious disease. Heavy rains for example, create insect breeding sites, drive rodents from burrows, and contaminate clean water supplies with runoff, waste, etc. Recent cases of cholera have been imported into Europe from Kenya, where a spreading epidemic has been linked to El Nino (Parkinson *et al*, 2014). Similarly, an increase in Cryptosporidiosis in the United Kingdom have been related to recent flooding (Bezirtzoglou, Dekas, & Charvalos, 2011). The explanation for this phenomenon is quite simple – pathogen replication kinetics in insects are dependent on temperature. Viral attachment and cellular infection are more efficient at higher temperatures. Higher temperatures generally lead to shorter incubation periods and faster dissemination rates among infected hosts. For example, Dengue virus infection rates are temperature-dependent, and demonstrate increased infection and transmission rate at higher temperatures (Waldock, Christophides, Hemming, Agosto, Evans, Fefferman, Gaff, Gumel, LaDeau, Lenhart, Mickens, Naumova, Ostefeld, Ready, Thomas, Velasco-Hernandez, & Michael, 2015).

Changes in the atmospheric abundance of greenhouse gasses, solar radiation, and land use properties all alter the energy balance of the climate system (Parham *et al*, 2015). The

rainforests and cloud forests of Costa Rica are unique in their beauty and in the biodiversity they sustain. However, the forests also act as carbon sinks that affect the rest of the world. A carbon sink is anything that absorbs more carbon than it releases, thus reducing the carbon cycling in the atmosphere. By preserving the forests of Costa Rica, valuable carbon sinks are left intact to combat the ever increasing greenhouse gasses accumulating in the atmosphere contributing to climate change. (FERN, 2016). Changing weather patterns have a considerable effect on health whether climate change is an accepted theory or not. Therefore, it is pertinent to conserve our natural resources and protect the environment, so it will protect us (Campbell-Lendrum, Bagayoko, and Sommerfeld, 2015).

Changing weather patterns also affect wildlife species in their natural habitats. In the tropics, sea surface temperatures and air temperatures have documented increased average temperatures from 1975 to 2000. At Monteverde, air temperatures increased by 0.18 C per decade, which is triple the average rate of warming for the twentieth century and 18 times the inferred average rate for a cloud forest from the ice age to modern times (Institute for Global Health and Health Policy, 2013). Studies show greatest declines in amphibian populations occurring during unusually warm years (Pounds, Bustamante, Coloma, Consuegra, Fogden, Foster, Marca, Master, Merino-Viteri, Puschendorf, Ron, Sanchez-Azofeifa, Still, and Young, 2006). In the cloud forests of Monteverde, warm years are associated with reduced mist frequency which ultimately affects bird, reptile, and amphibian populations, most significantly the disappearance of the golden toad and harlequin frog. Large-scale warming of the cloud forests reduces relative humidity and causes more local damage to species than deforestation. Shifting temperatures has also created more favorable conditions for *Batrachochytrium dendrobatidis* – a pathogenic chytrid fungus wreaking havoc on amphibian populations (Pounds

et al, 2006). With climate change promoting infectious disease and eroding biodiversity, the urgency to reduce greenhouse-gas emissions is not only an environmentalist concern, but a concern of public health.

Habitat Destruction

The rate of zoonotic disease emergence has increased markedly since the 1940s due to land-use alterations, urbanization, increased travel and trade, agricultural practices, encroachment into animal habitats, and increased awareness (Kulkarni *et al*, 2015). Environmental and socioeconomic changes impact wildlife populations that serve as reservoirs of zoonotic diseases, alter the dynamics of transmission among natural reservoir hosts, and alter the likelihood of animal-human transmission. These changes are all leading to increased transfer of infectious agents between species.

When domestic animals are raised in new environments, such as land near destroyed rain forests, both domestic and wild animals are exposed to species of animals and pathogens that they have not encountered before. This can result in infectious agents being transferred to a new species (Spickler, Roth, Galyon, & Lofstedt, 2010). In their original hosts, these agents may be carried sub-clinically or produce a mild form of disease. However, pathogens may produce severe disease when they enter new hosts. An example of such interspecies transfer occurred in Malaysia when a large pig farm was established in an area with a high population of fruit bats. The Nipah Virus was transmitted from the fruit bats to pigs, and spread rapidly through the naïve pig population causing severe disease. The virus was subsequently transmitted to people in close contact with the pigs. While fruit bats of the genus *Pteropus* are the main reservoir hosts, several species of insectivorous bats can carry the virus and infections have been reported in pigs, dogs, cats, horses, goats, and humans (Spickler *et al*, 2010). Destruction of habitat and increased

exposure of the wildlife-domestic animal interface is responsible for the introduction and establishment of Nipah in humans.

