5-2012

A Coupled Human and Natural Systems Approach to Understanding an Invasive Frog, Eleutherodactylus Coqui, in Hawaii

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A COUPLED HUMAN AND NATURAL SYSTEMS APPROACH TO UNDERSTANDING AN INVASIVE FROG, *ELEUTHERODACTYLUS COQUI*, IN HAWAII

by

Emily A. Kalnicky

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Ecology

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UTAH STATE UNIVERSITY
Logan, Utah

2012

ABSTRACT

A Coupled Human and Natural Systems Approach to Understanding an Invasive Frog, *Eleutherodactylus Coqui*, in Hawaii

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Utah State University, 2012

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Program: Ecology

Most ecosystems in the world have experienced some form of human impact. Global climate change, deforestation, and invasive species all affect the biodiversity of an area and, as a result of these human-driven impacts, ecosystems emerge that contain new species combinations previously undocumented. In order to better understand and manage these novel ecosystems, incorporating both social and natural components can be helpful. The overall objective of my research was to incorporate a coupled-systems approach to address social and biological factors affecting an invasive frog, *Eleutherodactylus coqui*, in Hawaii. Understanding these relationships allows suggestions to be made on potential management methods to control coqui populations, as well as more general suggestions for applying a similar approach to other novel ecosystem problems.

I conducted my research across the state of Hawaii. Specifically, the first research chapter focuses on research conducted across the island of Hawaii; the second on research conducted across the islands of Maui, Kauai, Oahu, and Hawaii; and the final chapter on research conducted in the Nanawale Forest Reserve (19°28’ N, 154°54’ W; elevation 230 m), in the southeast region of the island of Hawaii. Details for study locations can be found in each of the respective methods sections for these research chapters.

The first research chapter explores the coupled relationship between social and ecological variables and coqui frog abundance on private property by using both property-level surveys of natural variables and interviews of property owners. The second research chapter presents results from a quantitative study exploring the relationship between landowner attitudes, social influences, and coqui management behavior using a large mail survey. The final research chapter is an experimental examination of one of the most important ecological predictors for coqui success, habitat structure, and is broadly applicable to ecological research on the role of habitat structure in community dynamics.

Overall, I found that coqui density is affected by landowners’ attitudes and subsequent management behavior, but the frog’s density also influences these attitudes and behaviors. In this way, the success of the invasive coqui frog is part of a larger, coupled reciprocal system. Implications of the research, with a focus on placing the overall dissertation in the larger coupled social-natural research literature, are discussed in the final, conclusion chapter.

(247 pages)

PUBLIC ABSTRACT

A Coupled Human and Natural Systems Approach to Understanding

an Invasive Frog, *Eleutherodactylus coqui,* in Hawaii

Emily A. Kalnicky, PhD, Ecology

Human activities worldwide have altered nature in ways that create new combinations of species and environmental processes. To understand so-called "novel ecosystems" it is important to consider both the natural and the societal factors that shape them, and how those factors are interconnected or "coupled." We used such an approach to explore options for managing a non-native invasive frog, the coqui, which has become established on the island of Hawaii and threatens to spread to other parts of the state.

The nighttime calls of the coqui create a nuisance for property owners when populations become dense enough, as often occurs in Hawaii where the frogs have no natural enemies. Humans have tried various ways to eliminate coqui on the island of Hawaii with little success. Therefore we studied how property owners cope with their presence, both through management practices and psychological coping strategies. We also examined results of those efforts. People whose properties had more frogs were more likely to take action to reduce their numbers, but also attitudes toward the coqui were less negative when people had grown used to having to share their properties with the frogs. For those who cannot cope psychologically, we found it would be possible to manage properties to reduce densities but only when leaf litter and low shrubs were

completely removed from near a home. Information campaigns about managing coqui should be different when targeting people that already host frogs and those that do not.

ACKNOWLEDGMENTS

I would like to thank a number of individuals for their help along the dissertation journey. I would like to thank my major advisors, Drs. Mark Brunson and Karen Beard, for their feedback at all stages of this research; and my committee members, Drs. Thomas Edwards, Edward (Ted) Evans, and Christopher Monz, for their assistance from proposal to defense. I would also like to thank Susan Durham and Eddy Berry for statistical assistance; Mary Conner, Frank Howe, and Dave Koons for density estimation assistance.

I would like to thank the Quinney Foundation, the Utah State University Ecology Center, the Jack H. Berryman Institute, the United States Department of Agriculture, and the Vice Provost for Research, for providing funding for this research and for my studies. My research in Hawaii was made easier by support from Will Pitt and the USDA/APHIS Hilo field station; and Ron Ryel for providing access to field transportation. I will also be forever indebted to the individuals in Hawaii who took the time to share their experiences with me, allowed me on their properties, and taught me the meaning of living with aloha.

My research would not have been possible without all of the assistance I received from my field and lab technicians, who helped with everything from nighttime surveying for frogs to survey administration: Irina Chobanyan, Ryan Choi, Josh Easter, Rodrigo Ferreira, Jason Griffin, Jacob (Lew) Johnson, George Kalaau, Cameron Nay, Seth Price, Beth Roberts, Amy Rohman, and Abelardo Rojas; as well as insight and input provided from members of my labs at various stages of my research.

Finally, a great thank you to my parents, family, and friends for continued support, diversion, and always helping me to be mindful of the bigger picture.

Emily A. Kalnicky

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CHAPTER 1

INTRODUCTION

Most ecosystems in the world have experienced some form of human impact (Sanderson et al. 2002, Kareiva et al. 2007). Global climate change, deforestation, and invasive species all affect the biodiversity of an area (Sala et al. 2000, Hannah et al. 2002, Bradshaw et al. 2009). As a result of these human-driven impacts, ecosystems emerge that contain new species combinations previously undocumented in those areas (Hobbs et al. 2006). To better understand and manage these altered ecosystems, incorporating both social and natural components can be helpful (Hobbs et al. 2006, Gardner et al. 2009). My research incorporates a coupled-systems approach to address social and biological factors affecting the success of an invasive frog, *Eleutherodactylus coqui*, in an altered ecosystem in Hawaii. Understanding these relationships allow suggestions to be made on potential management methods to control coqui populations, as well as more general suggestions for applying a similar approach to other novel ecosystem problems.

Coupled Human and Natural Systems

While coupled human-nature interactions have been studied in the past, a solid understanding of the complexity of the systems has not been reached (Liu et al. 2007a). Part of the failure to reach this understanding of how coupled human and natural systems interact comes from the traditional separation of natural and social sciences (Rosa and Dietz 1998, Liu et al. 2007a). An emerging area of research, designed to integrate knowledge from various social and natural disciplines, is now known as the study of Coupled Human and Natural Systems, or CHANS (Liu et al. 2007a,b).

In recent years, discussion and research on CHANS has revealed the complex nature of the linked systems that evolve from both indirect and direct effects, which are manifested in spatial, temporal, and organizational couplings (Liu et al. 2007a, Alberti et al. 2011). While several models and frameworks have been suggested for exploring these linked systems, three major approaches come to mind: global policy models (Chapin et al. 2006); biocomplexity models (Pickett et al. 2005); and resilience models (Berkes and Folke 1998, Berkes et al. 2003, Folke 2006, Walker et al. 2006). While these models are currently being used to aid CHANS researchers, many researchers aim to develop their own models based on the unique components relevant to their system (Alberti et al. 2011). The models are often a compilation, or linking, of submodels designed to create coupled models that accurately represent and include all of the important human and natural variables, and interactions of these variables, in the system (Alberti et al. 2011).

In the field of ecology, arguably any research question or topic area could be expanded to include the human, or social, component, if it does not already. The overall goal of my dissertation research was to use the CHANS approach to better understand how human and ecological factors interact to affect a novel ecosystem shaped by biological invasions: the low-elevation forests and private properties in Hawaii. The research focused on the invasive *Eleutherodactylus coqui* frog in Hawaii, which is capable of altering ecosystem processes (Sin et al. 2008) and is socially undesirable (Kraus and Campbell 2002, Beard and Pitt 2005). Understanding how it is successfully invading requires an examination of both social and natural variables.

Coupled Human and Natural Systems Approach to Invasion Ecology

A non-native species introduced to a new area must first become established before it can spread. A variety of factors contribute to the success of a species at becoming established such as colonization pressure, biotic resistance, and resource availability (see Lockwood et al. 2007 for review). Once a non-native species is established, the actions of local people can have considerable influence on the spread, control, and prevention of invasions (McNeely 2001). Control efforts aim to minimize potential impacts by predicting locations the species may spread (Higgins et al. 1996, Tobin et al. 2007). Unfortunately, past attempts to develop a global predictor model for invasive species have largely been deemed unsuccessful (Higgins et al. 1996). More recently, researchers exploring predictive variables for invasive species have uncovered important relationships with species characteristics, environmental characteristics, and a combination thereof (see Kolar and Lodge 2001 for a review).

While predictive models are used in an attempt to explain what is actually occurring in the environment, a large part of the equation is often left out. Although it is well understood that humans play a role in the invasion process (Lockwood et al. 2007), the human dimensions of the system are often excluded from the predictive model or underplayed in attempts to understand invasion ecology (McNeely 2001).

Invasive species have the potential to affect the human health, biodiversity, and economics of an area. They can destroy native crops, disrupt nutrient cycling, carry pathogens, decrease property value, eliminate native species, and destroy homes and gardens (Mooney 2005). Annual costs for control, prevention, and cleanup due to invasive species are difficult to estimate, but have been estimated in the billions

(Pimentel et al. 2005). Many introductions are the result of unintentional human activities resulting from a general lack of an understanding (McNeely 2001, Garcia-Llorente et al. 2008).

With the spread of invasive species escalating due to increased globalization (Mack et al. 2000), more communities will be looking to control the problem in the most cost-effective and least environmentally harmful way (Evans 2003, Mooney 2005). Most researchers focus their attention solely on understanding the biology or ecology of an invader, but by doing this they fail to see the whole picture (Zavaleta et al. 2001, Hulme 2006, Buckley 2008, Carpenter et al. 2009).

While the biological or ecological knowledge of invasive species effects may be available, getting this information across to the general public is often a major barrier to prevention or control (Bremner and Park 2007). The more information the general public has on why a particular method of control is being used for an invasive species, the more likely the public will support that form of management (Mack et al. 2000, Fraser 2006, Bremner and Park 2007).

Because many introductions of invasive species are the result of unintentional human activities (McNeely 2001, Reichard and White 2001, Garcia-Llorente et al. 2008), and the actions of local people can have considerable influence on the spread, control, and prevention of invasions (McNeely 2001), researchers have begun using a CHANS approach to understanding processes influencing invasive species success (Rebaudo et al. 2011, Richardson et al. 2011).

Study Species-*Eleutherodactylus coqui*

The coqui frog (*Eleutherodactylus coqui)* is a small tropical terrestrial frog that is native to Puerto Rico and was first seen on the Hawaiian Islands in the late 1980s. The frog is believed to have been introduced through the horticultural trade (Kraus et al. 1999, Kraus and Campbell 2002). The coqui is now found on four of the Hawaiian islands-Hawaii, Kauai, Maui, and Oahu, but is mostly concentrated on the island of Hawaii (Beard et al. 2009).

Since introduction, the range of the coqui has expanded rapidly on the island of Hawaii due to both intentional and unintentional human behaviors (Kraus et al. 1999, Kraus and Campbell 2002). Between 2006 and 2007 the coqui expanded its range on the island of Hawaii from 2800 hectares to over 8000 (Sin 2008). Horticultural trade, human transport, and other anthropogenic effects, such as disturbance, could aid in the spread of this invasive species, but the role of each is presently unknown.

One widely known concern surrounding the coqui is noise nuisance. The frog's name originates from the male's territorial and reproductive call (Stewart and Rand 1992, Joglar 1998, Rivero 1998), which can reach up to 90 dB at 0.5 m (Beard and Pitt 2005) and is mostly heard between dawn and dusk (Woolbright 1985). Long-term exposure to this decibel level is said to be the equivalent of listening to a lawnmower and may result in hearing damage (CDC 1998). One study even showed that property values in close proximity to frog infestations were diminished as a result of the noise from the coqui (Kaiser and Burnett 2006).

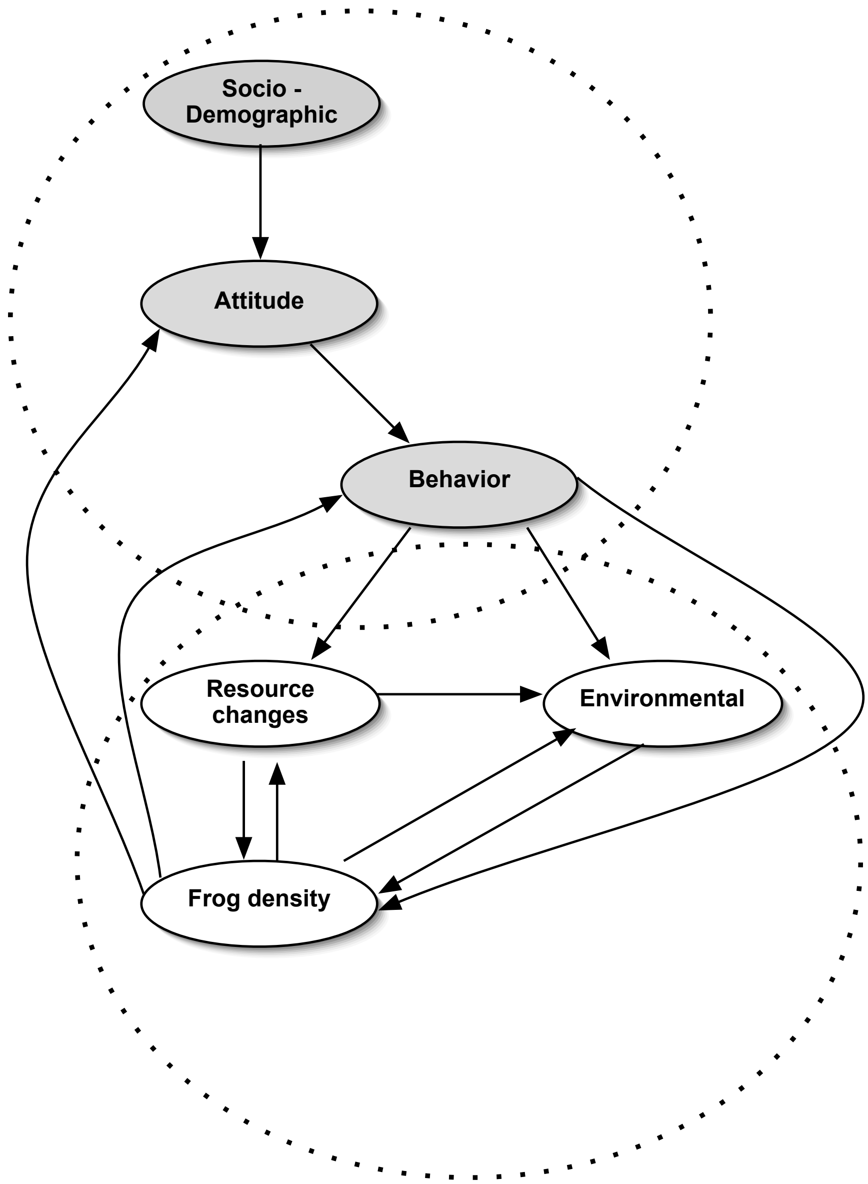
Costs for control and detection of the coqui in Hawaii County alone are estimated at $2.8 million per year, and efforts are now focused on treating small isolated populations to contain the spread (Beard et al. 2009, Anonymous 2010). Control efforts consist of a mix of chemical, mechanical, and agricultural methods. Property owners are encouraged to spray suspected frog habitats directly with a 16% citric acid solution, eliminate frog habitat, inspect potted plants, and treat coqui-infested green waste (Bertelmann n.d.). Hydrated lime and caffeine, which were cheaper to apply than citric acid, can no longer legally be sprayed on properties due to lapse in EPA approval (Beard et al. 2009).

Since the coqui's introduction, a large quantity of money has gone towards trying to control the frog, but current efforts may seem futile with the increasing range on the island of Hawaii and the general public's (often unintentional) role in this range expansion (Kraus et al. 1999, Kraus and Campbell 2002). Research that examines the entire system, rather than focusing solely on the biology of control, may be better able to pinpoint factors that can contribute to successful management or control of the coqui. A conceptual diagram of a coqui-centered coupled human-natural system is presented in Figure 1.1.

Dissertation Overview

My overall objective with this research was to apply a coupled systems approach to understand the factors affecting an invasive animal and the people living in an area affected by the animal. More specifically, my objective was to examine the influence of social and environmental variables on landowner's attitudes and actual behavior toward the invasive *Eleutherodactylus coqui* in Hawaii, as well as the impact of these variables on the invasive frog. Understanding the relationship between these variables allows me

Fig. 1.1. Coupled human and natural systems model for understanding factors affecting an invasive frog's density. Gray ovals represent social constructs while white ovals are natural constructs. Overlapping dotted circles represent the intersection of the social and natural variables, and the elements that would be included if a researcher was taking a more traditional approach to either understanding the social or natural components of the system.



to make suggestions for potential management methods to control coqui populations and also adds to our understanding of why these variables are important for an invasive frog's success. More generally, the results of the overall dissertation add to the CHANS literature and provide a coupled systems framework useful for studying other invasive species across the globe.

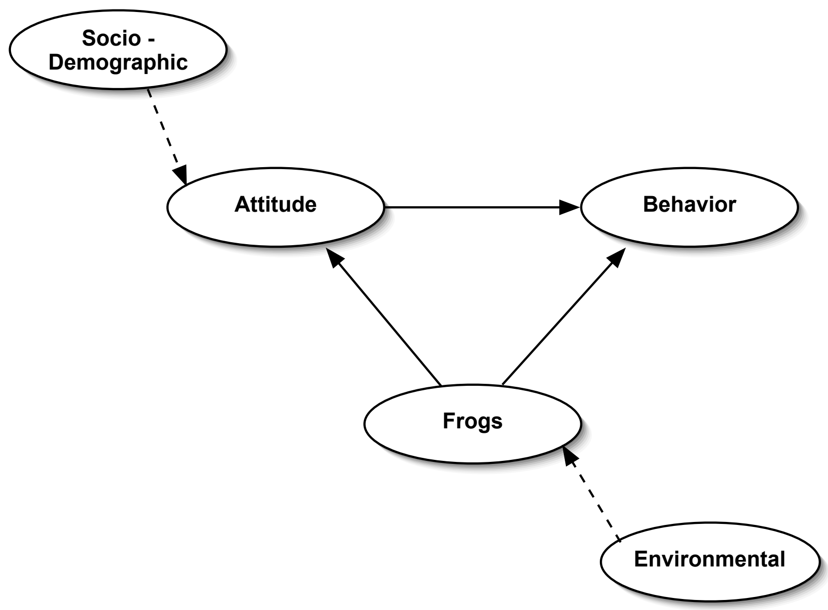
I conducted my research across the state of Hawaii. Specifically, the first research chapter focuses on research conducted across the island of Hawaii; the second on research conducted across the islands of Maui, Kauai, Oahu, and Hawaii; and the final chapter on research conducted in the Nanawale Forest Reserve (19°28' N, 154°54' W; elevation 230 m), in the southeast region of the island of Hawaii. Details for study locations can be found in each of the respective methods sections for these research chapters.

