The Potential Impact of Entomology on Large Animal Veterinary Practice in Texas

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Introduction

On March 23, 2020, I began an internship with Circle T Veterinary Services, which is a mobile veterinary service based in Sandia, Texas. From March to August, I traveled with Dr. Tobin Pennington to farms and ranches across South Texas conducting large animal farm calls. Dr. Pennington is the sole owner and practitioner of Circle T Veterinary Services, which he opened in 2012. It is a 100% mobile service, operating completely out of Dr. Pennington's truck. Circle T covers a large part of South Texas, with clients residing as north as Oakville, west to Cotulla, east to Rockport, and as south as McAllen.

A typical day working at Circle T Veterinary Services starts early in the morning, depending on how far we need to travel to make it to the first call. There is routine work to be completed, such as palpating and deworming cows, castrating calves, vaccinating horses, equine dental floats, and more. I have been able to witness a wide variety of illness and injuries, like broken legs, horses with nasopharyngeal cicatrix syndrome, bovine fetal extractions and fetotomy, and corneal ulcers. Emergencies, such as equine colic or lacerations occur often and must be treated quickly. In one day, we may travel hundreds of miles across South Texas.

In this paper, I examine the interconnections between veterinary medicine and another interest of mine, entomology. As a student in the Entomology Minor curriculum at Kansas State University, I have taken great interest in the study of insects and their effects on agriculture, ecosystems, and disease transmission. I wanted to explore the effects of arthropods on veterinary medicine because I plan on pursuing a DVM (Doctor of Veterinary Medicine) degree in the future. Below, I took experiences from my internship and researched them further, creating an in-depth look at the interactions between entomology and veterinary practice. I included a case study that I observed during my internship, which piqued my interest in West Nile Encephalomyelitis. The remainder of this paper then focuses on prevention strategies for several vector-borne diseases and emerging threats to the cattle industry. This analysis demonstrates my passion for entomology and veterinary medicine and my interest in the synergies between these two fields of study.

Case Report: A suspected case of West Nile Encephalomyelitis

Introduction

Entomology intersects with veterinary medicine when insects vector viruses, bacteria, and parasites that can cause illness in animals. An example of a vector-borne disease is West Nile encephalomyelitis, which is caused by the West Nile virus. This virus is maintained in a natural cycle between mosquitoes and birds, but animals like humans and horses can be infected incidentally (Colpitts et al, 2012). To fully recognize the implications of this vector-borne disease, it is helpful for veterinarians to have an understanding of vector biology and virus transmission. In this section, a suspected case of West Nile virus infection in equine is described, along with an overview of the history of the virus in the United States and the transmission cycle.

Case Presentation

On July 10th, 2020, Circle T Veterinary Services was called onto a ranch in Alice, Texas, to examine a 15-year-old grey mare. The horse had been used for ranch work, such as gathering and sorting cattle, on various ranches in the South Texas area. This area had also received ~4.61 inches of rainfall in June 2020, which is above normal (US Department of Commerce, 2021). The mare was fed twice a day and turned out on green pasture in between feedings. It had no history of vaccinations. The initial complaint from the owner was that the horse had not eaten during the previous two days and was 'acting strangely.' Upon examination, the mare presented with a low-grade fever, while respiratory and heart rate were normal. The horse was also drooping its bottom lip and when turned loose, would wander around aimlessly.

Based on the examination, the horse had symptoms consistent with West Nile encephalomyelitis, which is inflammation of the brain and/or spinal cord. This illness is caused by the West Nile virus and vectored by mosquitoes. West Nile encephalomyelitis does not have a specific treatment, only supportive care can be provided (Merck Veterinary Manual, 2021). The horse was treated with a dose of an anti-inflammatory drug, Dexamethasone, and was vaccinated for West Nile with Core EQ Innovator, a Zoetis manufactured product that is also labeled to protect horses from eastern and western equine encephalomyelitis, rabies, and tetanus. No further treatments were given, and the owner confirmed that the mare had returned to normal after three weeks.

Discussion

In 1999, West Nile virus was first detected in New York when four human cases had unusual symptoms and, around the same time, birds were dying. A combination of factors, including susceptible avian hosts, moderately competent mosquito vectors, and a favorable climate and environment, allowed the establishment of West Nile Virus (abbreviated as WNV) in the northeastern United States. Within four years after its introduction, WNV spread across the

United States and moved into Canada, Mexico, and Central and South America (Kramer et al, 2019).

