Chapter 1: Introduction and Statement of Purpose

1.1 Introduction

Infectious disease eradication has seen both success and failure over the past fifty years. The development of antibiotics and the global eradication of smallpox are two examples of the massive strides made in the elimination of several infectious diseases, as well as the prevention of measles and poliomyelitis (Haggett 1994). In spite of these accomplishments in public health, a number of diseases have newly emerged or expanded their range in recent decades. Migration and commerce, which are both derivatives of globalization, have contributed to the spread of diseases such as HIV, dengue, and cholera (Morse 1995). The movement of human populations into areas that were once heavily forested along with forced migration caused by international conflicts are two examples of the changes that have affected the increase in vector-borne diseases such as malaria and leishmaniasis (Haggett 1994; Patz et al. 2004).

In addition to changing human geographies that have impacted disease distribution, research indicates that characteristics of the physical environment have also contributed to shifts in disease patterns. Consequences of climate variability and change are evident with diseases such as malaria and hantavirus pulmonary syndrome which are influenced when temperatures become warmer and precipitation increases (PAHO 2002; Meade and Earickson 2005). In the case of hantavirus, the El Niño Southern Oscillation (ENSO) of 1993 created a wetter environment in the southwestern United States that encouraged growth of the piñon nut which is the primary food source for mice. This altered precipitation regime resulted in an explosion in the mouse population and placed humans closer to the infected urine of the mice (Meade and Earickson 2005). As for malaria, there is concern that increasing average temperatures will affect both the latitudinal and altitudinal range of the *Anopheles* mosquito, resulting in an increased risk for disease transmission in new regions as well as in diverse mountain ecosystems (Garrett 1994).

Other factors involved in the spread of disease can be seen in the effects of population movement and trade. For example, the *Aedes albopictus* mosquito was introduced to North America through shipping routes after being transported inside used tires that collected water and resulted in a suitable breeding site for the mosquito (Hawley et al. 1987). Similarly, the Chagas disease vector has been reportedly transported in luggage (Lent and Wygodzinsky 1979; Schofield 1979). Finally, the 2003 outbreak of severe acute respiratory syndrome (SARS) in Asia illustrates another route of disease transmission. SARS spread rapidly from person-to-person through communities, the health care system, and into other countries including Canada and Europe, further illustrating the need for public health education at all levels of society (Cooke and Shapiro 2003). Awareness of risk is the first step in amelioration of disease and early awareness can serve as a tool to prevent the emergence of disease (Morse 1995; Dias and Schofield 1999).

The emergence of Chagas disease presents an example of the way in which climate conditions and physician awareness can affect disease dispersion. Chagas disease is endemic in Central and South America and primarily spreads to humans via the triatomine vector (also known as the “kissing bug”) (Figure 1.1) (CDC 2006). The dynamic nature of climate and disease supports the need to examine the spatial and temporal patterns of triatomine biogeography along with physician and public health awareness of Chagas disease (American trypanosomiasis) in order to limit disease emergence in the United States. The transmission of Chagas disease to humans

Figure 1.1 Triatomine insect (CDC image, 2004 www.dpd.cdc.gov/dpdx/HTML/ImageLibrary/TrypanosomiasisAmerican_il.htm).

is facilitated by the domestic nature of the South and Central American triatomine, which places them in close proximity to or within human dwellings (Dias et al. 2002). The disease itself is caused by a parasitic protozoan, *Trypanosoma cruzi* (*T. cruzi*) (Figure 1.2) (CDC 2006).

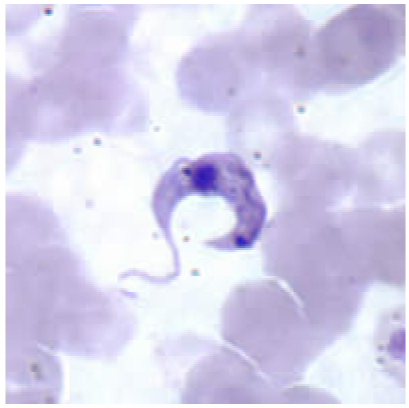

Figure 1.2 *Trypanosoma cruzi* (CDC image, 2004 www.dpd.cdc.gov/dpdx/HTML/ImageLibrary/TrypanosomiasisAmerican_il.htm).