This work is divided between three research chapters, one introductory, and one conclusion chapter. This introductory chapter provided some background information and context for the remainder of the dissertation.

The second chapter explores the coupled relationship between social and ecological variables and coqui frog abundance on private property. The main objective for this chapter was to determine how an invasive frog's abundance on private property was related to socio-demographic variables, attitude, management behavior, and relevant environmental variables. The model used to guide this research can be seen in Figure 1.2.

The third chapter presents results from a quantitative study exploring the relationship between landowner attitudes, social influences, and coqui management

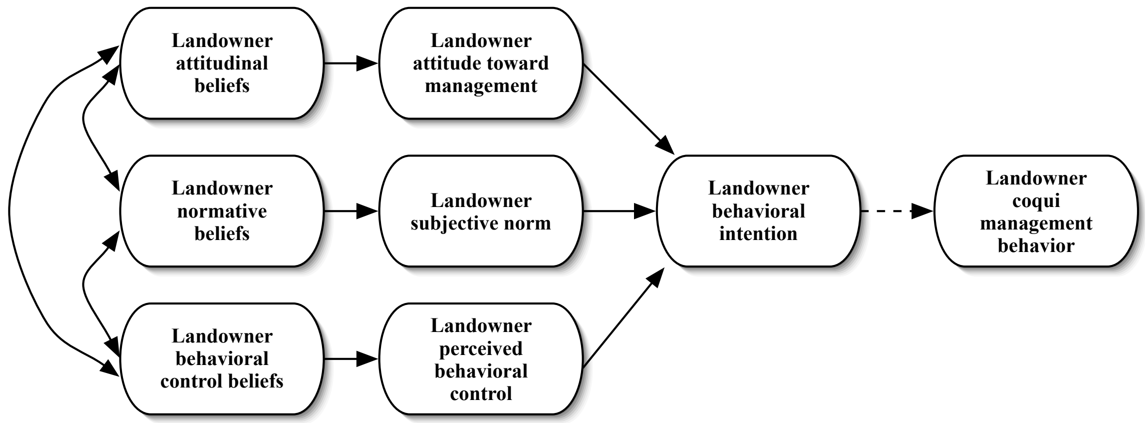
Fig. 1.2. Overall conceptual framework for the second research chapter. "Frogs" refers to frog abundance found on properties on the island of Hawaii; "Behavior" is the management behavior being performed by people living on the island of Hawaii; "Attitude" is the person's general attitude toward the coqui frog (negative or non-negative); "Socio-Demographic" includes various socio-demographic variables (age, gender, income, born in Hawaii, rent/own, east/west side of the island); and "Environmental" refers to various environmental variables thought to have a potential influence on frog abundance (canopy cover, leaf litter invertebrates, understory density).



behavior. This chapter builds upon the initial study described in the second chapter, by using interview data to guide construction of a large mail survey. The main objective for this chapter was to determine the predictability of Hawaii landowners' management behavior toward the invasive coqui and whether there are differences based on amount of exposure to the frog. The model used to guide this research can be seen in Figure 1.3.

The fourth chapter is an experimental examination of one of the most important ecological predictors for coqui success, habitat structure, and is broadly applicable to ecological research on the role of habitat structure in community dynamics. This chapter

Fig. 1.3. Overall predicted model of Hawaii landowner's intention to perform management behaviors toward the coqui. Based on the Theory of Planned Behavior and adapted from Ajzen (2006).

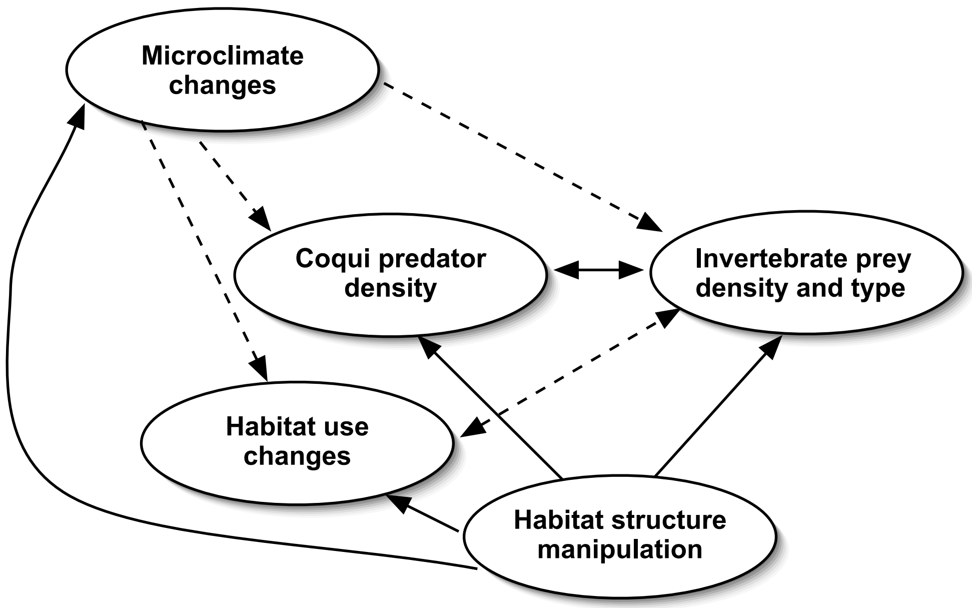


builds upon previous research in Puerto Rico and Hawaii, as well as results from the second and third research chapters related to types of management being performed and the role of various environmental variables on the coqui. The main objective of this study was to determine the effect of habitat manipulation on coqui and prey densities. The model used to guide this research can be seen in Figure 1.4.

The final, conclusion chapter synthesizes the results of the three data chapters, provides perspective for implications of the research, with a focus on placing the overall dissertation in the larger coupled social-natural research literature.

Each of the chapters includes the necessary background information and material within it, but, as necessary, the chapters refer to each other for additional information.

Fig. 1.4. Overall model guiding experimental manipulation of habitat structure (in the form of leaf litter and aboveground understory vegetation) on the densities of the generalist predator (*Eleutherodactylus coqui*), and its prey (leaf litter, flying, and foliage invertebrates), as well as changes in the microclimate and habitat use by the frog.



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CHAPTER 2

LEARNING TO LIVE WITH AN INVADER: HAWAII COQUI FROG INVASION AS A COMPLEX SOCIAL-ECOLOGICAL SYSTEM[1]

ABSTRACT

Since the introduction of the Puerto Rican coqui frog (*Eleutherodactylus coqui*) to the island of Hawaii in the late 1980s, its range has increased. The frog occurs on many private properties and has been determined to decrease property value. Accordingly, private landowners and community associations frequently try to eradicate local frog populations after they have invaded. However, the connection among coqui presence and abundance on properties, landowner attitudes, and their management behaviors is presently unknown. To address this gap in knowledge, we interviewed 87 people living on private property on the island of Hawaii from May to August 2008 to determine their impressions of frog abundance on their property, their attitudes toward frogs, and whether they participated in any management behaviors. We also collected a variety of ecological data on each property including coqui abundance. Just 23% of our participants reported doing any form of management. Participation in management was not related to a person's attitude toward the frog, but people were more likely to engage in management if they had more frogs on their property. People who had more frogs on their property and those who owned that property tended to have *less* negative attitudes toward the coqui. These results suggest that attitudes toward the frog become less negative once frogs invade and abundance increases. The apparent growing apathy toward frogs may

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[1] Co-Authors: Mark W. Brunson and Karen H. Beard. Written following *Ecology and Society* Journal specifications. IACUC permit #1356 and IRB permit #2061; State of HI DLNR Scientific Permit for Native Invertebrates #: FHM08-162

hinder efforts to encourage people to conduct management activities in this novel ecosystem.

INTRODUCTION

Social complexities surrounding invasive species

Novel, or altered, ecosystems occur as the result of new combinations of species and conditions that are currently present but were not previously occurring (Hobbs et al. 2006, Seastedt et al. 2008). Novel ecosystems are largely occurring as the result of human influences and are often found in urban or degraded landscapes (Hobbs et al. 2006). Increases in invasive species are one such potential result of human influences (Seastedt et al. 2008).

Invasive species have the potential to affect the human health, biodiversity, and economics of an area (Mooney 2005). Little is known about the connections between attitudes toward an invasive species, management behavior intended to control that species, and its local presence or abundance. Perceptions of invasive species can be culturally or historically based and result in strong attitudes toward invasive species (Coates 2006). The attitudes people have toward a pest species are related to the types of management people believe are appropriate for that species (Fraser 2006). Overall, peoples' attitudes toward different forms of management for invasive vertebrate species are related to the specificity of the management method and the humaneness (Barr et al. 2002, Fraser 2006). Additionally, attitudes toward wildlife and attitudes toward specific methods of managing for the particular species have been shown to be related to sociodemographic factors, such as age and gender (Miller and Jones 2005, 2006, Fitzgerald et al. 2007). The pattern of the relationship between attitudes toward invasive animals and various sociodemographic or other predictor variables is complex (Fitzgerald et al. 2007). Thus, a greater understanding of people's beliefs and behavior towards invasive species is necessary for successful management of an area (Reaser 2001, Coates 2006).

The more directly an invasive species impacts a person, the more likely he/she is to understand the potential benefits of a management program designed to eradicate the invasive species (Fraser 2006). Further, the more involved the general public is with decisions about control and management strategies to be used, the more effective the programs will be (Barr et al. 2002, Sheail 2003). Management for invasive species is dependent on coordination of managers and the effort of the general public to minimize costs and maximize effectiveness (Stokes et al. 2006, Epanchin-Niell et al. 2010).

While knowledge may be available regarding biological or ecological effects of an invasive species, getting this information across to the general public is often a major barrier to prevention or control (Bremner and Park 2007). The more information the general public has on why a particular method of control is being used for an invasive species, the more likely the public will support or participate in that form of management (Mack et al. 2000, Fraser 2006, Bremner and Park 2007). Additionally, understanding people's beliefs and behavior toward invasive species is necessary for successful management of an area (Reaser 2001, Coates 2006).

To examine the relationship between social and ecological variables in a novel, altered ecosystem, and subsequent management behaviors toward an invasive species, we chose an invasive frog in Hawaii, *Eleutherodactylus coqui* (the coqui), which is listed as one of the 100 “world’s worst” invaders (ISSG 2005). Most private property on the island of Hawaii can be considered a novel ecosystem because nearly all native ecosystems below ~500 m in elevation were altered or destroyed by centuries of agriculture and development (Mueller-Dombois and Fosberg 1998). Since the introduction of the invasive Puerto Rican coqui to the island of Hawaii in the late 1980s, its range has increased (Kraus et al. 1999, Kraus and Campbell 2002). Horticultural trade, human transport, and other anthropogenic effects, such as disturbance, could aid in the spread of this invasive species, but the role of each is presently unknown. The coqui is expected to continue expanding its range and eradication is no longer believed to be possible on the island of Hawaii (Beard et al. 2009, Bisrat et al. in press).

Specific ecological and social variables related to coqui frog invasion

One widely known concern surrounding the coqui is noise nuisance. The frog’s name originates from the male's territorial and reproductive call (Stewart and Rand 1992, Joglar 1998, Rivero 1998), which can reach up to 90 dB at 0.5 m (Beard and Pitt 2005) and is mostly heard between dawn and dusk (Woolbright 1985). As a result, property values in close proximity to frog infestation have in some cases been reduced (Kaiser and Burnett 2006).

Control efforts consist of a mix of chemical, mechanical, and agricultural methods. All are activities landowners can do themselves. Many of the control efforts on the island of Hawaii are conducted by volunteer community groups; in 2008, 43% of treated land was done by community associations (Anonymous 2010). Currently the only approved and recommended chemical control consists of direct application of citric acid to frogs and/or frog eggs. Mechanical control, including hand-capture, traps, barriers, and hot water treatments, has mostly been employed in smaller, high-risk settings such as nurseries. Cultural control includes checking plants at the nursery for coqui eggs or frogs before purchasing, and removing vegetation on a property because of frogs. Property owners are encouraged to spray suspected frog habitats directly with citric acid, eliminate frog habitat, inspect potted plants, and treat coqui-infested green waste (Bertelmann n.d.). If coqui control efforts were abandoned, island-wide impact on property values could increase, resort revenues could be negatively affected, and the risk of coqui spread to the other islands would increase (Anonymous 2010). Therefore, it is important to understand whether people already living with the frog are willing to engage in coqui management behaviors.

Attitudes toward the coqui in Hawaii appear to be polarized (see Fujimori 2001, Singer and Grismaijer 2005). Many in Hawaii think the species is a nuisance, but others are more positive about the frog and have launched campaigns to save it (Fujimori 2001, Kraus and Campbell 2002, Singer and Grismaijer 2005, Gonzalez-Pagan 2007). A major factor underlying the polarization in attitude is the noise nuisance. While some people state that the call reminds them of the countryside, and without the frog they would not be able to sleep, others complain that the frog keeps them awake and prevents them from talking to friends or watching TV at a normal volume in the evening (K. Beard and E. Kalnicky pers. comm. and pers. obs.).

One possible explanation for differences in attitudes toward the coqui in Hawaii could be cognitive dissonance. Social psychological theory suggests that people decrease their discomfort in holding opposite beliefs, ideas, or opinions by instead subconsciously changing one or both of the cognitions (Festinger 1957). Individuals living in areas currently infested with high densities of frogs may change their attitude toward the frog to live more peacefully. This pattern has been shown in pest management behaviors for rice farmers (Heong et al. 1998) and is probably grounded in some level of self-interest (Hills 1993).

While the coqui continues to spread in Hawaii, some areas have higher densities of frogs than others (Beard et al. 2008). Understanding the environmental variables related to coqui density will allow more specific suggestions for management strategies designed to reduce the number of frogs in a given area. In the most optimal sites in Hawaii, densities as high as 91,000 frogs/ha have been reported (Beard et al. 2008), representing one of the highest densities for terrestrial frogs in the world and well above what has been measured in its native Puerto Rico (Stewart and Woolbright 1996). Previous research on density and habitat structure has found higher coqui density with higher understory density in Hawaii (Beard et al. 2008). These high densities are also associated with higher invertebrate prey availability (Beard 2001, Beard et al. 2008). In Puerto Rico, the coqui is found in most places as long as there is sufficient canopy cover and high humidity (Schwartz and Henderson 1991). Thus, various environmental factors have previously been shown as important variables affecting coqui density in forested systems, but the relationship between these variables on private property managed by homeowners, and the possibility of reducing coqui density, is presently unknown.

Since the coqui introduction to Hawaii, over a million dollars has been spent annually to control it (Beard et al. 2009), and much of this effort has been done by volunteers (Anonymous 2010), but very little is known about how people's willingness to manage their property for frogs is linked to actually having frogs and/or people's attitudes toward frogs (Beard and Pitt 2005, Gonzalez-Pagan 2007). Thus, more research is needed on understanding people's attitudes and management behavior to determine where changes could be made to increase effectiveness for control strategies in Hawaii. Current emphasis for management on the island of Hawaii consists of providing education, control resources (i.e., citric acid), and focusing on populations of frogs with five or fewer calling males. However, current efforts to control frogs in Hawaii presently are not reaching public requests for assistance (Anonymous 2010).

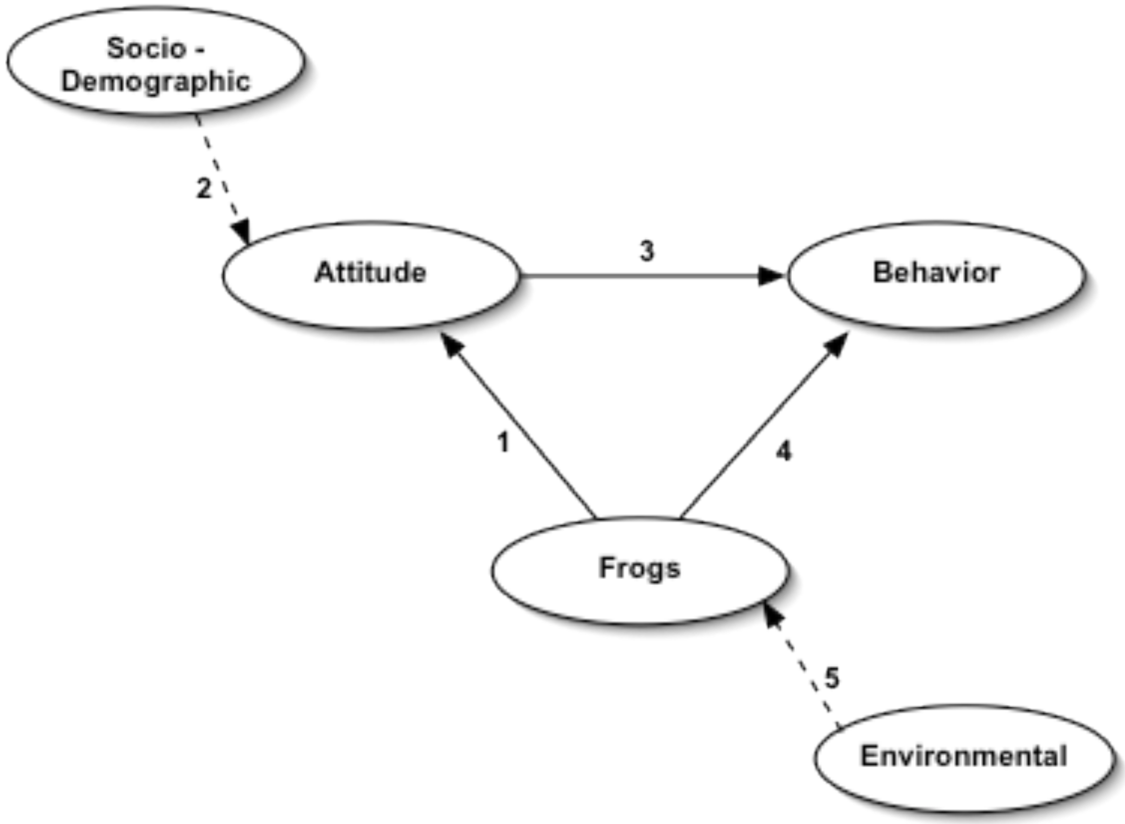
Objectives

Our overall objective for this study was to determine how an invasive frog's abundance on private property was related to both social and ecological variables (Figure 2.1). More specifically, we aimed to identify relationships between: (1) the presence and abundance of frogs on a property and general attitude toward the coqui (link 1 on figure); (2) socio-demographic characteristics and attitude toward the coqui (link 2 on figure); (3) attitude and management behavior directed toward the coqui (link 3 on figure); (4) presence or abundance of frogs on a property and management toward the coqui (link 4 on figure); and (5) relevant environmental variables and the abundance of frogs on a property (link 5 on figure).