Several aspects of mosquito biology contribute to their ability to be competent vectors and maintain the WNV transmission cycle. In nature, a cycle between mosquitoes and animal hosts maintains WNV (Figure 1). Birds are the preferred reservoir and when infected, some bird species show symptoms of disease and die while others are asymptomatic. The main host species responsible for preservation and transmission of WNV in the United States is the American Robin. Humans and horses are "dead-end" hosts, meaning the levels of viremia in the blood stream are too low to be transmitted to mosquitoes (Colpitts et al, 2012). The primary competent vectors of WNV are reported to be *Culex* mosquitoes (Habarugira et al, 2020). However, there is evidence that WNV can also infect *Aedes* species in nature (Colpitts et al, 2012). To acquire WNV, a hematophagous mosquito must take a blood meal from a viremic animal. Then, in the mosquito midgut, the virus needs to infect and replicate within the cells. The virus spreads through the hemolymph to the salivary glands. It is in the salivary glands that the virus accumulates, making transmission to the vertebrate host possible during feeding. Using their proboscis, mosquitoes probe the host's skin to locate a blood source. Simultaneously, mosquito saliva is injected into the skin's dermal layer (Colpitts et al, 2012). The saliva contains anticoagulation properties and proteins that evade the initial cell mediated immune response to facilitate blood feeding and potentially virus transmission (Habarugira et al, 2020). Within this inoculation site, WNV has been detected at one- and three-days post infection, even persisting for as many as 14 days (Colpitts et al, 2012).

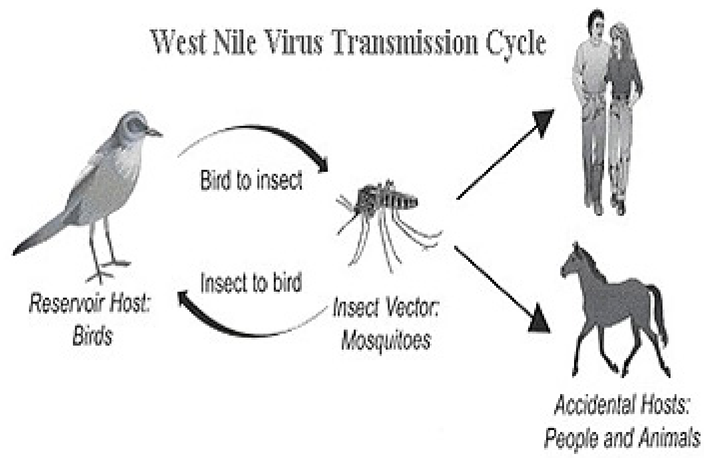

Figure 1. West Nile transmission cycle. The virus alternates between vertebrate hosts and mosquito vectors. Reservoir hosts are birds, while horses and humans are considered accidental hosts. Image credit: USDA APHIS. "*West Nile Virus (WNV)"* Accessed February 27, 2021. https://www.aphis.usda.gov/aphis/ourfocus/animalhealth/animal-disease-information/equine/wnv/west-nile-virus

A case of WNV in horses was first diagnosed in Canada in 2002. Most horses infected with WNV are asymptomatic, with approximately 20% developing clinical signs. The signs of infection include ataxia, hind limb weakness, blindness, multiple limb paralysis, lip droop/paralysis, fever, or acute death. Infection of WNV may resemble other diseases, such as rabies and eastern equine encephalitis (Paré and Moore, 2018). Horses are considered dead end hosts for WNV, as they do not develop levels of viremia that are high enough to be infectious for mosquitoes. (Habarugira et al, 2020).

To diagnose definitively a horse with West Nile encephalomyelitis, laboratory results must detect WNV or a WNV-specific immune response. There are several methods for detecting the virus, including virus isolation, RT-PCR amplification of WNV RNA, and immunohistochemistry for WNV antigen (brain or spinal cord tissue is preferred) (Paré and Moore, 2018). Serological diagnosis is also available for animals with symptoms of West Nile encephalomyelitis. A diagnosis is confirmed with detection of immunoglobulin M (IgM) antibody to WNV by enzyme-linked immunosorbent assay (ELISA) testing in serum or cerebrospinal fluid (Paré and Moore, 2018).