In 1909, Brazilian scientist Carlos Chagas discovered the *T. cruzi* protozoa in the hindgut of the triatomine and recognized that *T. cruzi* is transmitted through the feces (Usinger 1944; Lent and Wygodzinsky 1979; Kirchhoff 1993). Through the 1950s, cardiologist Emanuel Dias and his colleagues focused their efforts on the effects of Chagas disease on the heart, vitalizing Chagas disease research efforts (Coutinho 1999 Figures, Reproduced with permission by Sage Publications). Since that time, studies indicate that *T. cruzi* transmission routes include blood transfusion; organ transplantation; contamination of mucous membranes or conjunctiva; and through eating improperly cooked food (Kirchhoff et al. 1987; Leiby et al. 2000; CDC 2001; Leiby et al. 2002).

In the United States, the disease is considered to be sylvatic (wild), which means the disease transmission cycle is zoonotic and is maintained between the triatomine vector and non-human reservoir hosts (Lent and Wygodzinsky 1979). The primary host for most triatomine is rodents, and occasionally dogs, tree toads, birds, and lizards (Kagan et al. 1966; Lent and Wygodzinsky 1979; Ryckman 1984; Barr et al. 1995; Meurs et al. 1998; Bradley et al. 2000; Peterson et al. 2002; Beard et al. 2003).

Studies conducted throughout the Chagas-endemic regions of South and Central America indicate the effectiveness of vigilant triatomine monitoring within homes, even in areas where domestic triatomines have been eradicated (Ramsey et al. 2000; Abad-Franch et al. 2001; Prata 2001; Monroy et al. 2003; Enger et al. 2004; Pereira et al. 2006; Vazquez-Prokopec et al. 2006). Research into Chagas disease transmission in Latin American provides the valuable insight necessary to prevent disease emergence in the United States.

1.2 Statement of Purpose

To determine the risk of Chagas disease transmission in the United States, it is necessary to define the characteristics of triatomine biogeography that make it an effective disease vector as well as to illustrate the level of Chagas disease awareness within the vector's range. The geographic approach utilized in this thesis enables one to analyze and depict effects of the relationship between climate variability and triatomine biogeography as well as evaluate patterns associated with the five cases discovered in the United States. The results are significant in that they reveal the current and potential population and land area encompassed within the delineated higher risk range and depict the level of disease awareness among physicians within the delineated range.

This study uses a geographic information system (GIS) to delineate the current and future range of increased triatomine activity based upon the minimum temperature threshold for increased activity. Isolates of the triatomine species within the United States that are known to harbor *T. cruzi* and that exhibit qualities of domesticity are mapped. The qualities of domesticity are based upon whether the species is known bite humans and domestic dogs as well as reports indicating that the species has been found in the peridomestic setting. In addition to the range of a vector, awareness of the disease is crucial in recognizing the potential for a disease to emerge in a new location. Therefore, the second portion of the study evaluates the level of disease awareness among physicians in areas defined as geographically at higher risk for disease transmission through the use of a survey.

The purpose of this study is to define the interconnected role that climate conditions and physician awareness play in the potential emergence of Chagas disease, and to delineate the regions of the United States where Chagas disease is likely to emerge. This study is built on the theoretical frameworks of landscape epidemiology and disease ecology within medical geography as it explores the distribution of the triatomine and how that relates to the three factors of disease ecology, which are population, habitat, and behavioral characteristics (Meade and Earickson 2005). Factors within disease ecology that are of particular interest are the altering of habitats to accommodate population growth as well as human behavior as it considers the importance of disease awareness in prevention.