Predictions

We predicted that attitudes would be more negative among individuals who had more frogs on their property. Because at the time of the study the frogs had been on the

Fig. 2.1. Graphical representation of the overall conceptual framework for this study. Numbers represent specific objectives we had for each linkage, and are described in the text.



island for just two decades, we predicted that people born on the island would have a more negative attitude toward the frogs since they had experienced the quieter, pre-invasion condition. Similarly, we predicted that people on the east side of the island would have more negative attitudes toward the frog than people on the west side of the island because the area that the frogs have invaded on the east side of the island is larger than on the west side of the island. Because property values have been shown to decrease as a result of frog populations (Kaiser and Burnett 2006), we predicted that people who own property would feel more negatively toward the frogs than people who are renting. Following Ajzen's (1991) Theory of Planned Behavior, which posits that the likelihood of engaging in a behavior is influenced by a person's attitude toward that behavior (see Chapter 3), we predicted that people would be more likely to report managing their property to reduce frog populations if they held negative attitudes toward the coqui. We also predicted that having more frogs on a person's property would lead him/her to be more likely to engage in management behavior to reduce the number of frogs. Finally, we predicted that the abundance of environmental resources available to the coqui, such as canopy cover, prey, and understory structure, would be related to the abundance of frogs on a property.

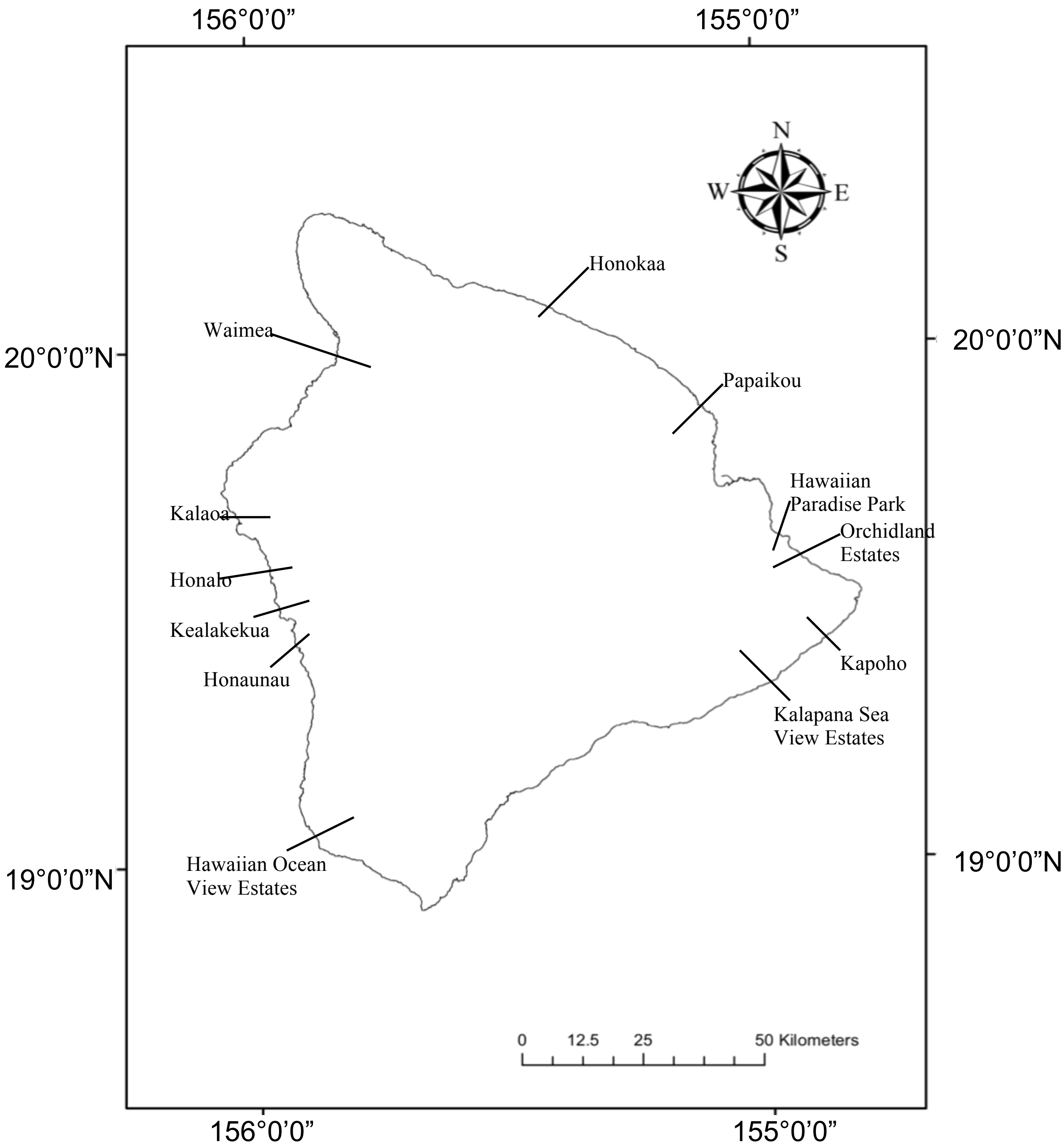
METHODS

We gathered data using a mixture of quantitative and qualitative methods. Our mixed methods approach included semi-structured interviews to determine attitudes and behaviors toward the coqui, and measures of ecological characteristics including coqui frog abundance on the interviewee's property, conducted during May to August 2008.

Study area

Using available GIS data for known presence of coqui frogs from the Hawaii Invasive Species Council database, we selected 12 communities across the island so that we had full coverage of all regions (Figure 2.2). We then identified participants from each community by randomly selecting roads and then houses. If there was no response after repeated knockings, we then selected the next random house. If there was a response, we recited a short script introducing ourselves, explaining what our research was about, explaining what participation would entail, and asking the individual if he/she was interested in participating. If the individual agreed to participate, we scheduled a

Fig. 2.2. Study locations on the island of Hawaii, May to August 2008.



time during the week, or later that weekend, to return and complete the interview and collect other information including frog abundance on the property. If the individual declined, then we went to the next randomly selected house and repeated the process until there were seven properties within each community. To recruit participants in each of the

12 communities, every five days we traveled to the next community and spent one day recruiting participants. Using this approach we completed interviews and property surveys at 87 residences across the island.

Data collection

We designed interview questions to gather information about the beliefs and attitudes of residents regarding the coqui, types of management they were doing, and knowledge of current outreach methods aimed at coqui prevention or control. We used a semi-structured interview technique to enable us to probe participants for deeper understanding (Kempton et al. 1995). Additionally, by beginning our research with a qualitative methodology, we were hoping to be able to elicit beliefs about coqui frogs that were prominent in people's minds and to detect possible nuances in beliefs or attitudes that might not be uncovered in a quantitative survey approach alone. The interviews ranged from 6 to 60 minutes in length, and we conducted them at the participant's home. We also asked participants to provide demographic information (see Appendix A). The specific questions we asked related to coqui attitude and coqui management behavior were:

1. In your opinion, what are some positive and negative aspects of the coqui frog?
2. Do you, or members of your household, do anything on your property for the coqui frog? (If yes… please describe)

While one researcher was conducting the interview, a second researcher measured the size of the property and delineated 10 m x 10 m plots where we could measure characteristics of the property (i.e., invertebrate abundance and habitat structure/type).

We determined the number of plots based on the property size: 1 or 2 plots if the property was less than 900 m^2, 3 plots if the property was between 901 and 3600 m^2, 4 plots if the property was between 3601 and 6400 m^2, 5 plots if the property was between 6401 and 10,000 m^2, and 6 plots for any property >10,000 m^2. We then randomly selected plots from all available plots on the property to survey.

In each of the randomly selected 10 m x 10 m plots, we sampled invertebrates. We collected leaf litter from one 1 m x 1 m subplot within each plot, and within 6 hours extracted invertebrates using Berlese funnels. We collected flying insects on one 10 cm x 18 cm sticky trap, per plot, placed 0.75 m off of the ground for 24 hours. We later counted and classified all invertebrates to scientific order in the laboratory with a dissecting microscope.

We determined the density of understory vegetation in each of the 10 m x 10 m plots by measuring the percent of 100 quadrants covered on a 0.5 m x 2 m coverboard (Nudds 1977) as in Beard (2007). We measured the percentage of ground cover at 20 points in a 1 m x 1 m quadrant by counting how many points in the quadrant landed on vegetation categories (forb, shrub, tree, lava, detritus, grass, moss, root, man-made). We measured canopy cover using a spherical densiometer (Forest Densiometers, Bartlesville, OK).

We returned to the interviewee's property after sundown (approximately 1900 h). In each of the plots, we walked in parallel lines 2.5 m apart for the length of the plot (i.e., 10 m). We walked slowly for 15 to 20 minutes, surveying with our headlamps left and right for frogs. When we saw or heard a frog, we recorded it to estimate frog abundance on the properties by averaging the total number of frogs seen or heard on the property across the number of plots on that property.

Data analysis

We transcribed the interview tapes verbatim and subjected the transcripts to content analysis. We used a method consistent with grounded theory analysis, allowing themes to come from the data, rather than previously being identified by the researcher (Glaser and Strauss 1967, Charmaz 2003). We averaged all of the environmental variable data collected across the number of plots on that property.

We performed all data analyses using SPSS version 19.0 (SPSS, Inc., Chicago, IL). To explore our first research objective, we ran a logistic regression with frog abundance (average number of frogs per plot) as the predictor variable, and attitude toward the coqui (negative or non-negative) as the response variable. We square-root transformed frog abundance to meet assumptions of normality. Because psychological phenomena such as attitudes may be more closely linked to *perceived* environmental conditions than actual conditions (Baldassare and Katz 1992), we also ran a chi-square test to detect whether a relationship existed between interviewees' own estimates of frog abundance (0 frogs, 1 or 2 frogs, 3 to 100 frogs, hundreds of frogs, and thousands of frogs) and their attitudes toward the coqui (positive, mixed, negative).

For our second research objective to examine relationships between socio-demographic characteristics and attitude toward the coqui, we first used correlation analysis to look at the relationships between various socio-demographic variables (age, gender, income, born in Hawaii, rent/own, east/west side of the island) and attitude. We then included the strongest (and least correlated with other variables) predictor variables in a binomial logit model with coqui attitude (non-negative or negative) as the response, and ownership and side of island as the predictor variables (rent or own; and east or west). We also ran general descriptive statistics (output in Appendix B).

For our third research objective to examine the relationship between attitudes and management behaviors, we first looked at the entire survey sample (*N* = 87) and used a chi-square test to determine if there was a relationship between whether a person managed for coqui (yes or no) and their attitude toward the frog (negative or non-negative). We then conducted the same test, including only the individuals who perceived they had frogs on their property (*N* = 50). We also looked for differences in amounts of various types of management (mechanical, chemical, and agricultural) commonly used for invasive species being conducted on people's property. Currently the only approved and recommended chemical control consists of direct application of citric acid to frogs and/or frog eggs. Mechanical control, including hand-capture, traps, barriers, and hot water treatments, has mostly been employed in smaller, high-risk settings such as nurseries. Cultural control includes checking plants at the nursery for coqui eggs or frogs before purchasing, and removing vegetation on a property because of frogs. We examined responses from the 18 individuals who reported managing for frogs and perceived they had frogs on their property to see if there was a relationship between quantity of management (mechanical, chemical, and agricultural) occurring and the participant's attitude (negative or non-negative) toward the frog, using a chi-square test.

To explore our fourth objective whether there was a relationship between frog abundance or presence on a person's property and management toward the coqui, we first ran a t-test with individuals performing management (yes or no) as the grouping variable and abundance of frogs as the test variable. We also ran a chi-square test to look at perceived abundance (0 frogs, 1 or 2 frogs, 3 to 100 frogs, hundreds of frogs, and thousands of frogs) as it related to a decision whether to implement management (yes or no).

Finally, to test our fifth objective and determine whether environmental variables related to the abundance of frogs on a person's property, we used correlation analyses to look at the relationship between frog abundance and various environmental variables thought to have a potential influence on frog abundance (canopy cover, leaf litter invertebrates, understory density, etc.). We then ran a multiple regression with four environmental predictor variables (% grass, % canopy cover, flying invertebrates, and leaf litter invertebrates) regressed upon frog abundance. The dependent variable was square-root transformed to meet the assumption of normality. An alpha level of 0.05 was used for all statistical tests, except for the multiple regression with environmental predictor variables, where an alpha level of 0.10 was used because of the high level of variability in ecological data, the small sample size, and exploratory nature of this analysis.

RESULTS

Participant demographics

Forty-six percent of the 87 individuals we interviewed were male ($N = 40$) and 54% were female ($N = 47$). The mean age of our participants was 53 years old (range 28 to 89 years). Seventy-two percent had at least some college education ($N = 63$), while 24% of those had an advanced degree ($N = 15$). Eighty percent of the people we interviewed owned their property ($N = 70$), while 17% were renting ($N = 15$) and two participants declined to answer. The majority (*N* = 63) were not born in Hawaii. Fourteen percent of participants interviewed preferred not to state their total family income (*N* = 12), 30% earned less than $49,999 (*N* = 26), 40% earned between $50,000 and $99,999 (*N* = 35), and 16% earned more than $100,000 (*N* = 14). Forty-two percent (*N* = 37) of the participants interviewed said that they did not have any frogs on their properties, while 4.6% had only 1 or 2 frogs (*N* = 4), 25.3% had between two and 100 (*N* = 22), 21.8% had "hundreds" (*N* = 19), and 5.7% (*N* = 5) had "thousands or lots." Based on our nightly counts, we found that 38 of the properties (43.7%) had coqui frogs. We did not detect frogs on 12 properties (13.8%) where respondents believed they had frogs.

General participant demographics were consistent with US Census data for 2005-2009, suggesting our sample was representative of individuals living in Hawaii. Specifically, for individuals older than 20, the median age range from the census data was 45 to 54 years old. Males made up 50.6% of the population, with females representing 49.4% of the population. Only 23% of the population was native Hawaiian or Pacific Islander, and the median household income was $64,661.

When asked to list all positive and negative characteristics related to the frog, 50 people listed only negative, six people listed only positive, and 31 people listed a mixture of positive and negative characteristics. We compared the population estimates given by interviewees who viewed the coqui positively to those of persons displaying mixed and negative attitude orientations and found no differences (Table 2.1). However, because the sample size of 6 was so low for persons with only positive attitudes, for the remainder of our analyses we combined that group with the 31 people with mixed attitude

Table 2.1. Distribution of attitudes toward coqui frog as it relates to participants' estimates of frogs on their property. Forty-two percent (*N* = 37) of the participants interviewed said that they did not have any frogs on their properties, while 4.6% had only 1 or 2 frogs (*N* = 4), 21.8% had "hundreds" (*N* = 19), 25.3% had between two and 100 (*N* = 22), and 5.7% (*N* = 5) had "thousands or lots."

Attitude	People's estimate of number of coqui on their property				
	0 frogs	1 or 2 frogs	3 to 100 frogs	Hundreds of frogs	Thousands of frogs
Positive	2	0	0	4	0
Mixed	7	0	14	7	3
Negative	28	4	8	8	2

orientations. Thus for future analyses we categorized our attitude groups as "negative" and "non-negative."

Overall, 77% of the participants (*N* = 67) did not participate in any management for the coqui frog, and 42.5% of the participants did not believe they had any frogs on their properties. Further, 16.1% (*N* = 14) said that they had not heard or did not know about types of management they could do to control the frog. Of those 23% (*N* = 19) engaging in management, all but one (*N* = 19) said they had received some information on how to manage their property for frogs. For the individuals that were participating in management for coqui on their property, or who knew of things they could be doing but were choosing not to, 44% received this information via word of mouth from other individuals on the island (*N* = 38).

Relationship of attitude to frog presence/abundance

Participants with a negative attitude toward the coqui were 1.76 times less likely to have frogs on their property ($p = 0.016$; see Appendix B, Table B-12). Furthermore, people who believed they had 3 or more frogs had more positive attitudes thanindividuals believing they had fewer frogs (chi-square test with $df=4$; $\chi^2 = 14.45$, $p = 0.006$).

Relationship of socio-demographic variables and attitude

Within this study, many of the socio-demographic variables were correlated with each other (Table 2.2). For example, more people born on the island of Hawaii lived on the west side of the island, and more people with lower incomes lived on the east side. People born on the island had a more negative attitude toward the coqui than people not born in Hawaii. After eliminating highly correlated variables to reduce multicollinearity, we chose two predictor variables: whether the person owned or rented the property where they were living, and whether they lived on the east or the west side of the island. Both were significant predictors of attitude toward the frog. People renting their property were nine times more likely to hold negative attitudes than if the person owned property and were approximately four times more likely if the person lived on the west side of the island rather than the east side of the island (details in Table 2.3). To determine if renters were more transient than participants who owned their property, we compared length of time at current property and found that renters were more transient than participants who owned their property ($t = -3.25$, $p = 0.002$).

Table 2.2. Correlation matrix for socio-demographic variables and attitudes toward frogs (*N* = 87). Education is coded in four groups: high school or lower, some college, 2 or 4 year degree, and advanced degree. Born in Hawaii is yes or no (1/0) if the person was born in Hawaii. Coqui attitude was coded as negative or non-negative (as described above), East or West is whether the person is living on the east or west side of the island (1 = East, 0 = West), Gender is Male/Female (0/1), Age is grouped into <46, 46-65, and > 65. Income is grouped as <$49,999, $50,000 to $99,999, >$100,000, and prefer not to say.

	Education	Born in HI	Rent/ Own	Coqui Attitude	East or West	Gender	Age	Income
Education	1	-0.35**	.006	0.16	0.28**	0.07	-0.06	0.13
Born in HI?		1	0.07	-0.22*	-0.33**	0.09	0.24*	0.17
Rent/Own			1	-0.34**	0.01	0.07	0.12	-0.06
Coqui Attitude				1	0.28**	-0.02	-0.06	0.02
East or West					1	-0.03	-0.12	-0.22*
Gender						1	-0.02	-0.15
Age							1	-0.02
Income								1

$^{*}p<0.05$, $^{**}p<0.01$

Table 2.3. Logistic regression showing the relationship between a person's attitude toward the coqui (negative or non-negative) and the location of his/her residence on the east or west side of the island, and whether he/she rents or owns the property. Own is coded as "1" for the rent/own variable, and west is coded as "1" for the east/west variable (N = 85).

