**Distribution Agreement**

In presenting this dissertation as a partial fulfillment of the requirements for an advanced degree from Emory University, I hereby grant to Emory University and its agents the non-exclusive license to archive, make accessible, and display my thesis or dissertation in whole or in part in all forms of media, now or hereafter known, including display on the world wide web. I understand that I may select some access restrictions as part of the online submission of this thesis or dissertation. I retain all ownership rights to the copyright of the thesis or dissertation. I also retain the right to use in future works (such as articles or books) all or part of this thesis or dissertation.

Signature:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_

Johanna S. Salzer Date

Applying Ecological Theory to Understand Biological Diversity, Anthropogenic Disturbance, and Disease among Terrestrial Small Mammals in Western Uganda

By

Johanna S. Salzer

Doctor of Philosophy

Graduate Division of Biological and Biomedical Sciences

Population Biology, Ecology, and Evolution

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Thomas R. Gillespie, Ph.D.

Advisor

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Darin S. Carroll, Ph.D.

Committee Member

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Inger K. Damon, M.D., Ph.D.

Committee Member

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Jacobus de Roode, Ph.D.

Committee Member

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Uriel Kitron, Ph.D.

Committee Member

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

James N. Mills, Ph.D.

Committee Member

Applying Ecological Theory to Understand Biological Diversity, Anthropogenic Disturbance, and Disease among Terrestrial Small Mammals in Western Uganda

By

Johanna S. Salzer

B.A., Florida State University, 2003

D.V.M., University of Illinois, 2007

Advisor: Thomas R. Gillespie, Ph.D.

An abstract of

A dissertation submitted to the Faculty of the

James T. Laney School of Graduate Studies of Emory University

in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

in

Graduate Division of Biological and Biomedical Sciences

Population Biology, Ecology, and Evolution

2014

**Abstract**

Applying Ecological Theory to Understand Biological Diversity, Anthropogenic Disturbance, and Disease among Terrestrial Small Mammals in Western Uganda

By

Johanna S. Salzer

Through the study of disease ecology, we seek to understand the mechanisms driving the complex interactions occurring among parasites, their hosts, and their environment. Ecologists dissect these complex ecological interactions through generalized principles, theories, and hypotheses. In order to understand the applicability and universality of these concepts, they must be applied to investigations conducted in natural systems. The aim of my dissertation was to test the generality of several ecological theories in a complex natural system. These studies were conducted in and around Kibale National Park, which is located in forested western Uganda. I examined terrestrial small mammal assemblages, consisting of members of the Order Rodentia (rodents) and Soricomorpha (shrews). These small mammals were collected from natural habitats experiencing varying intensities of anthropogenic disturbance. Additionally, I investigated the parasites they harbor, specifically poxviruses, *Trypanosoma* spp., *Giardia* spp., *Cryptosporidium* spp, and ectoparasites, which included fleas, lice, ticks, and mites. My work contributes to the field of disease ecology by exploring ideas and theories primarily restricted to less complex study systems. The four studies contained within my dissertation represent the successfully application of several foundational theories and novel ideas to improve our knowledge of how parasites are impacted by habitat disturbance and alterations in host community structure. My findings provide empirical evidence of the value and pitfalls of using generalized principles, theories, and hypotheses to understand host and disease dynamics in a complex natural system.

Applying Ecological Theory to Understand Biological Diversity, Anthropogenic Disturbance, and Disease among Terrestrial Small Mammals in Western Uganda

By

Johanna S. Salzer

B.A., Florida State University, 2003

D.V.M., University of Illinois, 2007

Advisor: Thomas R. Gillespie, Ph.D.

A dissertation submitted to the Faculty of the

James T. Laney School of Graduate Studies of Emory University

in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

in

Graduate Division of Biological and Biomedical Sciences

Population Biology, Ecology, and Evolution

2014

**ACKNOWLEDGEMENTS**

I want to thank my academic advisor at Emory University, Dr. Tom Gillespie. Since the first moment I walked into his office in the Pathobiology Department at the University of Illinois, Tom has supported and respected my intellectual interests and allowed me to forge my own path into the field of disease ecology and applied public health.

The mentorship and encouragement from my primary advisory at CDC, Dr. Darin Carroll, was crucial to my graduate research and experience. I am thankful to Darin for welcoming me onto his scientific team and providing me with an environment in which to grow and merge my veterinary skills with my growing skills as a disease ecologist.

I am also extremely grateful for my dissertation committee—Dr. Uriel Kitron, Dr. Inger Damon, Dr. Jaap de Roode, and Dr. Jim Mills. I am fortunate to have been guided by a committee of diverse expertise that meet at the nexus of ecological principles and applied public health.

Funding for my dissertation research came from a variety of sources. During my first year of graduate studies, the Department of Environmental Sciences supported me. Since this time, I have been supported through the Oak Ridge Institute for Science Education (ORISE) fellowship in the Poxvirus and Rabies Branch at CDC. Additional funding, which provided logistical field and laboratory support, was provided by Emory Global Health Institute, The University of Illinois Earth and Society Initiative, The University of Illinois Center for Zoonoses Research, NIH Grant T35 2006, and the Conservation Medicine Center in Chicago.

The inherent interdisciplinary nature of my scientific interests means many people have provided me with guidance and mentorship during my Ph.D. studies. I would like to thank Joanna Shisler, Innocent Rwego, Ananias Escalantes, Julian Kerbis Peterhans, Miguel Pinto, Dominic Travis, Val Beasley, Mark Kuhlenschmidt, William Stanley, Yu Li, Kevin Karem, Berry Brosi, Dennis Twamogisho, Vicki Olson, and Lihua Xiao.