References

Abad-Franch F, Paucar C. A, Carpio C, Cuba Cuba CA, Aguilar V. HM, Miles MA, 2001. Biogeography of Triatominae (Hemiptera: Reduviidae) in Ecuador: Implications for the Design of Control Strategies. Mem Inst Oswaldo Cruz 96, 611-620.

Barr SC, Van Beek O, Carlisle-Nowak MS, Lopez JW, Kirchhoff LV, Allison N, Zajac A, de Lahunta A, Schlafer DH, Crandall WT, 1995. *Trypanosoma cruzi* infection in Walker Hounds from Virginia. American Journal of Veterinary Research 56, 1037-1044.

Beard CB, Pye G, Steurer FJ, Rodriguez R, Campman R, Peterson AT, Ramsey J, Wirtz RA, Robinson LE, 2003. Chagas Disease in a Domestic Transmission Cycle, Southern Texas, USA. CDC Emerg Infect Dis 9, 103-105.

Bradley KK, Bergman DK, Woods JP, Crutcher JM, Kirchhoff LV, 2000. Prevalence of American trypanosomiasis (Chagas disease) among dogs in Oklahoma. J Am Vet Med Assoc 217, 1853-1857.

CDC, 2001. Chagas Disease After Organ Transplantation - United States, 2001. Morbidity and Mortality Weekly Report 51, 210-212.

———, 2006. Chagas Disease Fact Sheet. Division of Parasitic Diseases, Parasitic Disease Information. www.cdc.gov/ncidod/dpd/parasites/chagasdisease/factsht_chagas_disease.htm. 2007.

———, image, 2004 www.dpd.cdc.gov/dpdx/HTML/ImageLibrary/TrypanosomiasisAmerican_il.htm. DPDx Laboratory Identification of Parasites of Public Health Concern. Division of Parasitic Diseases, Parasitic Disease Information.

Cooke FJ, Shapiro DS, 2003. Global outbreak of severe acute respiratory syndrome (SARS). Int J Infect Dis 7, 80-85.

Coutinho M, 1999 Figures, Reproduced with permission by Sage Publications. Ninety Years of Chagas Disease: A Success Story at the Periphery. Social Studies of Science 29, 519-549.

Dias JCP, Schofield CJ, 1999. The Evolution of Chagas Disease (American Trypanosomiasis) Control after 90 Years since Carlos Chagas Discovery. Mem Inst Oswaldo Cruz 94, 103-121.

Dias JCP, Silveira AC, Schofield CJ, 2002. The Impact of Chagas Disease Control in Latin America - A Review. Mem Inst Oswaldo Cruz 97, 603-612.

Enger KS, Ordoñez R, Wilson ML, Ramsey JM, 2004. Evaluation of Risk Factors for Rural Infestation by *Triatoma pallidipennis* (Hemiptera: Triatominae), a Mexican Vector of Chagas Disease. Journal of Medical Entomology 41, 760-767.

Garrett L, 1994. The Coming Plague: Newly emerging diseases in a world out of balance. New York, Penguin Books, p. 568.

Haggett P, 1994. Geographical Aspects of the Emergence of Infectious Diseases. Geografiska Annaler 76(B), 91-104.

Hawley WA, Reiter P, Copeland RS, Pumpuni CB, Craig Jr. GB, 1987. *Aedes albopictus* in North America: Probable introduction in used tires from northern Asia. Science 236, 1114-1116.