	B	S.E.	Wald	df	Sig.	Exp(B)
Rent/own(1)	2.20	0.74	8.84	1	0.003	8.979
East/west(1)	1.35	0.54	6.33	1	0.012	3.852
Constant	-1.45	0.47	10.10	1	0.001	0.226

*p<0.05, **p<0.01

Relationship of management behavior to attitudes

There were no differences in attitude toward the coqui between those who did or did not report management behaviors (chi-square test with df=1; χ^2= 0.065, p = 0.799; Table 2.4). Because the sample included 37 people who did not believe they had frogs on their property, we also performed the analysis after limiting it to people who believed they had frogs on their property (N = 50), assuming they would be more likely to manage. There was still no difference in people's attitude and whether or not they managed (chi-square test with df=1; χ^2= 0.411, p = 0.522; Table 2.5).

On the assumption that people would be more likely to engage in direct forms of coqui removal (e.g., chemical control) if they felt more negatively toward the frogs, we also tested for the relationship between attitude and the type of management practice employed. Again, no differences were found (Table 2.6).

Table 2.4. Frequency of people who do or do not manage for frogs with relation to their attitude toward the coqui ($N = 87$).

	Do Management?		Total
	No	Yes	
Negative Attitude	39	11	50
Non-Negative Attitude	28	9	37
Total	67	20	87

Table 2.5. Distribution of people who do or do not manage for frogs with relation to their attitude toward the coqui, only for people who believed they had frogs on their property ($N = 50$).

	Do Management		Total
	No	Yes	
Negative Attitude	13	9	22
Non-Negative Attitude	19	9	28
Total	32	18	50

Table 2.6. Relationship between attitude orientations and management directed at controlling the coqui (chi-square test, alpha = 0.05) ($N = 18$).

	Do Mechanical Management		Total
	No	Yes	
Negative Attitude	4	5	9
Non-Negative Attitude	5	4	9
Total	9	9	18

a. Chi-square test with $df = 1$; $\chi^2 = 0.222$, $p = 0.637$

	Do Chemical Management		Total
	No	Yes	
Negative Attitude	2	7	9
Non-Negative Attitude	5	4	9
Total	7	11	18

b. Chi-square test with $df = 1$; $\chi^2 = 2.104$, $p = 0.335$

	Do Agricultural Management		Total
	No	Yes	
Negative Attitude	5	4	9
Non-Negative Attitude	5	4	9
Total	10	8	18

c. Chi-square test with $df = 1$; $\chi^2 = 0.0$, $p = 1.00$

Two people (of the 20 in our sample that reported engaging in management behaviors) reported managing even though they believed they did not have frogs. Both were using agricultural, pro-active management by checking plants before purchase to prevent spreading frogs from the store to their home.

Relationship of management behavior to frog presence/abundance

We also wanted to know if respondents' self-reported management behaviors were related to our own counts of frogs on their property (range from 0 to 16 frogs counted per 10 m x 10 m area). We found that on average, frog populations were higher on properties where residents said they had engaged in management activities (t=1.02, p= 0.005). We then tested whether the participant's *perceived* density of frogs on a property was related to reported management for the frogs and found no relationship (chi-square test with df=3; χ^2 = 3.34, p = 0.342; Table 2.7). The amount of frogs that participants perceived they had on their property was positively correlated with our actual frog counts (r = 0.490, p < 0.001).

We also tested for differences in the type of management being performed based on the people's perceived number of frogs on their property. Many participants were managing in multiple ways, thus the counts are larger than the sample of 20. There were no differences in type of management conducted and perceived estimates of frogs on a person's property (Table 2.8). In total, nine participants conducted forms of mechanical management, 11 participants conducted chemical, and 10 participants conducted agricultural (Figure 2.3).

Table 2.7. Relationship between whether or not people manage for coqui frogs and the amount of frogs they perceive they have on their property (chi-square test, alpha = 0.05) (N = 50).

	People's estimate of number of coqui on their property				
Manage?	1 or 2 frogs	3 to 100 frogs	Hundreds of frogs	Thousands of frogs	Total
No	4	13	11	4	32
Yes	0	9	8	1	18
Total	4	22	19	5	50

Fig. 2.3. Management approaches used by people who were actively trying to control coqui. Multiple responses were included for each person. (N = 20).

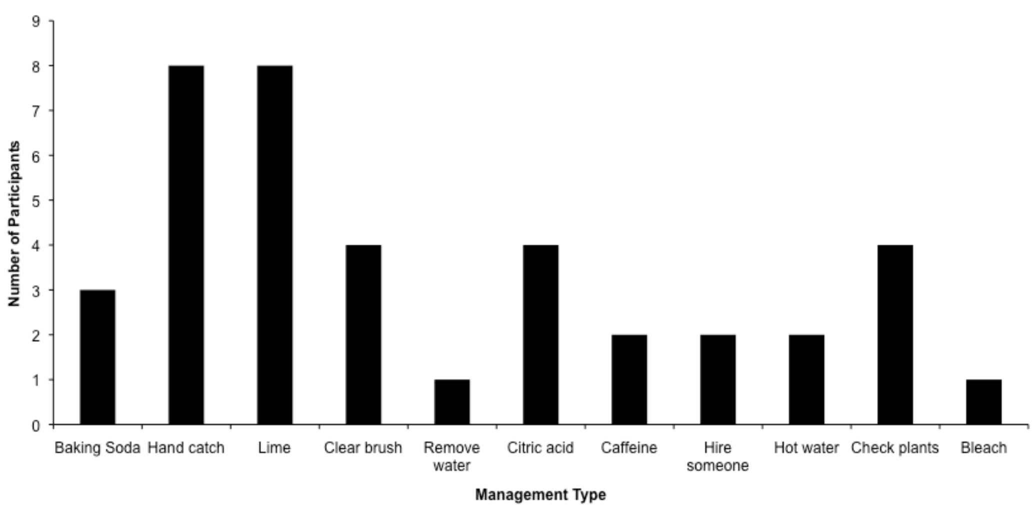


Table 2.8. Differences in types of management, based on people's estimates of frogs on their property and whether or not they report participating in specific coqui-directed control measures (chi-square test, alpha = 0.05) ($N = 20$).

People's estimate of number of coqui on their property					
Mechanical?	0 frogs	3 to 100 frogs	Hundreds of frogs	Thousands of Frogs	Total
No	2	5	3	1	11
Yes	0	4	5	0	9
Total	2	9	8	1	20

a. Chi-square test with *df* =3; $\chi^2 = 3.45$, $p = 0.328$

People's estimate of number of coqui on their property					
Chemical?	0 frogs	3 to 100 frogs	Hundreds of frogs	Thousands of Frogs	Total
No	2	3	3	1	9
Yes	0	6	5	0	11
Total	2	9	8	1	20

b. Chi-square test with *df* =3; $\chi^2= 4.34$, $p = 0.227$

People's estimate of number of coqui on their property					
Agricultural?	0 frogs	3 to 100 frogs	Hundreds of frogs	Thousands of Frogs	Total
No	0	7	3	0	10
Yes	2	2	5	1	10
Total	2	9	8	1	20

c. Chi-square test with *df* =1; $\chi^2 = 6.28$, $p = 0.099$

Relationship between environmental variables and frog abundance

Several of our environmental variables were correlated with each other (Table 2.9). For example, we found that canopy cover was positively related to number of trees, negatively related to lava cover, and positively related to understory density.

We used multiple regression to identify the influence of environmental factors on frogs that might be affected by property owners' management actions. To reduce multicollinearity, we selected the number of leaf litter invertebrates, number of flying invertebrates, percent grass cover, and percent canopy cover as predictors of frog abundance per transect. The overall model was significant ($F = 2.054$, $p = 0.094$), with canopy cover as the only significant predictor of frog counts ($p = 0.019$; Table 2.10).

DISCUSSION

Our conceptual framework for this study posited that coqui invasion and management on the island of Hawaii should be viewed within a coupled-systems framework in this novel, or altered, ecosystem; i.e., that social and ecological factors interact to influence both attitudes and behaviors toward the frog, and that those psychological and behavioral factors in turn can influence the abundance of the frog. The first assumption was supported, but in a direction that was unexpected: people who had more frogs on their property, those who owned that property, and those living on the west side of the island tended to have *less* negative attitudes toward the coqui. The first two findings are contradictory to our prediction but suggest that people living in areas with more frogs are beginning to habituate to them, which would explain why we saw more

Table 2.9. Correlation matrix for environmental variables and frog abudance. Flying invertebrate and leaf litter invertebrate are average amount collected per 10 m x 10 m plot. The % cover measures refer to the % cover for each of the categories in the 1 m x 1 m checkerboard laid on the ground within each plot. Ave % canopy and understory cover refers to average measurements made within the 10 m x 10 m sample areas on people's properties. Frog count refers to the average number of frogs we saw per 10 m x 10 m plot on the people's properties (*N*=87).

	Total Property Size	Total Flying	Total Leaf Litter	Ave % Forb	Ave % Shrub	Ave % Grass	Ave % Tree	Ave % Man-made	Ave % Lava	Ave % Detritus	Ave % Moss	Ave % Root	Ave % Understory Cover	Ave % Canopy Cover	Frog Count
Total Property Size	1	0.08	0.00	0.18	-0.05	-0.14	0.144	-0.04	-0.07	0.12	-0.01	-0.00	0.23	0.02	-0.02
Total Flying		1	0.02	0.16	-0.12	-0.07	0.04	0.00	0.03	-0.03	0.01	-0.09	0.08	0.12	-0.03
Total Leaf Litter			1	0.08	0.20	-0.06	0.03	-0.04	-0.00	-0.13	0.02	-0.05	0.12	0.16	-0.01
Ave % Forb				1	0.05	-0.46**	-0.17	0.05	-0.10	-0.19	0.08	-0.04	0.32**	0.09	0.08
Ave % Shrub					1	-0.20	-0.03	0.00	-0.24*	-0.09	-0.09	0.12	0.36**	0.18	0.05
Ave % Grass						1	-0.08	-0.17	-0.51**	-0.41**	-0.11	-0.02	-0.30**	-0.12	-0.16
Ave % Tree							1	0.16	-0.06	0.17	-0.09	-0.04	0.38**	0.34**	-0.06
Ave % Man-made								1	0.02	0.06	-0.05	-0.02	0.17	0.04	0.11
Ave % Lava									1	-0.06	-0.12	-0.11	-0.20	-0.35**	-0.03
Ave % Detritus										1	0.24*	0.11	0.06	0.31**	0.18
Ave % Moss											1	-0.04	-0.02	0.31**	0.16
Ave % Root												1	0.09	0.09	0.00
Ave % Understory Cover													1	0.44**	0.11
Ave % Canopy														1	0.26*

Table 2.10. Multiple regression examining the relationship between the square-root number of frogs per plot at each property and four environmental variables: mean % grass, mean % canopy cover, flying invertebrates abundance, and leaf litter invertebrates abundance (*N* = 87).

	Unstandardized coefficient β	Std. Error	t	Sig
Constant	0.536	0.268	2.001	0.049
% Grass	-0.004	0.003	-1.289	0.201
% Canopy cover	0.008	0.003	2.383	0.019*
Flying invertebrates	-0.003	0.004	-0.669	0.505
Leaf litter invertebrates	-0.001	0.001	-0.557	0.579

*p<0.05

non-negative attitudes in these participants. This participant summed up this general sentiment:

> I've sort of resigned to the fact that they're going to be here, um, I don't think that there's any way that they're going to leave.

Further, our interviews uncovered a theme of anxiety among individuals who do not yet have any coqui on their properties, but have strong negative attitudes toward them. People who do not yet live with the frog are bombarded with negative images of the frogs from the media and people who have had them for a while, often pertaining to the amount of noise they make (Beard et al. 2009) because the volume of frog calls is said to affect the ability to sleep (Bernardo 2002) and decrease property values (Kaiser and Burnett 2006). These negative messages could result in a sense of anxiety or negativity in individuals with less direct experience with the frog on their own property, which is consistent with the general use of fear in messaging related to invasive species across the world (Gobster 2005).

Additionally, people who own their property may reduce their negative attitude because they have less freedom to move to areas where there are not frogs, as renters often can, and because the psychological cost of disliking the coqui is greater for homeowners. In effect, homeowners may be experiencing cognitive dissonance (Festinger 1957) where they originally disliked the coqui, but are unable to relocate (or it is more burdensome to relocate) and so they must choose either to live uncomfortably, or to decrease their dissonance by adopting a less negative attitude toward the frog. In support of this, we found renters are more transient than participants who owned their property.

Several of the people who we interviewed spoke of the theme of "xenophobia," and how the coqui is another symbol of a nuisance that individuals not from the island bring with them. This idea of an invasive species becoming a symbol for a larger sociological issue has been reported elsewhere as well (Coates 2006). The issue of identifying invasive versus native species in Hawaii stirs up issues of historical injustice and prejudice (Helmreich 2005), and may help explain differences in attitudes seen in individuals born in Hawaii versus those not born in Hawaii.

While we found people to have strong attitudes toward the frogs, this did not translate into differences in amount or type of management being conducted. This result is contrary to our prediction that people with a negative attitude should feel more strongly about managing their property to control for coqui. However, it is consistent with the idea of people habituating to the coqui, because this translates into less effort being used to manage for them and also relates to the difficulty in predicting an individual's behavior from their attitude (Ajzen 1991). One reason for the lack of management could be that most practices are meant to remove frogs after invasion; however, a few of our interviewees reported proactive measures to prevent invasion. While the efficacy of management was not directly examined in our study, several participants indicated the success of these pro-active and immediate control approaches, as illustrated by the following quote and separate dialogue between the interviewer and interviewee (labeled as "E" and "P", respectively).

> When it turned out that apparently they were coming in on plants, uh, you know, then they've got to monitor that situation. And apparently they're on to that one. So they're immersing the potted plants in water or some such thing before they're allowed to be sold. And that's definitely, you know, we used to go down to Wal-Mart, you could hear the coquis in all the plants. You don't hear that now, so they're doing something.

> P: I've heard it here, um, uh, across the street, um a neighbor had, had one right when I moved in, and he worked hard to get rid of it E: And how long ago was that? P: um, 2006, October E: Okay, did he have a number of frogs, or? P: One. E: Just one. Okay P: Yeah. E: And does he know where it came in from or how he got it? P: Um, yeah, it came from their next-door neighbor and the neighbor had bought a plant in Hilo. E: And so how long did it take him to get rid of that frog? P: Um, about 2 months. E: Wow, so what did he try to do, like what was he doing to get rid of the frog? P: Um, he had to cut down vegetation, and then he, um, uh figured out kind of where it was located and then he put stuff out, I don't know. Lime or, I don't know what it was. Something that he would dust out there with. Um E: Some kind of chemical? P: Yeah E: Okay. And so then after the 2 months you didn't hear it anymore? P: Right E: And you haven't heard it since? P: I haven't heard it since.

While we found that people are more likely to adopt coqui behavior to manage for the coqui if they have frogs than if they do not, the perceived abundance of frogs did not translate into differences in management behavior. It is possible that the relationship between number of frogs and a person's behavior is complicated by the perceived difficulty of the management behavior, an issue that further research should explore.

Specifically, the amount of time, money, or equipment necessary to conduct a certain type of management may be strongly related to whether an individual will actually do the management (Stokes et al. 2006, Epanchin-Niell et al. 2010).

We found that areas with higher canopy cover had higher abundances of frogs. Canopy was positively correlated with other ecological variables such as understory density, tree density, and percent ground cover of leaf litter, moss, and lava (negative correlation). The positive correlation between canopy and understory density (and subsequent coqui abundance), is consistent with previous research suggesting a link between understory structure and coqui density (Stewart and Pough 1983, Beard et al. 2008). Due to the correlations between canopy and other environmental variables in our study, it is likely that these other environmental variables may be related to frog abundance on people's properties, but not enough is known to make management suggestions (Chapter 4 provides more detail).

While the majority of the participants were not actively managing to control for the coqui, those who were used forms of habitat manipulation or chemical application that could alter some of the environmental variables discussed in the previous paragraph. Helping to educate people on the most effective management and *why* people should want to do so seems critical, as suggested by the following interviewee:

> I scan the paper every day. There's a little bit here and there, but it's not specific. It has to be more specific, you know, if they want us to go around picking off coqui frogs, um, it's got to be clearer and more scientific about what, what is the problem and why are they such a problem, and I know they have no predators and they can just multiply like crazy, so, what do we do?

Education that is related to the most salient variables and that is made relevant to an individual, is likely to have the largest positive effect on participants (Morgan and

Gramann 1989) and result in the most effective management of invasive species (Shine and Doody 2011).

CONCLUSION

Understanding the linkages between the social and biological variables is important for successful management of a novel, altered ecosystem (Seastedt et al. 2008). In the case of private property on the island of Hawaii, residents whose properties harbor coqui frogs are more likely to be habituating to the frogs while those that do not yet have frogs exhibit a strong sense of anxiety toward them. This anxiety could be used to fuel more pro-active approaches, such as checking plant materials before purchase, that might aid in reduction or spread of the coqui. Further, once an area becomes newly invaded, channeling this anxiety into early eradication may be key to preventing the spread or establishment of the frog, but care should be taken to convey the message so as not to deter management due to overwhelming fear (Gobster 2005). While some interviewees shared success stories about pro-active and immediate control, further research should examine these approaches to be able to quantify the effect and make more specific management suggestions.

We found that having an invasive frog on a person's property translates into differences in attitude toward the frog, but a negative attitude does not directly translate into management behavior directed against the invasive. Future research could examine the relationship between attitude and management behavior to determine if difficulty of the behavior or other variables complicate the picture. Specifically, things like cost of conducting the management activity, time involved, labor intensity, knowledge needed, and/or special equipment needed, may mediate the relationship between attitude and actual management behavior.

A common theme in our interviews was the need for more detailed information on methods of control and general information on coqui frogs. Education campaigns designed to encourage management for invasive species may be most effective at reaching the people with negative attitudes if they tap into the negative anticipation or general unease expressed by our participants, and channel that energy into pro-active strategies and early control *if* they are shown to be effective beyond just the stories we heard from our participants.

While our study showed a link between an invasive frog's abundance and the use of management, we did not measure whether those practices would likely lead to reduced frog abundance over time, relative to properties where no management was done. Information about long-term, property-scale effectiveness of various management practices would be invaluable for assessing the utility of attitude-change strategies to promote landowner behavior. A similar coupled systems approach to understanding invasive species systems could then be applied to any number of organisms across the globe.