As humans continue to encroach on wildlife habitats, human-bat interactions are also increasing. Bats are utilizing artificial structures as roosts such as homes and bridges as their natural habitats are lost to urban expansion. This increased interaction can lead to epidemiological spillover of diseases that bats are known to carry. Numerous Marburg virus (MARV) cases were linked to cave activities like tourism and mining. MARV causes a hemorrhagic fever in humans that can be fatal. Severe Acute Respiratory Syndrome (SARS) is suspected to have emerged because of the use of bats as food in markets in China (Hayman, Bowen, Cryan, McCracken, O'Shea, Peel, Gilbert, Webb, & Wood, 2013). As Nipah virus broke, bats were suspected as the culprit due to habitat destruction resulting from intensified pig production. Hendra virus outbreaks have been associated with urbanization in Australia. The Ebola outbreaks in Africa are suspected to be closely involved with fruit bats and consumption of bushmeat. Given that bats are known reservoirs for Rabies, SARS, Hendra and Nipah viruses, Ebola, Coronavirus, and Marburg viruses, it is crucial we understand how bat ecology may influence disease dynamics and emergence of pathogens (Spickler *et al*, 2010). By preserving the ecosystem rather than destroying it, natural habitats are intact, interactions with wild and domestic species decreases, thus decreasing the risk of disease emergence (Hayman *et al*, 2013).

One study demonstrated an increase in deforestation of the Amazon by 4% resulted in an increased incidence of malaria by 50%. Malaria is transmitted by mosquitoes that have been documented to thrive in the sunlight and water of deforested areas (Robbins, 2012). This demonstrates the important concept of understanding emerging infectious diseases by

understanding the protective effects of keeping nature intact, and recognizing the consequences of destroying it.

Deforestation is an important factor contributing to increased interactions of wildlife-human interface. In the Kyasanur forest of India, a tick-borne *Flavivirus* emerged from the clearance of forest used for grazing cattle (Singh & Gajadhar, 2014). Cattle are a major host for this particular tick species and carried the virus out of the forest leading to over 1000 human cases each year. In Western Uganda, deforestation has increased the encounter rates and overlap between native primates, humans, and domestic animals. In this part of Africa, proximity to forests facilitates hunting of bushmeat and in return, humans became infected with a new viral hemorrhagic fever, known as Ebola. Modification of landscapes by human activities is also linked to increased incidence of the tick-borne bacteria known as Lyme Disease in North America; fragmentation of forested landscapes exacerbates spatial overlap of reservoir hosts, the white-footed mouse, the black-legged tick vectors, and humans. In parts of Turkey, land has been cleared for labor and then abandoned, allowing secondary vegetation to grow which provides shelter for hosts of ticks, like small mammals, thus promoting larger vector populations (Singh & Gajadhar, 2014). This is also believed to be a driving factor in the ongoing epidemic of Crimean-Congo hemorrhagic fever (Estrada-Pena *et al*, 2014) in Africa, the Middle East, and Asia. Overall, the examples of disease emergence as natural habitats are destroyed from expanding agriculture and urbanization across the globe are endless. It exponentially increases the risk of human contact with wildlife-related zoonotic diseases.

Preservation of Species

Among ecosystems, a chain of hierarchy exists comprised of predators and prey. Each species is inextricably tied to the next, forming complex interactions within the ecosystem. As

certain levels of the ecosystem are destroyed, the risk for diseases to spill-over into human populations increases dramatically, thus bringing forth the importance of species preservation.

Bats provide a unique ecological role as insect predators, seed dispersers, and pollinators in the ecosystem. As a whole, bats have become an interesting species to ecological research as models for evolutionary diversity, ecomorphology, emerging diseases, and conservation (Kunz & Fenton, 2005). Bats are currently the victim of the largest mammalian extinction our generation will see. Their existence is threatened by the increased human population growth, habitat destruction, environmental pollution, and emergence of a deadly fungal disease caused by *Pseudogymnoascus destructans*, more commonly known as White-Nose Syndrome. The United States Geological Survey estimates that the population of bats in North America has declined by 80% since the emergence of White-Nose Syndrome in 2006 (USGS, 2016). In temperate areas, bats are the primary predator of insects. A recent economic analysis indicates that the insect suppression and pollination service of bats for the agricultural industry in the United States is valued up to 50 billion dollars per year (USGS, 2016). Insectivorous bats consume over half their body weight in insects each night. This is especially helpful for tomato, artichoke, watermelon, and countless other vegetable farms in North America. The declining bat population is estimated to result in billions of dollars in increased pesticide cost and agricultural damages each year.

Most flowering plants cannot produce fruit without pollination; examples of such plants that are dependent on bat pollinators include bananas, peaches, cloves, agave, etc (Bat Conservation International, 2016). As seed disperses, bats travel vast areas at night spreading seeds to repopulate deforested areas and benefit agriculture by spreading seeds of avocado, dates, figs, cashews, and many more. Even bat feces, called guano, is a valuable rich fertilizer that is

mined and sold for a profit. Bats are often considered a “keystone species” for their role in ecology – without their seed dispersal and pollination, ecosystems gradually collapse as plants fail to thrive. Natural forest remnants are crucial for the persistence of bats, as roosting requires natural habitats (Bat Conservation International, 2016). As previously discussed, with habitat destruction, humans are invading natural habitats and bats are roosting in more urban areas increasing human-bat interactions and increasing risk of disease transmission. It is also speculated that the emergence of tropical diseases transmitted by mosquitoes, such as Dengue and Chikungunya, is linked to the dramatic loss of bat populations within the past decade. With diminished bat populations, insects like the mosquito have lost their primary predator and thrive unscathed.