Kagan IG, Norman L, Allain D, 1966. Studies on *Trypanosoma cruzi* isolated in the United States: A Review. Rev. Biol. Trop. 14, 55-73.
Kirchhoff LV, 1993. American Trypanosomiasis (Chagas' Disease) -- A Tropical Disease Now in the United States. The New England Journal of Medicine 329, 639-644.
Kirchhoff LV, Gam AA, Gilliam FC, 1987. American Trypanosomiasis (Chagas' Disease) in Central American Immigrants. The American Journal of Medicine 82, 915-920.
Leiby DA, Herron Jr. RM, Read EJ, Lenes BA, Stumpf RJ, 2002. *Trypanosoma cruzi* in Los Angeles and Miami blood donors: impact of evolving donor demographics on seroprevalence and implications for transfusion transmission. Transfusion 42, 549-555.
Leiby DA, Rentas FJ, Nelson KE, Stambolis VA, Ness PM, Parnis C, McAllister HA, Yawn DH, Stumpf RJ, Kirchhoff LV, 2000. Evidence of *Trypanosoma cruzi* Infection (Chagas' Disease) Among Patients Undergoing Cardiac Surgery. American Heart Association Circulation 102, 2978-2982.
Lent H, Wygodzinsky P, 1979. Revision of the Triatominae (Hemiptera, Reduviidae), and Their Significance as Vectors of Chagas' Disease. Bulletin of the American Museum of Natural History 163, 123-520.
Meade MS, Earickson RJ, 2005. Medical Geography. Second ed. New York, The Guilford Press.
Meurs KM, Anthony MA, Slater M, Miller MW, 1998. Chronic *Trypanosoma cruzi* infection in dogs: 11 cases (1987-1996). J Am Vet Med Assoc 213, 497-500.
Monroy MC, Bustamante DM, Rodas AG, Enriquez ME, Rosales RG, 2003. Habitats, Dispersion and Invasion of Sylvatic *Triatoma dimidiata* (Hemiptera: Reduviidae: Triatominae) in Petén, Guatemala. Journal of Medical Entomology 40 800-806.
Morse SS, 1995. Factors in the Emergence of Infectious Disease. Emerging Infectious Diseases 1, 7-15.
PAHO. 2002. Panama: Core Health Data Selected Indicators: Pan American Health Organization.
Patz JA, Daszak P, Tabor GM, Aguirre AA, Pearl M, Epstein J, Wolfe ND, Kilpatrick AM, Foufopoulos J, Molyneux D, Bradley DJ, 2004. Unhealthy Landscapes: Policy Recommendations on Land Use Change and Infectious Disease Emergence. Environ Health Perspect 112, 1092-1098.
Pereira MH, Gontijo NF, Guarneri AA, Sant'Anna MRV, Diotaiuti L, 2006. Competitive displacement in Triatominae: the *Triatoma infestans* success. Trends in Parasitology 22, 516-520.
Peterson AT, Sánchez-Cordero V, Beard CB, Ramsey JM, 2002. Ecologic Niche Modeling and Potential Reservoirs for Chagas Disease, Mexico. Emerging Infectious Diseases 8, 662-667.
Prata A, 2001. Review: Clinical and epidemiological aspects of Chagas disease. The Lancet Infectious Diseases 1, 92-100.
Ramsey JM, Ordoñez R, Cruz-Celis A, Alvear AL, Chavez V, Lopez R, Pintor JR, Gama F, Carrillo S, 2000. Distribution of domestic triatominae and stratification of Chagas Disease transmission in Oaxaca, Mexico. Medical and Veterinary Entomology 14, 19-30.

Ryckman RE, 1984. The Triatominae of North and Central America and the West Indies: A Checklist with Synonymy (Hemiptera: Reduviidae: Triatominae). Bull. Soc. Vector Ecol. 9, 71-83.

Schofield CJ, 1979. The behaviour of Triatominae (Hemiptera: Reduviidae): a review. Bulletin of Entomological Research 69, 363-379.

Usinger RL. 1944. The Triatominae of North and Central America and the West Indies and their Public Health Significance, Public Health Bulletin No. 288, ed. U. S. P. H. Service: U.S. Government Printing Office.

Vazquez-Prokopec GM, Ceballos LA, Marcet PL, Cecere MC, Cardinal MV, Kitron U, Gürtler RE, 2006. Seasonal variations in active dispersal of natural populations of *Triatoma infestans* in rural north-western Argentina. Medical and Veterinary Entomology 20, 273-279.

Chapter 1 Figures

Page