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CHAPTER 3

EXPERIENCE VERSUS RUMOR: MANAGEMENT BEHAVIOR FOR AN INVASIVE FROG IN HAWAII DEPENDS ON EXPOSURE-LEVEL TO THE INVADER[2]

ABSTRACT

In this study, we used the Theory of Planned Behavior as a model for understanding intention to conduct management of an invasive frog in Hawaii. We surveyed 494 individuals living in areas where the invasive frogs are common (island of Hawaii), and 296 individuals living in areas where they are essentially absent (Kauai, Maui, and Oahu). Attitudes predicted behavioral intention more strongly for participants living in areas where frogs were common, while subjective norms more strongly predicted behavioral intention when the frogs were not common. Findings suggest that intentions to participate in specific behaviors toward an invasive species are influenced by an individual's prior exposure and experience with that species. When designing public information campaigns to elicit action against invasive species, a strategy focused on attitude change may work best where experience with the species is common, while a normative approach may be better where invasion is anticipated, but not yet widespread.

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INTRODUCTION

One of the results of global environmental change is the increased spread of non-native species to places where they have the capacity to alter ecosystems and interfere with human activities (Lockwood, Hoopes, & Marchetti, 2007; McNeely, 2001; Mooney, 2005; Pejchar & Mooney, 2010; Pysek & Richardson, 2010). Annual costs in the United States for invasive species have been estimated as high as $128 billion (Pimentel, Zuniga, & Morrison, 2005). Many introductions are caused by unintentional human activities (García-Llorente et al., 2008; McNeely, 2001; Reichard & White, 2001). As a result, various government agencies and nonprofit organizations engage citizens in actions to stop invasions (Sheail, 2003; Stokes et al., 2006). However, conveying the appropriate information to the general public to elicit help in controlling an invasion is often a major barrier to prevention or control (Bremner & Park, 2007; Shine & Doody, 2011). Whether or not a person actually performs the desired management behavior is likely due to a variety of different factors. This paper addresses some predictors of private landowner's intention to perform management behavior for an invasive frog in Hawaii, using the widely applied Theory of Planned Behavior as the conceptual framework.

The Theory of Planned Behavior

Attitudes that are accessible, based on direct personal experience and are consistent with overall beliefs, are better predictors of behavior than less direct, less accessible, or less consistent attitudes (Ajzen, 2006). Additionally, individuals that act more on internal cues than external cues for their actions have higher attitude-to-behavior consistency (Ajzen, 1991; Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975). The importance of subjective norms in influencing behavior, as well as the concept that behavioral intentions mediate the attitude-behavior relationship (Armitage & Christian, 2004), were important factors in development of the Theory of Planned Behavior (TPB) (Ajzen, 1991) and its precursor, the Theory of Reasoned Action (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975). While the latter theory was well-accepted and widely applied (see Sheppard, Jon, & Warshaw, 1988), it has been largely supplanted by TPB, which incorporated the concept that behavioral intention is determined by perceived behavioral control (Madden & Ellen, 1992). Therefore, individuals are more likely to perform a specific behavior if they hold more positive attitudes toward the behavior, perceive a strong social norm favoring the behavior, or believe their actions can have a predictable and desired effect.

The TPB has been applied to a broad array of research questions including prediction of health-related behaviors (Godin & Kok, 1996; Plotnikoff et al., 2010), leisure choices (Ajzen & Driver, 1992; Quintal, Lee, & Soutar, 2010), entrepreneurial intentions (Krueger & Carsrud, 1993; Shook & Bratianu, 2010), exercise (Norman & Smith, 1995), recycling and waste behaviors (Oskamp et al., 1991; Taylor & Todd, 1995; White & Hyde, 2011), pollution reduction (Cordano & Frieze, 2000) and other environmental behaviors including invasive weed control and related conservation behaviors by farmers (Beedell & Rehman, 1999; Fielding, Terry, Masser, & Hogg, 2008; Prinbeck, Lach, & Chan, 2011; Wauters et al., 2010).

Attitudes and Behavior Toward Invasive Species

The topic of invasive species is one that commonly evokes strong reactions (Coates, 2006; Shine & Doody, 2011). The attitudes people have toward an invasive are often culturally or historically based (Coates, 2006) and can be related to the type of management a person is willing to use for a particular species (Andreu, Vilà, & Hulme, 2009; Fraser, 2006; García-Llorente et al., 2008). The more direct experience an individual has with an invasive, the more likely he/she will be able to understand the potential benefits of management programs (Fraser, 2006). Changes in attitudes and behavior may be necessary to minimize the effects of invasives where people do not view them as negative (Daehler, 2008).

Additionally, attitudes toward wildlife and attitudes toward methods of managing species have been shown to be related to socio-demographic factors, such as age and gender (Fitzgerald, Fitzgerald, & Davidson, 2007; García-Llorente et al., 2011; Miller & Jones 2005, 2006). The pattern of the relationships between attitudes toward invasives and various socio-demographic or other predictor variables are complex (Fitzgerald et al., 2007). Because management effectiveness is dependent on coordination of managers and the general public (Epanchin-Niell et al., 2010; Gardener, Cordell, Anderson, & Tunnicliffe, 2010; Stokes et al., 2006), greater understanding of people's beliefs and behaviors is necessary for successful management (Coates, 2006; Fischer & van der Wal, 2007; Reaser, 2001). This information can then be used to design outreach programs to generate an informed public that will actively participate in time, money, and energy-efficient management (Gherardi, Aquiloni, Diéguez-Uribeondo, & Tricarico, 2011; Shine & Doody, 2011; Vanderhoeven et al., 2011; Witmer et al., 2009). In the case of government action to control an invasive, the more information the general public has on why a particular method is being used, the more likely the public will support that form of management (Bremner & Park, 2007; Fraser, 2006; Mack et al., 2000).

The Coqui Frog (*Eleutherodactylus coqui)* in Hawaii

To examine the relationship between attitudes and intention to manage and actual management behavior for an invasive species, we chose an invasive frog in Hawaii, *Eleutherodactylus coqui* (hereafter, the coqui). Since its introduction to the Hawaiian Islands in the late 1980s, its range has increased primarily due to unintentional human behaviors (Kraus & Campbell, 2002; Kraus, Campbell, Allison, & Pratt, 1999). It is thought to have initially been introduced through the horticultural trade, more specifically the sale of nursery plants (Kraus & Campbell, 2002; Kraus et al., 1999). Horticultural trade, human transport, and other anthropogenic effects, such as disturbance, aid in its spread, but quantification of the role of each is presently unknown. The coqui is expected to continue expanding its range on the island of Hawaii, where eradication is no longer believed possible (Beard, Price, & Pitt, 2009). Control efforts have eradicated the coqui from Oahu, and reduced coquis to one small (6 ha) and one larger (87 ha) population on Kauai and Maui, respectively (Anonymous, 2010) and current management efforts on these islands are focused on eradicating the frog (Anonymous, 2010).

Attitudes and Behavior Toward the Coqui

One widely known concern surrounding the coqui is noise nuisance. The frog's name originates from the male's territorial and reproductive call (Joglar, 1998; Rivero, 1998; Stewart & Rand, 1992), which can reach up to 90 dB at 0.5 m (Beard & Pitt, 2005) and is mostly heard between dusk and dawn (Woolbright, 1985). Property values in close proximity to frog infestations have been reduced (Kaiser & Burnett, 2006).

Interviews we conducted across the island of Hawaii revealed that people tend to feel more negatively toward the coqui if their property does not harbor the frog (Chapter 2). People whose properties have been invaded tend to display less negative attitudes, suggesting a reduction in anti-coqui sentiment may occur after invasion (Chapter 2). We found no relationship between the anti-coqui management behaviors performed and people's attitudes toward the frogs (Chapter 2). To better understand these findings, we used TPB to elucidate the relationships between attitudes, values, beliefs, and norms that might influence willingness to manage coqui infestations. We expect these factors influence willingness to participate, and actual participation, in control efforts.

Objectives

Based on our previous research suggesting differences in attitudes and management behavior as a result of exposure to the frog (Chapter 2), one objective of this study was to compare predictors of behavioral intentions in individuals with different levels of exposure to the frogs. To do this, we compared the island of Hawaii where coqui frogs have been established for over 20 years with the other three main islands where frogs have been detected but are not present, or if they are present, are highly restricted geographically. Because the TPB suggests a predictable relationship between attitudes, subjective norms, and perceptions of control and self-reported behavioral intention, a second objective of this study was to investigate the strength of the relationship between these variables and actual intention to manage for the coqui (see Figure 3.1). Because behavioral intention is not always predictive of actual behavior, our

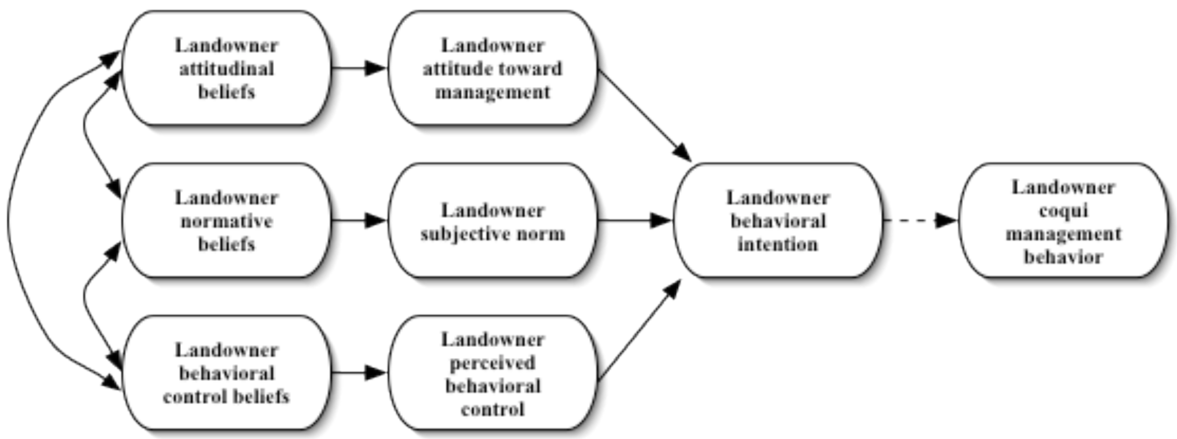

Figure 3.1. Conceptual model of predictors of management intentions and actual management behaviors directed toward the invasive coqui frog in Hawaii, derived from the Theory of Planned Behavior (Ajzen, 2006).

final objective was to investigate the relationship between self-reported management behavior and self-reported behavioral intentions.

METHOD

Elicitation Study

Because of the importance of understanding population-specific beliefs in the design of TPB studies, we conducted an elicitation study using semi-structured interviews of 87 people living on the island of Hawaii to understand phrasings, topics of importance, and salient beliefs regarding management behavior to the people living there (Chapter 2; Cheung, Chan, & Wong, 1999). Examples of questions were: "How would you describe the coqui frog to someone who doesn't know what it is?", "In your opinion, what are some positive and negative aspects of the coqui frog?", and "Do you or members of your household do anything on your property for the coqui frog?" (Chapter 2). The interviews were content analyzed and the most common phrasings for management behaviors related to behavioral intention, as well as belief behaviors, and direct measures, were used to construct questions for the TPB mail survey.

Pilot Study

To reduce respondent fatigue from a lengthy survey, we first created a pilot instrument based on Ajzen's recommendations (Ajzen, 2006) and the results of our elicitation study, and we then tested it by contacting a subset of participants from the first study. Four participants, two males and two females ranging in age from 44-74 years, completed a sample survey posted online. Instructions were given for participants to complete the survey and indicate any confusing questions or difficulties they had completing the survey. Following Ajzen's (2006) survey design suggestions, questions for each of the constructs were checked for internal consistency. For the questions related to salient beliefs, questions did not need to be internally consistent, but needed to be understandable. In total, five of 16 questions related to our direct measures were removed for low internal consistency and six of 30 questions related to the belief measures were removed because they were confusing.

Main Study

Using the results of the elicitation and pilot studies, we constructed a close-ended questionnaire to measure attitude, subjective norm, perceived behavioral control, behavioral intention, reported behavior, and the belief variables related to the direct constructs. The survey booklet consisted of 76 questions and was 11, 21.6 cm x 14 cm pages (see Appendix C). In total, 35 of the questions were designed to measure TPB, and the rest of the questions measured demographic information as well as other specifics related to the coqui, for which descriptive statistics are reported in Appendix D. The questions were presented in a fixed random order. Questions related to the TPB portion were measured on a 7-point scale (from -3 to 3).

Ajzen (2006) includes information on how to best construct TPB questionnaires to account for as much variance as possible, ensure correct measurements of the constructs, and ensure conclusions drawn can be drawn. All of the predictors of behavioral intention, and behavioral intention itself, are latent variables, meaning they cannot be directly observed but instead need to come from observable survey responses. Attitude, subjective norm, and perceived behavioral control are direct variables in the model, whereas attitudinal beliefs, norm beliefs, and control beliefs are the foundations for these direct variables. The belief strength for each foundational variable is multiplied by the outcome evaluation and summed over all accessible behavioral outcomes to produce a belief composite that should be directly predictive of the direct measure of that variable (Ajzen, 2006). The models that we were testing are in Figures 3.2 and 3.3.

Direct Measures Toward Performing Coqui Management Behavior

Four items assessed the participant's attitude toward managing the coqui on their property (labeled as A1, A2, A3, and A4; see Table 3.1). These items should correlate with each other and exhibit high internal consistency (Ajzen, 2006). Cronbach's alpha is commonly used to measure internal consistency. Cronbach's alpha is measured on a scale of 0 to 1, with values closer to 1 indicating greater internal consistency (Bland &

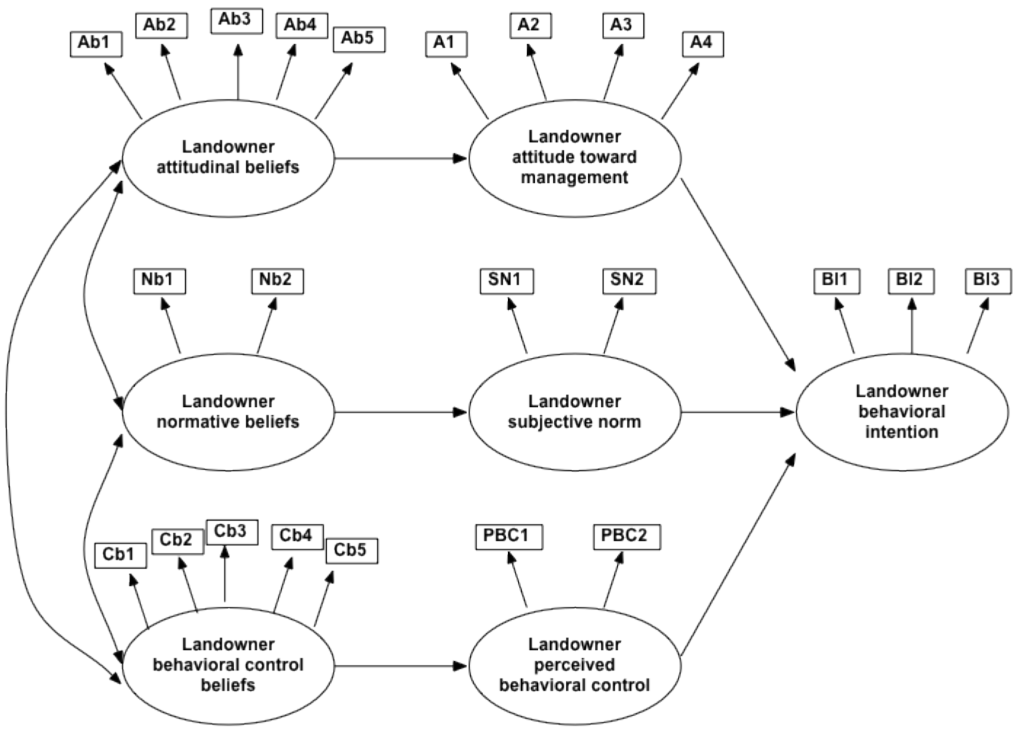

Figure 3.2. Structural equation model of predictors of intention to manage for an invasive frog in Hawaii. Observable variables are represented by rectangles in the diagram and are described in the methods. This model was used both for people surveyed on the island of Hawaii, and for respondents living on the state's other three largest islands- Kauai, Maui, and Oahu.

Altman, 1997). Cronbach's alpha was .726, suggesting an acceptable level of internal consistency.

Two items assessed the participant's subjective norms toward managing for the coqui on their property (labeled as SN1, SN2; see Table 3.1). Cronbach's alpha was .650.

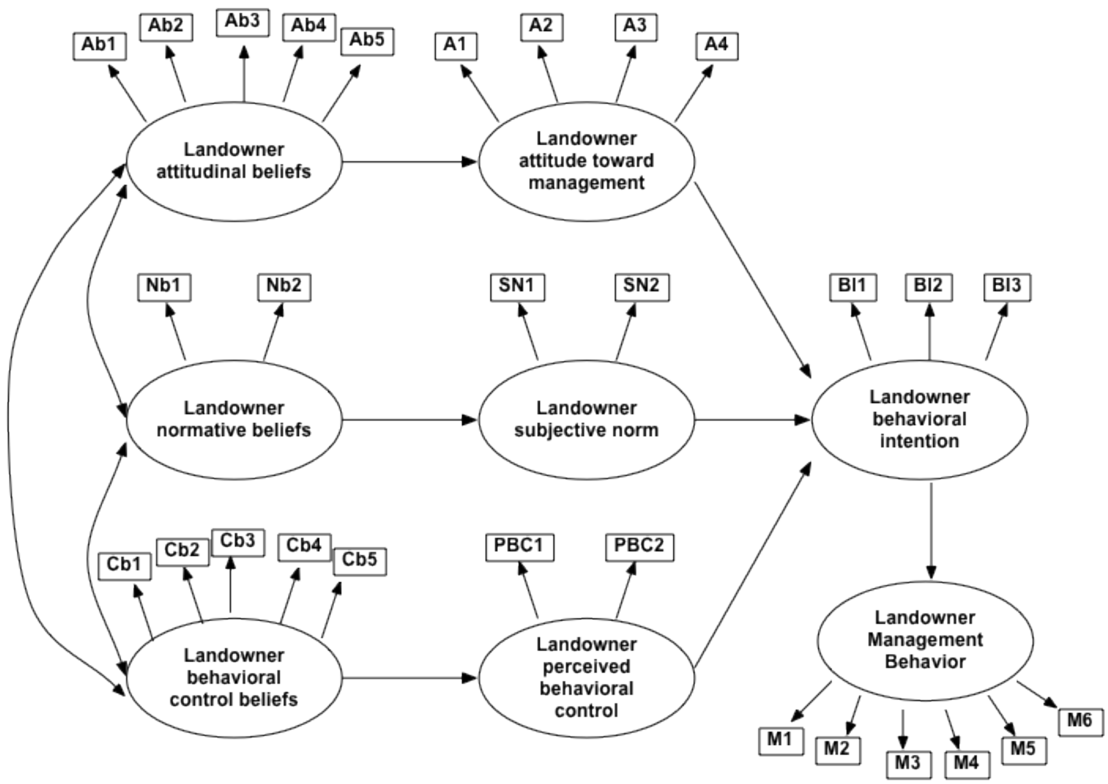

Figure 3.3. Structural equation model of predictors of intention to manage coqui frogs and for actual management behavior. Observable variables are represented by rectangles in the diagram and are described in the methods. This model was used for the subsample of survey respondents who reported engaging in behaviors intended to affect frog presence and/or abundance.