While no laboratory testing was completed, and therefore no definitive diagnosis can be made based on the detection of the infectious agent, several considerations make this case to be highly likely attributable to West Nile encephalomyelitis. (1) In June 2020, the surrounding area received ~4.61 inches of rainfall, which is above the historical average for this region (US Department of Commerce, 2021). Increased amounts of precipitation and a warm climate provide mosquito vectors with a suitable rearing habitat. With an increasing vector population, WNV infections are likely to increase as well (Allan et al, 2008). (2) Cases of WNV infections in horses have been reported previously in Texas. The Texas A&M Veterinary Medical Diagnostic Laboratory documented an increase in WNV infections in horses from 2010-2012 (Texas A&M Veterinary Medical Diagnostic Laboratory, 2021). In 2020, there were 69 cases of equine WNV in the United States reported to the ArboNet reporting system (USDA APHIS, 2021). (3) The mare described in the case had no history of vaccinations and presented with several of the characteristic signs of West Nile encephalomyelitis, such as lip droop, fever, and ataxia. (4) After treatment with anti-inflammatory drugs, the mare’s symptoms receded and she returned to normal after three weeks. Considering these factors, this case in all likelihood is attributable to West Nile encephalomyelitis.

With ideal environmental conditions, mosquito vectors population will increase and likely increase WNV infections (Allan et al, 2008). However, WNV infection in horses is preventable due to the availability of several USDA-approved vaccines, which are introduced in the next section of this manuscript.

Prevention and treatment options for common vector-borne diseases in livestock animals in the U.S.

Entomology and veterinary medicine intersect when insects serve as vectors for viruses and parasites. In the equine industry, the spread of WNV by mosquitoes is of chief concern to owners and veterinary practitioners. In addition, ticks are harmful ectoparasites that can cause reduction in body weight, damage to hides, and serve as vectors in cattle. Fortunately, there are preventative measures that can deter the spread of mosquito- and tick-borne diseases, including vaccines, acaricides, and integrated vector management.

Equine

A major concern for veterinarians and equine owners alike is the threat of WNV infection. As discussed in the Case Report, West Nile Virus can be transmitted from mosquitoes to equine, with signs of infection including fever, ataxia, inflammation of the nervous system, and more (Pare and Moore, 2018). WNV infection can cause health and economic consequences for equine and their owners, thus, efforts have been made to develop and encourage the use of equine vaccines for WNV (Saiz, 2020). The Animal and Plant Health Inspection Service (APHIS) is responsible for regulating veterinary vaccines and other products of biological origin in the United States. In order for a vaccine to be manufactured, a license for the facility and each product is required. Before this license can be issued, the manufacturer must demonstrate to the United States Department of Agriculture (USDA) that the product is pure, safe, potent, and efficacious ("Vaccine licensure in the United States", 2021).

Currently, there are several WNV vaccines available for horses, including the West Nile Innovator that was administered in the case reported above. Four of these vaccines are listed in Table 1. West Nile Innovator demonstrated to be 96.7% effective in a 2003 outbreak (Epp et al, 2005). There are some limitations, such as the need for annual boosters due to the short duration of the induced immunity. Nevertheless, the availability of efficacious vaccines has reduced equine WNV cases by almost 70% from 2002 to 2003 ("2003 Equine West Nile Virus Outlook for the United States", 2003).

Bovine

Name	*Manufacturer*	*Earliest Age*	*Repeat dose in*	*Annual booster*
Equi-Jec WNV	Boehringer Ingelheim	4 months	3 to 4 weeks	Yes
Prestige WNV	Merck	6 months	3 to 4 weeks	Yes
Vetera West Nile	Boehringer Ingelheim	4 months	3 to 4 weeks	Yes
West Nile Innovator	Zoetis Animal Health	10 months	3 to 4 weeks	Yes

Table 1. WNV Equine Vaccines. General information for four equine vaccines is given above, including the manufacturer, earliest age to give the vaccination, when to repeat the dose, and if an annual booster is required. ://www.valleyvet.com/library/west-nile-horse-vaccine-comparison.html?grp=UUUU&grpc=UUUU&grpsc=UUUU&ccd=IGO057&gclid=CjwKCAiAhbeCBhBcEiwAkv2cY01koC4GzBD7Ngp4tuJoM1G-Nb8YNHLEvVWGPN0QhW7ymSOK2IpOFRoCe1oQAvD_BwE