Bats are a fascinating species to study because of their crucial role in the environment, but also because of their differences from other mammals including highly gregarious social structures, long lifespans, and highly specialized sonar physiology. Bats demonstrate extraordinary survival rates considering the pathogens they harbor, and the complexity of their immune system could help us better understand our own and further control these pathogens (Hayman *et al*, 2013). It is crucial to preserve this species in the environment for their role as pollinators and seed dispersers, but arguably more important their role as insect predators with consideration of how emerging diseases are transmitted.

Chapter 4 - Conclusion

For emerging diseases, strengthening of public health surveillance worldwide to provide early warning has been the primary recommendation of expert groups for the past two decades. The World Health Organization created a new initiative known as the Global Outbreak Alert and Response Network, Canada initiated a Global Public Health Intelligence Network, and the Centers for Disease Control and Prevention in the United States initiated a Global Emerging Infections Surveillance and Response System (Morse, Mazet, Woolhouse, Parrish, Carrol, Karesh, Zambrana-Torrel, Lipkin, & Daszak, 2012). All of these programs, and many more, are directed towards early detection of emerging zoonotic diseases. Any conservation effort is noble, the point of this report is to outline the role that conservation has in public health – in addressing ecological issues where they are happening to prevent continued habitat destruction, preventing factors that influence climate change, protecting endangered species and ecological hierarchies, and overall protecting the health of all species. The key to understanding emerging infectious diseases is to understand the protective effects of an intact ecosystem, and recognizing the consequences of destroying it.

The core and elective courses in the Master of Public Health curriculum provided a foundation of information that assisted me through my field experience and project. My field experience through Conservet supplied real world experience and exposure to some of the most unique ecosystems in the world in which to apply my classroom knowledge and passion.

Epidemiology, Biostatistics, and Quantitative Analysis taught me how to interpret data and develop unbiased conclusions from number sets. I was able to apply this knowledge in the field work I completed, in addition to the countless journal articles I poured over in the progression of this paper and in the future.

Environmental Toxicology provided me with a useful background knowledge of toxicity of a variety of sources, in addition to the risks and hazards required to meet a toxicity level. This knowledge is crucial in interpreting concepts involving climate change due to greenhouse gases, human waste, agricultural run-off, etc. A complete understanding is useful in devising intervention strategies to prevent further damage to the ecosystem.

Administration of Health Care Organizations developed my understanding of human health care in this country. To promote public health from any avenue, I believe a thorough understanding of the health care industry itself is important. It was also fascinating to learn about healthcare in Costa Rica, in comparison to that of the United States. With global comparisons, various strategies can be implemented in different contexts in order to promote public health around the world.

Social and Behavior Sciences broadened by understanding of the factors that influence health care – from an individual to community to global scale. To best promote public health and conservation medicine, appropriate targets must be reached and this course delved into the different levels of intervention and strategies.

Strategic Health Communications taught me several theories involving health communication. Through this class, we explored public health campaigns in the past – in the United States and internationally – discussed them at large, and applied what we learned in a campaign of our own. I really enjoyed exploring different theories of communication that involve psychology of what drives people to change their behavior. This knowledge is important to keep in mind with any sort of public health campaign – you must understand what drives people in order to promote a behavior change for them to undertake. There are so many applications I took away from this class about interpersonal communication, mass media

communication, patient-doctor relationships, etc. I've been fortunate to apply this knowledge with every farmer and expert ecologist I worked with in Costa Rica, in addition to using such skills in the writing of my report.

Bacteriology, Virology, and Immunology all proved to be beneficial knowledge in this field experience. As we were there to survey the environment for presence of pathogens, a working knowledge of many viral and bacterial diseases was crucial, as well as understanding the immunology of humans and animals. Understanding these concepts was beneficial for studying disease ecology in the rainforest.

Trade and Agriculture was also a beneficial course in pursuit of this endeavor. With studying disease ecology, countless important factors arise involving public policy, international trade, and agricultural economics that ultimately drive disease emergence, emergency response, healthcare, and conservation efforts. I think the future of conservation and public health lies with economic strategies and by demonstrating economic benefits, the role of conservation in public health will be preserved.

The opportunity to study conservation medicine in Costa Rica was the perfect fit for me in the pursuit of completing my field experience. The wealth of biodiversity is truly remarkable, and proved to be a fascinating area of interest to me in the future of my public health career. Real world, international experience was an amazing setting for me to apply my knowledge and gain a greater understanding of environmental health as it pertains to public health.

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