Two items assessed the participant's perceived behavioral control of managing for the coqui on their property (labeled as PBC1, PBC2; see Table 3.1). Cronbach's alpha was .078, suggesting low internal consistency between the two measures. As we are not constructing an index for these two measures, but rather are leaving them as individual items in our structural equation model (SEM), the low internal consistency is of little concern.

Table 3.1. Structural equation model variables and related survey questions.

Variable	Survey Question
A1	For me to manage my property for coqui frogs on a regular basis is (range: extremely difficult to extremely easy)
A2	For me to manage my property for coqui frogs on a regular basis is (range: extremely bad to extremely good)
A3	For me to manage my propery for coqui frogs on a regular basis is (range: extremely worthless to extremely valuable)
A4	For me to manage my property for coqui on a regular basis is (range: tiring to energizing)
SN1	Most people who are important to me manage their properties for coqui frogs on a regular basis (range: defnitely false to definitely true)
SN2	It is expected of me that I manage my property for coqui frogs on a regular basis (range: definitely false to definitely true)
PBC1	Whether or not I manage my property for coqui frogs on a regular basis is completely up to me (range: completely disagree to strongly agree)
PBC2	I am confident that if I wanted to I could manage my property for coqui frogs on a regular basis (range: definitely false to definitely true)
BI1	I plan to manage my property for coqui frogs on a regular basis (range extremely unlikely to extremely likely)
BI2	I will make an effort to manage my property for coqui frogs on a regular basis (range: strongly disagree to strongly agree)
BI3	I intend to manage my property for coqui frogs on a regular basis (range: strongly disagree to strongly agree)

Three items assessed the participant's behavioral intention of managing for the coqui on their property (labeled as BI1, BI2, BI3; see Table 3.1). Cronbach's alpha was .922.

Belief Composites Toward Performing Coqui Management Behavior

Five items assessed the participant's attitudinal beliefs of managing for the coqui on their property (labeled as Ab1, Ab2, Ab3, Ab4, Ab5; see Table 3.2). These five items are composite scores of attitudinal belief strength and outcome evaluation calculated using an expectancy-value model (i.e., multiplying belief strength by outcome evaluation, and summing the products over all accessible behavior outcomes).

Two items assessed the participant's normative beliefs of managing for the coqui on their property (labeled as Nb1, Nb2; see Table 3.2). These two items are composite scores of normative belief strength and outcome evaluation calculated using an expectancy-value model (as described above).

Five items assessed the participant's control beliefs of managing for the coqui on their property (labeled as Cb1, Cb2, Cb3, Cb4, Cb5; see Table 3.2). These five items are composite scores of control belief strength and outcome evaluation calculated using an expectancy-value model (as described above).

Analysis

Data were analyzed with SEM using AMOS 18.0 (2010) in SPSS version 19.0 (SPSS, Inc., Chicago, IL) with maximum likelihood estimation. Due to the non-normality of the data resulting from people picking the extremes and middle scores, and

Table 3.2. Structural equation model belief composite variables and related survey questions. For these variables, two survey questions are multiplied together to get the overall composite belief score, which are indicated before and after the "x" in the table.

Variable	Survey Questions Multipled to get Composite Score
Ab1	If managing coqui frogs required a large time commitment it would be (range: extremely bad to extremely good) x Managing my property for coqui frogs on a regular basis will result in a large time commitment (range: extremely unlikely to extremely likely)
Ab2	Having better control over the coqui frog on my property is (range: extremely bad to extremely good) x Managing my property for coqui frogs on a regular basis will help me have better control over the coqui frog on my property (range: extremely unlikely to extremely likely)
Ab3	Interacting more with my neighbors or other individuals in my community is (range: extremely bad to extremely good) x Managing my property for coqui frogs on a regular basis will give me an opportunity to interact with my neighbors and other individuals in my community (range: extremely unlikely to extremely likely)
Ab4	Using more chemicals on my property is (range: extremely bad to extremely good) x Managing my property for coqui frogs on a regular basis will cause me to use more chemicals on my property (range extremely unlikely to extremely likely)
Ab5	Spending lots of my money to manage for coqui frogs is (range: extremely bad to extremely good) x Managing my property for coqui frogs on a regular basis will cause me to spend a lot of money (range: extremely unlikely to extremely likely)
Nb1	My neighbor thinks that I should manage my property for coqui frogs on a regular basis (range: extremely unlikely to extremely likely) x Generally speaking, how much do you want to do what your neighbor thinks you should do? (range: not at all to very much)
Nb2	The count or state thinks that I should manage my property for coqui frogs on a regular basis (range: extremely unlikely to extremely likely) x Generally speaking, how much do you want to do what the county or state thinks you should do? (range: not at all to very much)
Cb1	Not receiving enough education on management activities for the coqui would make it (range: much more difficult to much easier) for me to manage my property for coqui frogs on a regular basis x How often do you feel that you do not receive enough education on management activities for the coqui frog? (range very rarely to very frequently)

Cb1	Not receiving enough education on management activities for the coqui would make it (range: much more difficult to much easier) for me to manage my property for coqui frogs on a regular basis x How often do you feel that you do not receive enough education on management activities for the coqui frog? (range very rarely to very frequently)
Cb2	If I felt ill, tired, or old, it would make it more difficult for me to manage my property for coqui frogs on a regular basis (range: stronly disagree to strongly agree) x How often do you feel ill, tired, or old? (range: very rarely to very frequently)
Cb3	If I have less spending money than I hoped for, it would make it more difficult for me to manage my property for coqui frogs on a regular basis (range: strongly disagree to strongly agree) x How often do you have less spending money than you had hoped for? (range: very rarely to very frequently)
Cb4	Unanticipated demands on my time would make it (range: much more difficult to much easier) for me to manage my property for coqui frogs on a regular basis x How often do you have unanticipated demands on your time? (range: very rarely to very frequently)
Cb5	My neighbors managing their land in a way that negatively affects me would

due to the overall large sample size, we used bootstrapping to assess the stability of the parameter estimates. Bootstrapping is a common approach to handle non-normal data in SEM (Byrne, 2001). We ran 2000 bootstrap samples on each of our SEM models.

Correlation matrices between the direct variables and belief variables were calculated as were the unstandardized path coefficients, standard errors, significance level, and a measure of the bias from the bootstrapped model to the maximum likelihood model. To compare path coefficient estimates across the three subsamples, the unstandardized regression weights are reported in the tables and figures.

Participants

Potential participants were randomly selected from all residents of the islands of Hawaii, Kauai, Maui, and Oahu using GIS (Geographic Information Systems) land parcel data. From our previous research, we discovered differences in attitudes toward the frog based on whether a person rented or owned their property (Chapter 2). For this reason, and to increase our ability to make conclusive statements about predictors of behavior and behavioral intention, for this study we were only interested in responses from individuals who currently owned land in Hawaii. Thus, the first question on the survey asked participants "Do you currently own land in Hawaii?" and instructed them that if they answered "No," they should return the blank survey in the enclosed postage paid envelope.

The mail surveys were delivered to 4,000 potential participants across the islands of interest: 2,000 surveys mailed to potential homeowners on the island of Hawaii, and 2,000 to potential homeowners split evenly across the islands of Kauai (N=666), Maui (N=667), and Oahu (N=667). While the sampling effort varied on each island with population, cluster sampling was done randomly on each of the islands, such that the clusters can be considered heterogeneous within the cluster for each island, and homogeneous between the clusters for the three islands (Kish, 1965, cited in Tidwell, 2005). Thus, for purposes of this study, participants from the islands of Kauai, Maui, and Oahu were lumped into one category because these participants have presumably had little direct experience with the coqui, while responses from the island of Hawaii were analyzed separately because these participants had presumably more direct experience with the coqui.

We followed Dillman's (2000) four-wave tailored design for administering our survey. We mailed 4,000 surveys in our initial sampling wave. One week later, we mailed a follow-up/thank you postcard to all participants. Approximately 2 weeks after the postcard mailing, we sent a cover letter and mail survey to all nonrespondents. We continued the survey until we were no longer receiving any in the mail (approximately 4 months from initial wave).

RESULTS

Overall Sample

In total, 125 surveys were returned as undeliverable (31 from the island of Hawaii and 94 from the other three islands), and a total of 90 surveys were returned uncompleted by participants indicating that they did not currently own land in Hawaii. Overall, 1,025 completed surveys were returned. Of these, 740 completed all of the questions from the TPB section of the survey, so that their responses could be used in the model described in this chapter (18.5% of the original mail sample). Respondents from the island of Hawaii accounted for 494 completed TPB surveys while recipients from the other three islands combined completed 246 surveys. From the 740 completed surveys, 212 people were actively managing in a way to influence coqui frog numbers and were used as a subsample to look at the predictors of reported behavior. Only three of the individuals actively managing for the coqui owned land on Kauai, Maui, or Oahu.

Descriptive Statistics

The majority of the surveys were returned from the island of Hawaii (N=486; 67.7%), 9.1% came from Kauai (N=67), 14.7% from Maui (N=109), 9.1% from Oahu (N=67), and <1% from people that own property on multiple islands (N=11; 8 included island of Hawaii and were thus placed in that grouping).

For the whole sample, 356 participants (48.1%) were female, 364 (49.2%) were male, and 20 (2.7%) did not provide this information. Mean age was 58.5 (range 18 to 94 years old). Fifteen percent (*N*=112) had less than a college education, 62% (*N*=456) had at least some college, and 21% (*N*=152) had an advanced college degree. Twenty-eight percent earned <$49,999 (*N*=208), 35% earned between $50,000 and $99,999 (*N*=260), 18% earned > $100,000 (*N*=133), and 14% preferred not to say (*N*=107).

General participant demographics were consistent with US Census data for 2005-2009, suggesting our sample was representative of individuals living in Hawaii. Specifically, for individuals older than 20, the median age range from the census data was 45 to 54 years old. Males made up 50.6% of the population, with females representing 49.4% of the population. Only 23% of the population were native Hawaiian or Pacific Islander and the median household income was $64,661.

Almost all (97%) of the participants knew what a coqui frog was. Because results of our initial interviews suggested that people whose properties have already been invaded may feel less negatively toward the coquis, while those who do not yet have frogs on their property feel especially negative toward them (Chapter 2), we included several survey items designed to directly measure those sentiments. In total, 82.2% "dislike" or "strongly disliked" the coqui, while 2.7% "like" or "strongly liked," 2.8% did not know what it was, and the remaining 10.5% held a "neutral" opinion toward the coqui. When asked if "in the last 12 months have you felt alone in your efforts to manage for coquis?", 19% agreed; and 22% responded affirmatively when asked if "in the last 12 months have you felt like giving up on trying to manage for coquis on your property?". When asked if "in the last 12 months have you worried the coquis would come to your area (if they aren't already), or increase in number (if they are there already)?", 68.4% responded affirmatively.

Means and standard deviations (SD) for all direct variables in the model are presented in Table 3.3. Means and SD for all belief variables in the model are presented in Table 3.4. Overall descriptive statistics for all questions are presented in Appendix D.

Island of Hawaii

Descriptive Statistics

For the subsample of individuals from the island of Hawaii, 226 participants (45.8%) were female, 257 (52%) were male, and 11 (2.2%) did not provide this information. Mean age was 58.2 (range 18 to 93 years old). Twelve percent (N=76) had less than a college education, 61% (N=304) had at least some college, and 21% (N=104) had an advanced college degree. Thirty-two percent earned < $49,999 ($N$=158), 33% earned between $50,000 and $99,999 ($N$=164), 17% earned > $100,000 ($N$=82), and 14% preferred not to say (N=68).

Testing of the SEM for Behavioral Intention

Path coefficients, standard errors, significance level, and biases for the bootstrapped model (hereafter model parameters) are presented in Table 3.5, and path coefficients and significance level (hereafter coefficients) are also presented in Figure 3.4. The correlation matrix for the direct variables in the model are presented in Table 3.6, and the belief variables are presented in Table 3.7.

Overall, the low bias estimates for the path coefficients suggest little discrepancy between the bootstrapped estimates and the original maximum likelihood estimates.

Table 3.3. Means (M) and standard deviations (SD) for scales used in structural equation models as direct measures (range -3 to 3). A are attitude measures, PBC are perceived behavioral control measures, SN are subjective norm measures, and BI are behavioral intention measures.

Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*
	Hawaii island (*N*=494)		Other islands (*N*=246)		People managing for frogs (*N*=212)	
A1	.48	1.94	.66	1.90	.78	1.91
BI1	.46	2.04	.49	1.90	1.06	1.85
A2	.44	1.97	.64	1.63	.62	1.94
PBC1	1.58	1.81	.94	1.80	1.73	1.82
SN1	-.30	1.84	.14	1.54	-.09	1.92
A3	.66	1.97	.91	1.71	1.00	1.91
SN2	-.41	2.11	.20	1.86	.68	2.02
BI2	.64	1.94	.83	1.67	-.26	2.11
A4	-1.13	1.51	-.79	1.47	1.20	1.68
BI3	.30	2.04	.49	1.71	-1.24	1.54
PBC2	.53	2.07	.90	1.67	.83	1.91

Because the data are non-normal and the sample size is relatively large, the chi-square estimate of model fit will not give the best estimates (Bearden, Sharma, & Teel, 1982; Byrne, 2001). The GFI (Goodness of Fit Index) for this model explains the relative amount of variance and covariance that is explained by the model and ranges from 0 to 1.00. The GFI for our model was .741 (values closer to 1 are best). The RMSEA (Root Mean Square Error of Approximation) takes into account the error of approximation in the population. The RMSEA for our model was .078 (values less than .05 are best, but values up to .08 represent reasonable errors of approximation) (Bearden et al., 1982; Byrne, 2001). The results suggest an acceptable fit for our model. Model adjustments

Table 3.4. Means (M) and standard deviations (SD) for scales used in structural equation models as belief (indirect) measures (range -9 to 9). Ab refers to the attitudinal beliefs, Nb are the normative beliefs, Cb are the control beliefs, and BI are the behavioral intentions.

Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*
	Hawaii island (*N*=494)		Other islands (*N*=246)		People managing for frogs (*N*=212)	
Ab1	-2.19	5.59	-2.22	5.68	-2.63	5.63
Ab2	2.92	5.31	2.70	4.89	3.34	5.48
Ab3	-.64	5.05	-.30	4.98	-.38	5.16
Ab4	1.55	4.61	1.57	4.69	1.61	4.83
Ab5	-1.50	5.12	-1.53	4.81	-1.03	5.47
Nb1	.093	4.05	.03	4.01	1.23	4.13
Nb2	.359	3.99	.87	3.63	.08	4.07
Cb1	-.07	5.19	.15	5.12	-.23	5.13
Cb2	-2.01	4.35	-2.27	3.92	-2.21	4.23
Cb3	-.23	4.58	-1.17	4.56	-.26	4.45
Cb4	-.279	4.54	.18	4.07	-.77	4.67
Cb5	2.03	4.96	2.03	4.92	1.68	4.93

suggested in the documentation for the AMOS software to improve model fit required departure from our theory; thus, because the purpose of the analysis was to test theory, we retained all parameters necessary to do so. Attitude was the strongest predictor of behavioral intention (b= .425), followed by subjective norm (b= .381). Perceived behavioral control was not predictive of behavioral intention.

Table 3.5 Unstandardized path coefficient estimates for the island of Hawaii only. C.R. is the critical ratio, or test statistic. A are attitude measures, PBC are perceived behavioral control measures, SN are subjective norm measures, and BI are behavioral intention measures. All bias estimates were within +/- .001.

		Estimate	S.E.	C.R.	P
Attitude	<--- Attitude Belief	.056	.017	3.360	<.001***
Subjective Norm	<--- SN Belief	-.092	.023	-4.006	<.001***
PBC	<--- PBC Belief	.014	.019	.755	.450
Behavioral Intention	<--- Attitude	.425	.032	13.480	<.001***
Behavioral Intention	<--- Subjective Norm	.381	.029	13.188	<.001***
Behavioral Intention	<--- PBC	-.023	.032	-.718	.473
Indirect A1	<--- Attitude Belief	.122	.048	2.525	.012*
Indirect A2	<--- Attitude Belief	.050	.046	1.076	.282
Indirect A3	<--- Attitude Belief	.236	.043	5.544	<.001***
Indirect A4	<--- Attitude Belief	.034	.040	.850	.395
Indirect A5	<--- Attitude Belief	1.000			
Indirect SN	<--- SN Belief	1.000			
Indirect SN2	<--- SN Belief	-.004	.044	-.088	.930
A1	<--- Attitude	1.000			
A2	<--- Attitude	.493	.040	12.285	<.001***
A3	<--- Attitude	.523	.039	13.341	<.001***
SN1	<--- Subjective Norm	.399	.035	11.370	<.001***
SN2	<--- Subjective Norm	1.000			
BI1	<--- Behavioral Intention	1.000			
BI2	<--- Behavioral Intention	.995	.036	27.505	<.001***
BI3	<--- Behavioral Intention	1.054	.038	28.049	<.001***
PBC1	<--- PBC	1.000			
PBC2	<--- PBC	.014	.052	.279	.780
Indirect PBC	<--- PBC Belief	-.159	.053	-2.989	.003**
Indirect PBC2	<--- PBC Belief	1.000			
Indirect PBC3	<--- PBC Belief	.178	.047	3.821	<.001***
Indirect PBC4	<--- PBC Belief	.049	.047	1.041	.298
Indirect PBC5	<--- PBC Belief	-.228	.050	-4.521	<.001***
A4	<--- Attitude	.235	.034	7.003	<.001***

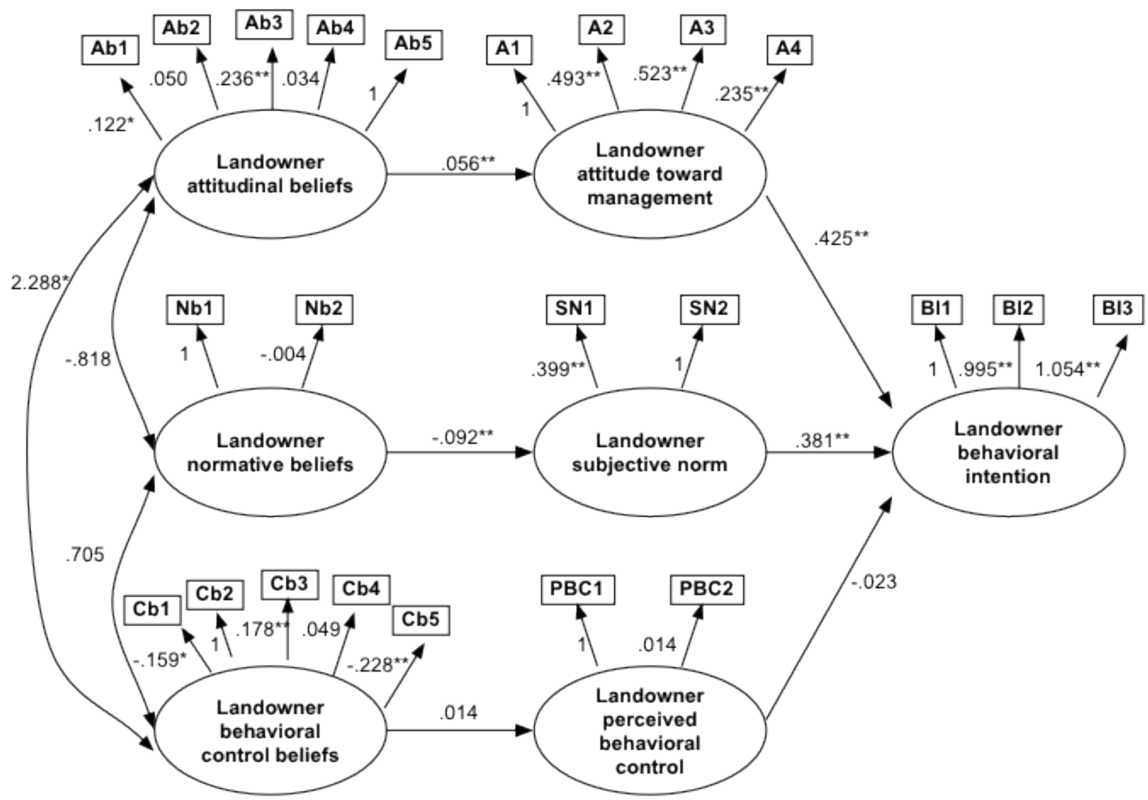

Figure 3.4. Path coefficients for the island of Hawaii only. All numbers in Figure 3.4 are unstandardized. *p<.05, **p<.01.