<u>Ticks and Tick-borne diseases</u>

The cattle industry also faces the threat of vector-borne diseases, especially those that are vectored by ticks (Domingos et al, 2013). These ectoparasites alone can cause reduction of body weight, lowered milk and meat production, and can damage leather hides (Domingos et al, 2013). Bite marks from ticks can diminish the value of a hide by 20-30%. Tick-borne diseases (TBDs) are recognized for causing great economic losses in livestock animals across the globe. The global costs of ticks and TBDs are estimated to be from 13.9 to 18.7 billion (USD) annually (Ghosh et al, 2007). Examples of TBDs include Lyme, Rocky Mountain spotted fever, theileriosis, babesiosis, anaplasmosis, and heartwater. In addition, TBDs have also impacted human health through their zoonotic potential.

A common method of tick control is the use of acaricides, which are pesticides used to kill ticks and mites. There are several different types of acaricides, such as Amidin, Doramectin, Ivermectin, and Spinosin. The efficacy of these formulations was determined in a study completed in Brazil. In the experiment, populations of *Rhipicephalus microplus* were collected from dairy herds. the results of this experiment are shown in Table 2 (Brito el al, 2011). The most economically important ectoparasite of cattle worldwide is considered to be *R. microplus* (Esteve-Gasent et al, 2020).

Acaricide	*Min. efficacy (%)*	*Max. efficacy (%)*
Cypermethrin	48.35	70.5
Deltamethrin	61.22	76.84
Cypermethrin + dichlorvos	68.91	81.47
Cypermethrin + chlorpyrifos + citronellal	72.41	86.37
Doramectin	86.21	100
Ivermectin	86.84	100
Abamectin	81.34	100
Milbemycin	94.84	100
Spinosin	93.21	100

Table 2. Efficacy values for common acaricides. The results of the experimental study conducted in Brazil are shown in the table above. The efficacy of each acaricide was based on populations of *Rhipicephalus microplus* collected from dairy herds. These acaricides are available in the United States. Table made from data presented in:
Brito LG, Barbieri FS, Rocha RB, Oliveira MCS, Ribeiro ES. Evaluation of the Efficacy of Acaricides Used to Control the Cattle Tick, Rhipicephalus microplus, in Dairy Herds Raised in the Brazilian Southwestern Amazon. *Veterinary Medicine International*. 2011;2011:e806093. doi:10.4061/2011/806093

However, acaricides are not environmentally friendly and have residual effects in milk and meat products (Domingos et al, 2013). The environmental precautions of acaricides includes proper disposal and avoiding excess spills and pours that could potentially leach toxins into the surrounding area. In addition, the chemical residues in milk and meat products can be hazardous to consumers if withdrawal periods for food animals are not followed (De Meneghi et al, 2016). Also, acaricides can be used inappropriately, leading to acaricide-resistant ticks. The high intensity of acaricide use in tick management has created this resistance (Rodriguez-Vivas et al, 2018). These ticks have genetic mutations that allow the lethal dose to be higher for them than for the majority of the species (Domingos et al, 2013). The concerns of acaricide use has led to new chemical and non-chemical approaches to control to be developed (Rodriguez-Vivas et al, 2018).

Due to the limitations of acaricides, the most sustainable option of tick control is integrated pest/vector management (IPM/IVM) (Ghosh et al, 2007). In this management technique, two or more tick control technologies are utilized to control tick populations, with the goal being to achieve parasite control in a cost-effective, sustainable, and environmentally conscious manner (Rodriguez-Vivas et al, 2018). A potential component of IPM is utilizing a tick vaccine. There are several variations on these vaccines, including vaccines against both ticks and pathogen/parasite and broad-spectrum vaccines against multiple tick species (Ghosh et al, 2007). Two tick vaccines became commercially available in the early 1990's, which are TickGARD and Gavac (Merino et al, 2013). However, these vaccines are only available in Australia and Latin America, respectively (Merino et al, 2013). More recently, a vaccine using an aquaporin antigen has undergone vaccine trials in Brazil. In two cattle pen trials, this vaccine showed efficacy of 75% and 68% (Guerrero et al, 2014) and thus holds promise as a more effective control method against *Rhipicephalus microplus.*