Conducting fieldwork requires a team of individuals that are committed to long hours of physical and mental labor. The field collections of small mammals would not have been possible without the hard work and dedication of Amanda Jo Williams-Newkirk, Sandra Ockers, Charles Akora, Isaiah Mwesige, Anna Czekala, Abigail Mathewson, Clement Nyikiriza, Charles Kyalisima, Derek Meyer, Michele Madonia, Liz Falendysz, and Dennis Twinomugisha. Additionally, I express my gratitude to the 371 Ugandan small mammals that were humanely euthanatized in order for this study to be conducted.

I was assisted in the laboratory by a number of exceptional undergraduates from the Department of Environmental Sciences: Stefanie Lang, Kristen Cross, Ian Fried, Deema Elchoufi, Dana Greenlee, and Benjamin Kramer-Roach.

Additionally, I would like to thank my network of friends for their support throughout this process. There are many individuals whose friendships have brought me much joy throughout my graduate studies; many thanks to Ariane Peralta, Amanda Jo Williams-Newkirk, Serena Carroll, Guisi Amore, Emily Lankau, Emily Jentes, Brian Peters, Hector Gutierrez, Josh Howard, Christy Hughes, and Sancho Salzer.

Lastly, I would like to thank my family. My parents, James and Sara Salzer, have provided me with unconditional love and support through a total of twenty-nine years of continuous education. I am forever thankful to them for instilling in me a love of learning and adventure. I thank my brother, Jackson Somphonphakdy and my sister, Christianne Blumberg, for always providing me with much love from home. Finally, I am grateful to my husband, R. Ryan Lash, for his unwavering love and support over the duration of my graduate studies and for years to come.

**TABLE of CONTENTS**

**CHAPTER 1**  pg. 1

*Introduction:* *Ecological theory and practice at the interface of biological diversity, anthropogenic disturbance, and disease*

1.1 Theory and its role in disease ecology pg. 5

1.2 Examining the theory pg. 14

1.3 References pg. 17

**CHAPTER 2** pg. 23

*Effects of habitat disturbance on African small mammal communities*

2.1 Summary pg. 23

2.2 Introduction pg. 24

2.3 Materials and Methods pg. 26

2.4 Results pg. 32

2.5 Discussion pg. 36

2.6 Figures pg. 44

2.7 Tables pg. 47

2.8 References pg. 49

**CHAPTER 3** pg. 53

*Effects of anthropogenic and demographic factors on patterns of parasitism in African small mammal communities*

3.1 Summary pg. 53

3.2 Introduction pg. 54

3.3 Materials and Methods pg. 55

3.4 Results pg. 61

3.5 Discussion pg. 62

3.6 Figures pg. 66

3.7 Tables pg. 68

3.8 References pg. 70

**CHAPTER 4** pg. 74

*Effects of anthropogenic disturbance on native and invasive trypanosomes of rodents in forested Uganda*

4.1 Summary pg. 74

4.2 Introduction pg. 75

4.3 Materials and Methods pg. 77

4.4 Results pg. 81

4.5 Discussion pg. 84

4.6 Figures pg. 91

4.7 Tables pg. 93

4.8 References pg. 94

**CHAPTER 5** pg. 98

*Serologic evidence for circulating orthopoxviruses in peridomestic rodents*

*from rural Uganda*

5.1 Summary pg. 98

5.2 Introduction pg. 99

5.3 Materials and Methods pg. 100

5.4 Results pg. 104

5.5 Discussion pg. 106

5.6 Figures pg. 110

5.7 References pg. 112

**CHAPTER 6** pg. 115

*Strengths, Limitations, and Conclusions*

6.1 Key Findings and Strengths pg. 116

6.2 Limitations pg. 119

6.3 Future Direction and Next Steps pg. 122

6.4 References pg. 124

**TABLE of FIGURES**

**Figure 1.1:** Complex interactions among the environment, pg. 3

host, and pathogens.

**Figure 2.1:** Map of Kibale National Park and surrounding areas. pg. 44

**Figure 2.2:** Comparison of the composition of small mammal communities pg. 45

in and around Kibale National Park.

**Figure 2.3:** Rarefied species richness of small mammals. pg. 46

**Figure 2.4:** Relationship between species richness and coexistance. pg. 46

**Figure 3.1:** Examining associations between habitat, host species, and parasite pg. 66 communities.

**Figure 4.1:** Relative abundance of small mammals across various habitats. pg. 91

**Figure 4.2:** Prevalence of *Trypanosoma varani* and *T. lewisi* pg. 92

**Figure 5.1:** Map of Uganda. pg. 110

**Figure 5.2:** Orthopoxvirus Western Blot assay results. pg. 111

**TABLE of TABLES**

**Table 1.1:** List of relevant ecological concepts, their graphical pg. 4

 expression, and basic equations.

**Table 2.1:** Small mammals collected in and around Kibale National Park. pg. 47

**Table 2.2:** Classification of species as forest-dwelling, grassland, pg. 48

and/or peridomestic.

**Table 3.1:** Hosts and parasites collected from various habitats in pg. 68

western Uganda.

**Table 3.2:** Relationships between parasite prevalence pg. 69

and environmental factors.

**Table 4.1:** Prevalence of trypanosomes among host species. pg. 93