Islands of Kauai, Maui, and Oahu Combined

Descriptive Statistics

For the subsample of individuals from the other three islands, 130 participants (52.8%) were female, 107 (43.5%) were male, and 9 (3.7%) did not provide this information. Mean age was 59.2 (range 28 to 94). Fifteen percent (N=36) had less than a college education, 62% (N=152) had at least some college, and 20% percent (N=48) had an advanced college degree. Twenty percent earned <$49,999 ($N$=50), 39% earned between $50,000 and $99,999 ($N$=96), 21% earned >$100,000 (N=51), and 16% preferred not to say (N=39).

Table 3.6. Correlation matrix for direct measures for the island of Hawaii only. A are attitude measures, PBC are perceived behavioral control measures, SN are subjective norm measures, and BI are behavioral intention measures.

	A1	BI1	A2	PBC1	SN1	A3	SN2	BI2	A4	BI3	PBC2
A1	1	.545**	.484**	-.007	.200**	.515**	.354**	.552**	.301**	.586**	.446**
BI1		1	.548**	-.078	.397**	.648**	.513**	.815**	.376**	.814**	.558**
A2			1	.064	.271**	.490**	.409**	.561**	.422**	.577**	.611**
PBC1				1	-.156**	-.127**	-.174**	-.102*	.004	.099*	.162*
SN1					1	.541**	.534**	.531**	.172**	.625**	.326**
A3						1	.680**	.773**	.073	.725**	.366**
SN2							1	.708**	.159*	.652**	.338**
BI2								1	.140*	.774**	.431**
A4									1	.222**	.259**
BI3										1	.400**
PBC2											1

* $p<.05$, ** $p<.01$.

Testing of the SEM for Behavioral Intention

Model parameters are presented in Table 3.8 and coefficients in Figure 3.5. The correlation matrix for the direct variables are presented in Table 3.9, and the belief variables are presented in Table 3.10.

Subjective norm is the strongest predictor of behavioral intention (b= .515), followed by attitude (b= .277). Perceived behavioral control was not a significant predictor of behavioral intention.

Table 3.7. Correlation matrix for indirect variables (latent measures) for the island of Hawaii. Ab refers to the attitudinal beliefs, Nb are the normative beliefs, Cb are the control beliefs, and BI are the behavioral intentions.

	Ab1	Ab2	Ab3	Ab4	Ab5	Nb1	Nb2	Cb1	Cb2	Cb3	Cb4	Cb5	BI1	BI2	BI3
Ab1	1	.063	.040	.079	.113*	.054	-.071	-.047	.089*	.135**	.039	-.048	.143**	.116*	.124**
Ab2		1	.022	.159**	.048	-.088	-.018	-.024	-.068	-.070	-.066	-.099*	.366**	.399**	.397**
Ab3			1	.013	.242**	.005	.019	-.087	.045	-.005	.059	-.093*	.079	.035	.069
Ab4				1	.038	-.014	.054	-.001	-.081	.028	.051	.082	.198**	.198**	.160**
Ab5					1	-.039	-.068	-.128**	.102*	.038	.065	-.287**	.145**	.145**	.183**
Nb1						1	-.004	-.044	.040	.016	.076	.050	-.135**	-.150**	-.175**
Cb1							1	.075	.022	-.076	-.065	.077	-.016	-.032	-.043
Cb2								1	-.133**	-.067	-.012	.204**	-.102*	-.135**	-.158**
Cb3									1	.170**	.047	-.200**	.083	.035	.071
Cb4										1	.153**	-.075	.038	-.020	.008
Cb5											1	.037	-.099*	-.103*	-.129**
BI1												1	-.058	-.069	-.096*
BI2													1	.815**	.814**
BI3														1	.851**

**p*<.05, ***p*<.01

Table 3.8 Unstandardized path coefficient estimates for the islands of Kauai, Maui, and Oahu combined. C.R. is the critical ratio, or test statistic. All bias estimates were within +/- .002. A are attitude measures, PBC are perceived behavioral control measures, SN are subjective norm measures, and BI are behavioral intention measures.

		Estimate	S.E.	C.R.	P
Attitude	<--- Attitude Belief	.028	.025	1.114	.265
Subjective Norm	<--- SN Belief	-.036	.030	-1.233	.218
PBC	<--- PBC Belief	.010	.029	.327	.744
Behavioral Intention	<--- Attitude	.277	.036	7.658	<.001***
Behavioral Intention	<--- Subjective Norm	.515	.043	11.967	<.001***
Behavioral Intention	<--- PBC	-.001	.035	-.021	.984
Indirect A1	<--- Attitude Belief	.156	.075	2.095	.036*
Indirect A2	<--- Attitude Belief	-.073	.065	-1.128	.259
Indirect A3	<--- Attitude Belief	.347	.062	5.579	<.001***
Indirect A4	<--- Attitude Belief	.007	.062	.109	.913
Indirect A5	<--- Attitude Belief	1.000			
Indirect SN	<--- SN Belief	1.000			
Indirect SN2	<--- SN Belief	.030	.058	.512	.609
A1	<--- Attitude	1.000			
A2	<--- Attitude	.277	.052	5.358	<.001***
A3	<--- Attitude	.463	.049	9.377	<.001***
SN1	<--- Subjective Norm	.442	.045	9.880	<.001***
SN2	<--- Subjective Norm	1.000			
BI1	<--- Behavioral Intention	1.000			
BI2	<--- Behavioral Intention	.983	.069	14.300	<.001***
BI3	<--- Behavioral Intention	.970	.071	13.718	<.001***
PBC1	<--- PBC	1.000			
PBC2	<--- PBC	.150	.058	2.564	.010*
Indirect PBC	<--- PBC Belief	-.242	.082	-2.955	.003**
Indirect PBC2	<--- PBC Belief	1.000			
Indirect PBC3	<--- PBC Belief	.025	.074	.331	.740

			Estimate	S.E.	C.R.	P
Indirect PBC4	<---	PBC Belief	-.013	.066	-.195	.846
Indirect PBC5	<---	PBC Belief	-.412	.076	-5.438	<.001***
A4	<---	Attitude	.184	.048	3.849	<.001***

****p*<.001, ***p*<.01, **p*<.05

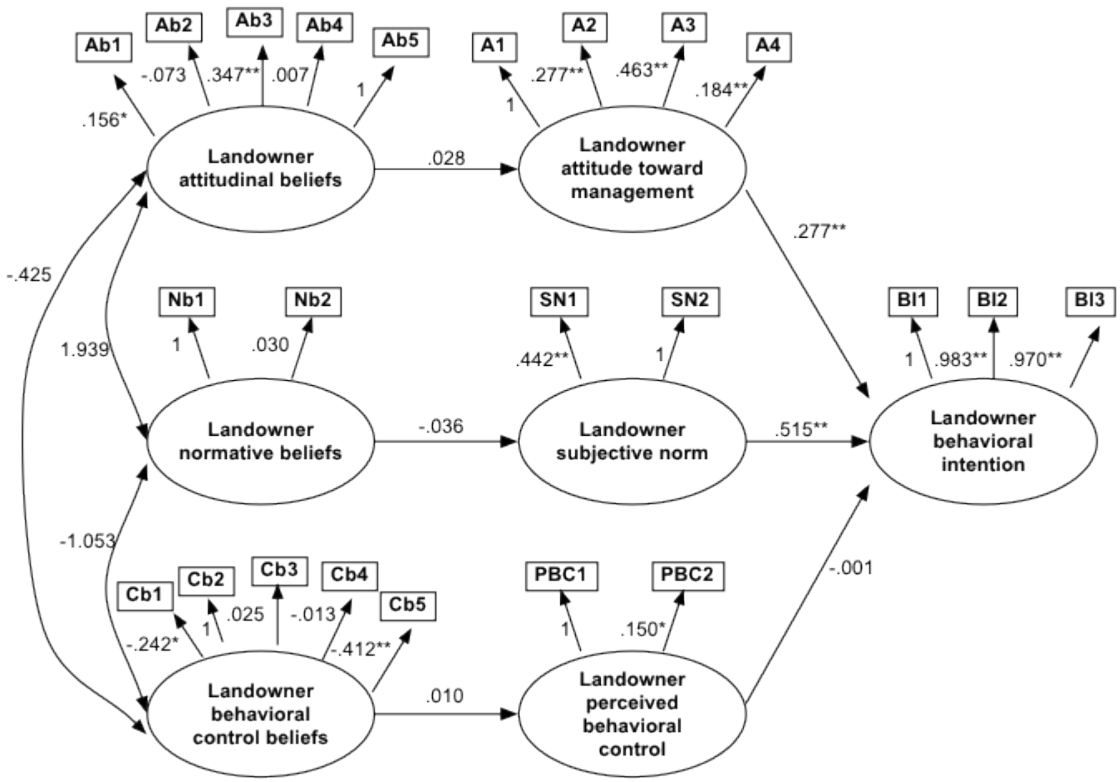

Figure 3.5. Path coefficients for the islands of Kauai, Maui, and Oahu combined. All numbers in Figure 3.5 are unstandardized. **p*<.05, ***p*<.01.

Full Model for Respondents Reporting Management Behavior

Descriptive Statistics

For the respondents that reported conducting some type of management, 85 participants (40.3%) were female, 120 (56.9%) were male, and 6 (2.8%) did not provide

Table 3.9. Correlation matrix for direct measures for the islands of Kauai, Maui, and Oahu combined. A are attitude measures, PBC are perceived behavioral control measures, SN are subjective norm measures, and BI are behavioral intention measures.

	A1	BI1	A2	PBC1	SN1	A3	SN2	BI2	A4	BI3	PBC2
A1	1	.518**	.324**	-.048	.353**	.514**	.399**	.518**	.239**	.513**	.430**
BI1		1	.403**	.029	.538**	.652**	.591**	.710**	.123	.703**	.357**
A2			1	.101	.356**	.408**	.345**	.437**	.352**	.484**	.502**
PBC1				1	-.063	-.018	.032	.017	-.034	-.035	.162*
SN1					1	.541**	.534**	.531**	.172**	.625**	.326**
A3						1	.680**	.773**	.073	.725**	.366**
SN2							1	.708**	.159*	.652**	.338**
BI2								1	.140*	.774**	.431**
A4									1	.222**	.259**
BI3										1	.400**
PBC2											1

$^*p$<.05, $^{**}p$<.01.

that information. Mean age was 57.8 (range 18 to 89 years old). Fourteen percent (*N*=30) had less than a college education, 60% (*N*=131) had at least some college, and 21% percent (*N*=45) had an advanced college degree. Thirty percent earned < $49,999 (*N*=64), 34% percent earned between $50,000 and $99,999 (*N*=72), 20% earned >$100,000 (*N*=43), and 9% preferred not to say (*N*=19). Differences in amount and type of management being performed are presented in Table 3.11.

Table 3.10. Correlation matrix for indirect variables (latent measures) for the islands of Kauai, Maui, and Oahu combined. Ab refers to the attitudinal beliefs, Nb are the normative beliefs, Cb are the control beliefs, and BI are the behavioral intentions.

	Ab1	Ab2	Ab3	Ab4	Ab5	Nb1	Nb2	Cb1	Cb2	Cb3	Cb4	Cb5	BI1	BI2	BI3
Ab1	1	.081	.066	.059	.133*	.037	.116	.022	.293**	-.026	.023	-.314**	.079	.106	.098
Ab2		1	-.130*	.327**	-.072	.062	.188**	.025	-.100	-.126*	.061	.034	.384**	.423**	.359**
Ab3			1	.039	.336**	-.061	-.153*	.009	.048	.102	.001	-.075	-.173**	-.188**	-.111
Ab4				1	.007	.104	.153*	.004	-.023	-.111	.134*	.126*	.217**	.266**	.289**
Ab5					1	.114	.001	-.192**	.236**	.165**	.104	-.131*	-.080	-.077	-.049
Nb1						1	.033	.027	-.067	-.047	.166**	.065	-.042	-.137*	-.130*
Cb1							1	.117	-.022	-.078	.025	-.072	.251**	.299**	.277**
Cb2								1	-.185**	-.117	-.049	.148*	-.016	-.047	-.078
Cb3									1	.021	-.012	-.328**	.031	.058	.141*
Cb4										1	.096	-.002	-.170**	-.183**	-.243**
Cb5											1	-.062	-.067	-.063	-.009
BI1												1	-.056	-.032	-.085
BI2													1	.710**	.703**
BI3														1	.774**

$*p<.05$, $**p<.01$.

Testing of the SEM for Actual Behavior

Model parameters are presented in Table 3.12 and coefficients in Figure 3.6. The correlation matrix for the direct variables are presented in Table 3.13 and the belief variables are presented in Table 3.14.

Overall, the low bias estimates for the path coefficients suggest little discrepancy between the bootstrapped estimates and the original maximum likelihood estimates.

Because the data are non-normal and the sample size is relatively large, the chi-square estimate of model fit is not going to give the best estimates (Bearden et al., 1982; Byrne,

Table 3.11. Self-reported frequency of various types of management behaviors being performed.

	Frequency of conducting management behavior				
Type of Management	One time	1-3 times/ month	4-12 times/ month	13-27 times/ month	Every day
Hand capture	32	66	23	8	5
Lime	49	23	6	0	1
Coqui wand/ trap	9	5	2	0	3
Caffeine	16	9	3	1	1
Baking soda	20	22	5	1	1
Citric acid	46	29	6	3	0
Clear vegetation	28	81	17	8	3

2001). The RMSEA for this model was .09. As described above, this fit index is slightly higher than expected for ideal fit, but the adjustments suggested to improve model fit (Byrne, 2001) required departure from our theory. Because the purpose of the analysis was to test theory, we retained all parameters necessary to do so.

Attitude is the strongest predictor of behavioral intention (b= .442), followed by subjective norm (b= .156). Perceived behavioral control is not a significant predictor of behavioral intention. Behavioral intention is not a significant predictor of reported behavior.

Table 3.12. Unstandardized path coefficient estimates for individuals who reported engaging in behaviors intended to influence coqui presence and abundance. C.R. is the critical ratio, or test statistic. All bias estimates were within +/- .007. A are attitude measures, PBC are perceived behavioral control measures, SN are subjective norm measures, and BI are behavioral intention measures.