One of the parasites that can be transmitted by ticks, specifically by *Rhipicephalus (Boophilus) annulatus* (the southern cattle tick) and *Rhipicephalus microplus*, is the apicomplexan *Babesia bovis* (see Figure 2). This parasite causes a disease commonly referred to as tick fever. Bovine babesiosis has an acute and chronic stage of infection. The acute stage is characterized by fever, lethargy, anorexia, and anemia. In the chronic stage, animals tend to be asymptomatic (Esteve-Gasent et al, 2020). Cattle also experience a loss of meat and milk production, and occasionally die from this disease.

Bovine babesiosis is controlled by three main methods: tick management, tick vaccines, and anti-babesia drugs. A tick eradication program targeting the southern cattle tick was established as early as 1943 . This U.S. Cattle Fever Tick Eradication Program was successful in eliminating *R. microplus* and *R. annulatus* from the continental United States in 1943. In Mexico, a national tick eradication program was operated between 1974 and 1984. However, today it is estimated that 52% of the national territory in Mexico is infested with these *Rhipicephalus spp* and ~75% of cattle are at risk of developing babesiosis (Esteve-Gasent et al, 2020).

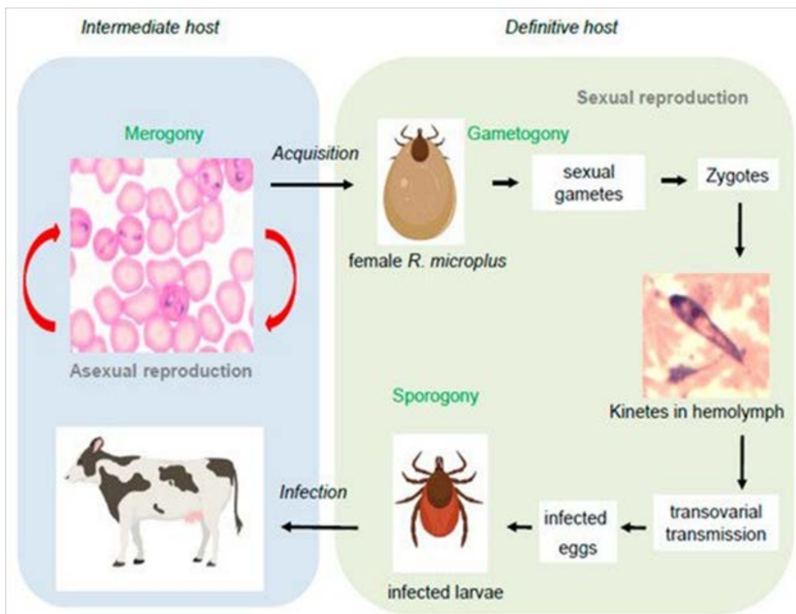

Figure 2. Transmission cycle of *Babesia bovis.* Cattle become infected after being bitten by infected larvae. The protozoan undergoes asexual reproduction in the cattle intermediate host and then infects female ticks during a blood meal. Sexual reproduction of *B. bovis* occurs in the tick and is passed to the eggs through transovarial transmission. Image credit: Gallego-Lopez et al. 2019, Figure 2, "*Babesia bovis* life cycle", CC BY 4.0. No changes were made to the figure.

The U.S. continues to import a significant number of live cattle from Mexico; 1.3 million live cattle in 2019 alone (Esteve-Gasent et al, 2020). to control *Rhipicephalus spp*, a permanent quarantine zone along the United States' southern border with Mexico is implemented to monitor and control outbreaks of the tick . This quarantine zone covers 500 miles from Del Rio, Texas, to the Gulf of Mexico (USDA, 2021).

In addition to tick control, bovine babesiosis can be treated using a number of chemical compounds that are effective against bovine *Babesia* parasites, including Nerolidol, Artesunate, and Atovaquone, which are available in the United States (Mosqueda et al, 2012). In severe cases of infection, supportive therapy such as blood transfusions, anti-inflammatory drugs, dextrose, and tick removal may be necessary (Mosqueda et al, 2012).

Additional Threats

An arthropod parasite that continues to be a potential threat to livestock in the United States is the New World screwworm, *Cochliomyia hominivorax* (Figure 3). This fly was initially eradicated from the United States in 1966, but in 2016, this species was reintroduced into the Florida Keys. Female flies are attracted to wounds and mucous membranes of warm-blooded animals and lay eggs in the area. The hatched larvae feed on the living tissue and causes a condition known as myiasis. Mammals, including humans, serve as hosts for the New World screwworm (NWS) most often, but other warm-blooded animals can be hosts as well. NWS myiasis can occur with pre-existing wounds, but mucous membranes can also be sites of infections.

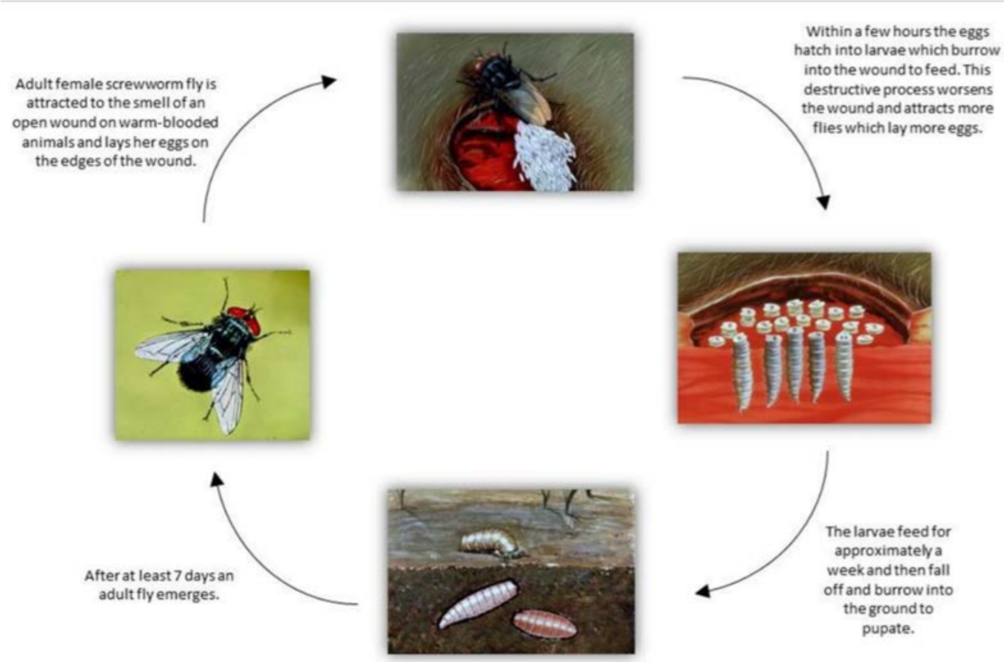

Figure 3. Life Cycle of New World Screwworm. The adult female screwworm fly lays her eggs on the open wound of a warm-blooded animal. The host range includes humans, cattle, sheep, and others. The larvae hatch and burrow into the wound to feed, which lasts for approximately one week. After falling to the ground, the larvae pupate and the adult fly emerges seven days later. Image credit: United States Department of Agriculture. "Disease Response Strategy. New World Screwworm Myiasis." FAD PReP- Foreign Animal Disease Preparedness & Response Plan. Accessed March 18, 2021.

Signs of an infested wound include pus, drainage, discharge of blood and serum, and a distinctive odor. Egg masses in a ‘shingle-like’ pattern may be visible around the edges of the wound. Animals can die of secondary bacterial infections, toxicity, and/or trauma within one to two weeks if left untreated. The fly was eradicated for the second time in the United States in 2017, but cases are reported periodically due to importation, and pose a continued threat to wildlife, livestock, and humans alike (USDA, 2021). A simple diagnostic test, developed by ARS-USDA, is available to determine whether recovered larvae are indeed *C. hominovorax* (USDA, 1998). Deployment of such diagnostic tools is critical for early detection, as a coordinated response to eradicate screwworm is otherwise necessary.

An emerging threat to both livestock and humans is the appearance of a new tick species in the United States. In 2017, the invasive Asian longhorned tick, *Haemaphysalis longicornis,* made its first appearance in the United States in New Jersey. After this initial detection, the tick spread to 11 states: Arkansas, Connecticut, Kentucky, Maryland, New Jersey, New York, North Carolina, Pennsylvania, Tennessee, Virginia, and West Virginia (Pritt, 2020). The rapid spread of the tick is likely due to its ability to reproduce parthenogenetically and tolerate a broad range of climate conditions (Tufts, 2019). The Asian longhorned tick is a threat because of its potential to transmit pathogens, such as *Rickettsia rickettsii*, the causative agent of Rocky Mountain spotted fever, a disease that affects humans and dogs (Stanley et al, 2020). This tick is also known to reach extremely high numbers on a single host, as females are capable of producing thousands of eggs at one time. Heavy infestations can limit growth and cause severe blood loss in animals. Further research is needed to determine the vector competence and vectorial capacity of *Haemaphysalis longicornis* (Pritt, 2020).

Summary

Entomology impacts veterinary medicine in the form of several important diseases that have been discussed in this paper, including West Nile encephalomyelitis, babesiosis, and myiasis. West Nile virus infection can occur in equine when horses are bitten by an infected mosquito. The virus can cause a disease known as West Nile Encephalomyelitis, which refers to inflammation of the brain and spinal cord (Merck Veterinary Manual, 2021). Sixty-nine cases of equine WNV were reported to the ArboNet reporting system in 2020 (USDA APHIS, 2021). There are several vaccines available to prevent horses from contracting WNV (Epp et al, 2005). The cattle industry faces a large threat from diseases that are vectored by ticks. The global costs of ticks and TBDs are estimated to be from 13.9 to 18.7 billion (USD) annually (Ghosh et al, 2007). *Babesia bovis* is a protozoan parasite transmitted by the tick *Rhipicephalus annulatus* and causes a disease known as tick fever. The U.S. Cattle Fever Tick Eradication Program monitors cattle traveling across the U.S.- Mexico border to prevent outbreaks of the tick (Esteve-Gasent et al, 2020). Another parasite that had a recent presence in the United States is the New World screwworm. After being previously eradicated in 1966, the fly larvae reappeared in the Florida Keys in 2016. The NWS is associated with a disease known as myiasis, which is caused by the fly larvae residing within living tissue on its host. The fly was eradicated for the second time from the United States in 2017 (USDA, 2021). Finally, the Asian longhorned tick, *Haemaphysalis longicornis,* made its appearance in the United States in 2017 (Pritt, 2020). This invasive tick species is a zoonotic threat due to its ability to transmit Rocky Mountain spotted fever (Stanley et al, 2020). All arthropod parasites and vectors of disease discussed in this manuscript are present in Texas, and highlight the multitudes of threats that arthropods pose to the livestock industry in this state. Veterinarians constitute a critical line of defense against these infections as they can encounter them in routine clinical settings. Therefore, veterinary practice requires knowledge of fundamental arthropod-borne disease ecology as well as treatment and control options.

Personal Conclusion

Throughout the process of writing this paper, I was able to further my knowledge on arthropod-borne illnesses of large animals and investigate topics that piqued my interest. While reading about West Nile Encephalomyelitis, I discovered how fortunate we were to have a positive outcome for the horse we treated when WNE is known to be fatal if left untreated. The case study and subsequent discussion of vaccinations emphasized the importance of annual vaccinations for equine and other species. Illnesses like WNE are easier and more affordable to prevent, rather than treat. Being raised in an agricultural-based community, I wanted to learn more about how entomology is important in the cattle industry. Ticks are always a concern, but the damage they can cause is much more widespread than I originally thought. My community's proximity to the U.S.-Mexico border made the threat of tick fever caused by *Babesia bovis* an important topic that I wanted to discuss in this paper. I have witnessed multiple tick scratches by the Texas Animal Health Commission with Dr. Pennington and on multiple ranches in the South Texas area. It is an ongoing threat in this area, and one that is not likely to fade anytime soon.

My internship with Circle T Veterinary Services and subsequent literary analysis of my experience has allowed me to broaden my knowledge and further my understanding of the connections between entomology and veterinary medicine. At the beginning of my college education, I realized I was interested in entomology, but was unsure on how it could influence my veterinary studies. Through writing this review, I have realized that these two fields are more intertwined than I can begin to articulate, and my knowledge of entomology can only help me as I pursue a career in veterinary medicine.

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