			Estimate	S.E.	C.R.	P
Attitude	<---	Attitude Belief	.066	.027	2.463	.014
Subjective Norm	<---	SN Belief	-.054	.035	-1.555	.120
PBC	<---	PBC Belief	.046	.029	1.556	.120
Behavioral Intention	<---	Attitude	.442	.049	9.032	<.001***
Behavioral Intention	<---	Subjective Norm	.156	.041	3.767	<.001***
Behavioral Intention	<---	PBC	.031	.047	.660	.509
Behavior	<---	Behavioral Intention	.007	.051	.131	.896
Indirect A1	<---	Attitude Belief	.162	.079	2.038	.042
Indirect A2	<---	Attitude Belief	.310	.075	4.136	<.001***
Indirect A3	<---	Attitude Belief	.058	.073	.785	.433
Indirect A4	<---	Attitude Belief	1.000			
Indirect A5	<---	Attitude Belief	.176	.077	2.281	.023
Indirect SN	<---	SN Belief	1.000			
Indirect SN2	<---	SN Belief	.007	.068	.108	.914
A1	<---	Attitude	.416	.062	6.649	<.001***
A2	<---	Attitude	.496	.061	8.125	<.001***
A3	<---	Attitude	1.000			
SN1	<---	Subjective Norm	.344	.058	5.929	<.001***
SN2	<---	Subjective Norm	1.000			
BI1	<---	Behavioral Intention	1.000			
BI2	<---	Behavioral Intention	.947	.059	15.918	<.001***
BI3	<---	Behavioral Intention	1.132	.066	17.067	<.001***
PBC1	<---	PBC	1.000			
PBC2	<---	PBC	.057	.076	.745	.456
Indirect PBC	<---	PBC Belief	-.370	.079	-4.657	<.001***
Indirect PBC2	<---	PBC Belief	1.000			
Indirect PBC3	<---	PBC Belief	.120	.072	1.666	.096

Indirect PBC4	<--- PBC Belief	.116	.076	1.534	.125
Indirect PBC5	<--- PBC Belief	-.142	.080	-1.785	.074
A4	<--- Attitude	.253	.052	4.812	<.001***
Handcapture	<--- Behavior	-.126	.084	-1.508	.132
Lime	<--- Behavior	-.099	.055	-1.807	.071
catch	<--- Behavior	.086	.047	1.817	.069
caffeine	<--- Behavior	-.059	.046	-1.291	.197
Baking soda	<--- Behavior	-.056	.056	-1.004	.315
Citric acid	<--- Behavior	-.095	.059	-1.602	.109
Clear veg	<--- Behavior	.097	.079	1.235	.217
Other	<--- Behavior	1.000			

***p<.001, **p<.01, *p<.05

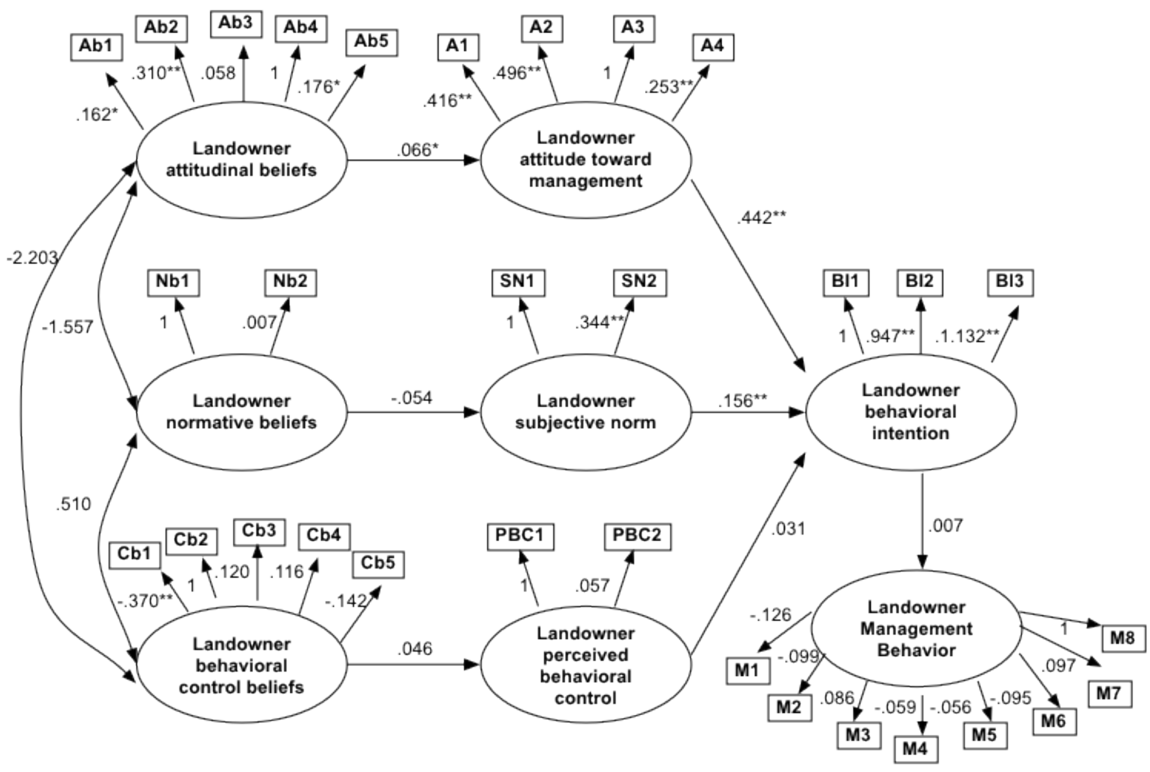

Figure 3.6. Path coefficients for individuals who reported engaging in behaviors intended to influence coqui presence and abundance. All numbers in Figure 3.6 are unstandardized. *p<.05, **p<.01.

Table 3.13. Correlation matrix for direct measures for individuals who reported engaging in behaviors intended to influence coqui presence and abundance. A are attitude measures, PBC are perceived behavioral control measures, SN are subjective norm measures, and BI are behavioral intention measures.

	A1	BI1	A2	PBC1	SN1	A3	SN2	BI2	A4	BI3	PBC2
A1	1	.466**	.496**	.142*	.098	.416**	.430**	.276**	.450**	.275**	.522**
BI1		1	.548	.002	.290**	.535**	.540**	.402**	.745**	.376**	.807**
A2			1	.078	.218**	.488**	.608**	.340**	.558**	.436**	.616**
PBC1				1	-.149*	-.072	.051	-.181**	-.044	.019	-.048
SN1					1	.318**	.280**	.378**	.287**	.124	.325**
A3						1	.621**	.535**	.616**	.3174*	.588**
SN2							1	.540**	.575**	.443**	.590**
BI2								1	.452**	.319**	.454**
A4									1	.411**	.831**
BI3										1	.408**
PBC2											1

**p*<.05, ***p*<.01.

DISCUSSION

Overall Sample

In general, response rates for natural resource mail surveys have decreased over the last 10 years and tend to be lower when the questions are complex or not as salient to the respondents (Connelly, Brown, & Decker, 2003). Thus, the lower response rate for the islands of Kauai, Maui, and Oahu as compared to the island of Hawaii may be a

Table 3.14. Correlation matrix for indirect variables (latent measures) for individuals who reported engaging in behaviors intended to influence coqui presence and abundance. Ab refers to the attitudinal beliefs, Nb are the normative beliefs, Cb are the control beliefs, and BI are the behavioral intentions.

	Ab1	Ab2	Ab3	Ab4	Ab5	Nb1	Nb2	Cb1	Cb2	Cb3	Cb4	Cb5	BI1	BI2	BI3
Ab1	1	.027	-.061	.139*	.095	.155*	-.109	-.068	.128	.137*	.034	.032	.155*	.100	.119
Ab2		1	-.024	.274**	.032	-.049	-.075	.041	-.108	-.119	-.066	-.043	.376**	.464**	.436**
Ab3			1	.054	.230**	.011	.112	-.079	.029	-.104	.015	.025	-.001	-.015	.026
Ab4				1	.155*	-.078	.082	.096	-.108	-.029	-.003	.084	.114	.137*	.122
Ab5					1	-.014	-.046	-.166*	.113	.071	.048	-.232**	.212**	.192**	.241**
Nb1						1	.007	-.007	.029	-.043	.157*	.128	-.035	-.023	-.081
Cb1							1	.307**	-.038	-.161*	-.003	.096	-.020	-.070	-.116
Cb2								1	-.305**	-.071	-.092	.247**	-.031	-.078	-.139*
Cb3									1	.114	.105	-.122	.109	-.029	.053
Cb4										1	.159*	.021	.108	-.061	.032
Cb5											1	.029	-.202**	-.146*	-.101
BI1												1	-.028	-.070	-.096
BI2													1	.745**	.807**
BI3														1	.831**

*$p<.05$, **$p<.01$

reflection of a lack of salience of the coqui frog to people who are not currently surrounded by the frog in the environment.

Comparing Determinants of Behavioral Intention and Actual Behavior

Comparing individuals who are currently performing a behavior, are not performing it, or are planning on performing it in the future, can aid in revealing the true reasons for people's behavioral choices (Ajzen & Cote, 2008). Because we had individuals at all of these stages of performing a behavior, our results enable us to reveal more accurately the full picture surrounding management behavior directed at an invasive frog. Overall, we found the relationship between predictors of behavioral intention were different depending upon exposure to the frogs. Further, and more generally, we found support for a predictable relationship between landowners' attitudes, social norms, behavioral intentions and reported behaviors. Specifically, we found differences in predictors of behavioral intention depending upon whether the participants come from an area where the frog is common (i.e., island of Hawaii), or in areas where populations of frogs are really isolated or non-existent (i.e., Kauai, Maui, or Oahu). In areas where the invasive frogs are common, attitude is a stronger predictor of intention to manage, whereas the management intentions of people living in areas where the frogs are not as common are more strongly influenced by subjective norms.

Our study suggests that in areas where an invasive species is not commonly found, outreach campaigns aimed at getting people to manage for the invasive could focus on people's desire to do what others believe they should be doing (i.e., tapping into their subjective norms). For people living in areas where there already are lots of the particular invasive, outreach campaigns are likely to be less successful at targeting norms and should instead focus on changing people's attitudes toward management behaviors that are thought to influence the invasive's presence or level of negative impact. Simply eliciting negative attitudes toward the invasive may not be sufficient to encourage people to manage because our previous research, specific to the coqui, has shown that the more people are exposed to the frogs, the less negatively they feel toward them (Chapter 2). Research on using fear or "threat" in campaigns to direct management behavior for invasive species suggests it may not produce the desired outcome (Gobster, 2005), especially without also promoting positive attitudes toward behaviors that can be useful in addressing the threat.

More generally, our findings suggest that outreach campaigns targeted at getting people to manage for a specific invasive species may need to have a different targeted approach depending on the status of the invasion (i.e., early or late). Education that is related to the most salient variables and that is made relevant to an individual, is likely to have the largest positive effect on participants (Morgan & Gramann, 1989) and result in the most effective management of invasive species (Shine & Doody, 2011).

We did not find a relationship between perceived behavioral control and the intention to manage for an invasive species, nor for reported management behavior. The lack of a relationship between perceived behavioral control and behavioral intention could be the result of difficulty in accessing people's control beliefs in our survey (Ajzen, 2002); however, conducting both an elicitation and pilot study should have reduced the likelihood of wording difficulties (Ajzen, 2006). Thus, the finding of a lack of a strong relationship between perceived behavioral control suggests that most people feel that the intention to behave (or the actual behavior) are within their control, thus whether or not they actually perform the behavior is due more to their attitudes or subjective norms, which is consistent with the theory of reasoned action for behaviors that are within an individual's volitional control (Ajzen, Czasch, & Flood, 2009).

While the relationship between behavioral intention and behavior was positive for the individuals doing self-reported management behaviors, the relationship was not significant. The finding that TPB better predicts intention to behave than to actually behave is not uncommon (e.g., Ajzen, Brown, & Carvajal, 2004; Fife-Schaw, Sheeran, & Norman, 2007). Accurately measuring actual behavior from self-reported studies leaves room for error, which can reduce the likelihood of detecting significance.

Although TPB studies commonly use self-reported measures for actual behavior as a surrogate for actual behavior, the two measures are not necessarily equivalent (Ajzen et al., 2004; Fife-Schaw et al., 2007). The difficulty with self-reported behavior is the possibility that people will respond in a way that they think the researcher wants (social desirability bias), or they are not able to remember accurately their management behavior (recall bias). Future research could re-examine the connection between behavioral intention to manage for an invasive species and actually managing for them by doing property-level surveys or a similar method to directly observe actual behavior.

We found that individuals living in areas with more exposure to an invasive frog were more likely to manage based on their attitude toward property management behaviors directed at reducing frogs, whereas people with less exposure were more likely to rely on social pressure to determine whether or not they intend to manage for the invasive frog. These findings could aid managers in designing outreach strategies to get individuals to behave in a specific way toward the invasive species because they suggest that a "one size fits all" strategy for management will not be successful for invasive species (Shine & Doody, 2011).

CONCLUSION

The results of our study confirm that two of the classic TPB variables (i.e., subjective norms and attitude toward the behavior) are important at predicting both the intention to perform a behavior and actually performing the behavior. However, the relationship between behavioral intention and self-reported behavior was extremely low. Based on the individual questions assessing self-reported management behavior and the low relationship between these measures and self-reported behavior, future studies should determine better measures of self-reported behavior to increase the power of conclusions that can be drawn.

Possibly the most interesting theoretical finding from this study was that there are detectable differences in the influence of TPB variables on behavioral intention depending upon a person's experience with the behavior. Prior to direct experience performing the behavior of interest, normative influences are the strongest predictors of behavioral intention. However, the more direct experience a person has, the more their personal attitude will predict his/her behavioral intention. Thus, when trying to elicit a new behavior in individuals, care should be taken to craft social media campaigns or use peer groups to influence normative beliefs. However, once an individual has experience with the behavior, social media campaigns are unlikely to change the desire to perform the behavior as the individual is now being motivated by his/her own attitudes toward the behavior of interest. Overall, our research suggests that managers seeking to affect behavior of individuals will need to incorporate different strategies depending upon the amount of experience with the behavior the individuals have, in order to be most effective.

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CHAPTER 4

COMMUNITY LEVEL RESPONSE TO HABITAT STRUCTURE MANIPULATIONS: AN EXPERIMENTAL CASE STUDY IN A TROPICAL ECOSYSTEM[3]

ABSTRACT

Manipulation of habitat structure is one method for altering community dynamics. In an age where global change is resulting in altered, novel ecosystems containing changes in habitat structure and functioning, understanding potential impacts of habitat structure changes seems particularly pressing. We conducted an experiment in Hawaii to determine the relative importance of habitat structure, represented by leaf litter and vegetation, on a predator and its potential prey's abundance in a tropical ecosystem. This study used a completely randomized design consisting of five, 20 m x 20 m experimental plots, four treatments and a control plot, in four replicate blocks, for a total of 20 plots. The four treatments consisted of two vegetation treatments (50% and 100% removal of vegetation with diameter at breast height <5 cm) and two leaf litter treatments (50% and 100% removal). Removal of 50% of habitat structure was not sufficient to provide for long-term changes in predator or potential prey densities. Only full removal of habitat structure resulted in changes in density of the generalist predator, *Eleutherodactylus coqui*, over a four-month period. Overall, individuals making management suggestions for the invasive *E. coqui* may want to reconsider structure removal due to potential

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[3] Co-authors: Mark W. Brunson and Karen H. Beard. Written for submission to *Forest Ecology and Management*. Amended IACUC permit #1356. Sate of HI DLNR Injurious Wildlife Export Permit #EX 09-15; State of HI DLNR Scientific Permit for Native Invertebrates #: FHM10-208; State of HI DLNR, Division of Forestry and Wildlife Permit for Access, Collecting, and Research.

impacts on the endemic invertebrate community and microclimate. This study provides greater understanding for the impact of habitat structure manipulation, a typical management employed to control an invasive frog, in a novel ecosystem. The results suggest that this management strategy affects community composition in this novel ecosystem.

1. INTRODUCTION

Many ecosystems are rapidly being transformed into new, non-historical configurations due to a variety of local and global changes. As a result of these so-called novel, or altered ecosystems, there is a need for a revision to conservation and restoration norms (Hobbs et al., 2006; Seastedt et al., 2008). One such norm is the manipulation of habitat structure to influence undesirable species, often called cultural control. The role of habitat structure has long been studied as an important variable affecting community structure (Lawton, 1983; Gardner et al., 1995; Tews et al., 2004) and predator-prey relationships (Kareiva, 1987; Denno et al., 2005; Michel & Adams, 2009). Habitat structural complexity provides areas for foraging, oviposition, temperature control, hibernation, shelter, and mate display (Halaj et al., 2000), as well as regulation of microhabitat variables such as temperature, humidity, and light availability (Smith, 1972; Crowder and Cooper, 1982). An intermediate level of habitat structural complexity is said to allow for the co-existence of predator and prey (Crowder and Cooper, 1982).

Previous research using experimental manipulations of habitat structure in a variety of ecosystems has found mixed effects on density of predator and prey species (Pianka, 1973; Orth et al., 1984; Ryall and Fahrig, 2006; Henden et al., 2011). In spiders, generalist predator density has been found in some studies to be more affected by prey availability than habitat complexity (Birkhofer et al., 2008), while in other studies prey density has been found to be more affected by habitat than prey (Halaj et al., 1998, 2000; Birkhofer et al., 2007). Still other studies have found that both predator density and habitat are important in determining prey density (Crowley, 1978; Halaj and Wise, 2002; Buskirk, 2005).

With global change resulting in an increase in novel, or altered ecosystems that exhibit significant changes in structure and function (Seastedt et al., 2008), understanding anthropogenic influences on habitat structure changes on community dynamics will be increasingly important. Previous research suggests these changes in habitat structure may result in ecological traps for prey species (Hawlena et al., 2010) and have management level implications for maintaining amphibian densities (Salo et al., 2010).

Novel, or altered ecosystems occur as the result of new combinations of species and conditions that are currently present but were not previously occurring (Hobbs et al., 2006; Seastedt et al., 2008). These ecosystems are increasingly occurring as the result of human influences. Invasive species are one such potential result of human influences (Seastedt et al., 2008). Understanding the establishment of altered ecosystems is crucial for successfully managing them. However, managing novel ecosystems is no easy task, because the target may continuously be moving as all management strategies in these systems can be viewed as experiments (Landres et al., 1999). In the past managers would just remove processes or components that did not fall in their perception of the desirable system, but these so-called desirable systems may be unattainable (Seastedt et al., 2008).

One location where novel ecosystems are especially prevalent is Hawaii, where nearly all native ecosystems below ~500 m in elevation have been altered or destroyed by centuries of agriculture and development (Mueller-Dombois and Fosberg, 1998). Various forms of direct and indirect control are used in Hawaii to manage for undesirable non-native species, including the introduced frog, *Eleutherodactylus coqui* (Beard et al., 2009). In Hawaii over $2.8 million has been spent annually to try to eliminate the frogs, with limited success (Beard et al., 2009). In this situation, efforts to remove *E. coqui* are unlikely to restore the ecosystem to an historical state or to move the ecosystem to a more desirable state. In fact, incorporating the coqui into a novel Hawaiian Ecosystem is likely to result in the most successful management strategy in Hawaii by recognizing the changes the frog brings to the system, as well as the changes the suggested management for the frog brings to the system.

Habitat structure may be an important regulator of *E. coqui* and its potential invertebrate prey. *E. coqui* is a small terrestrial frog native to Puerto Rico and introduced to Hawaii in the late 1980s via the horticultural trade (Kraus et al., 1999). Since the introduction of *E. coqui*, its range has increased (Kraus et al., 1999; Kraus and Campbell, 2002), and the frog can be found in some parts of the island with densities of two to three times as high as native Puerto Rico (Woolbright, 1996; Woolbright et al., 2006; Beard et al., 2008).

Both leaf litter and vegetation are believed to serve as habitat for *E. coqui* in Puerto Rico and Hawaii. In Puerto Rico, leaf litter often provides spaces for oviposition and brooding clutches (Stewart and Pough, 1983; Townsend and Stewart, 1986), but this may not be the case in Hawaii where lava substrate may provide this structure for the frogs (Beard et al., 2009). In fact, the often higher densities of coqui found in Hawaii are likely due to more retreat sites in the form of rocky soil substrate (Stewart and Pough, 1983; Woolbright, 1996; Woolbright et al., 2006; Beard et al., 2008; Tuttle et al., 2009). In Hawaii there is a positive relationship between vegetation density and coqui (Beard et al., 2008). *E. coqui* use habitat structure in the form of vegetation to attract mates (Stewart and Pough, 1983; Townsend and Stewart, 1986; Townsend, 1989) and as refuge and breeding sites (Drewry, 1970; Stewart and Pough 1983; Townsend, 1989).

In Puerto Rico, coqui have densities positively related to invertebrate densities (Woolbright, 1989; Beard, 2001), but *E. coqui* may not be prey-limited in Hawaii (Beard et al., 2008), even with the high energy demands of *E. coqui,* which consume up to 690,000 prey items per hectare per day in the highest density areas (Beard et al., 2008). The frogs are opportunistic and can change the dominant prey consumed depending on availability in the environment (Stewart and Woolbright, 1996; Beard, 2007). In Hawaii, coqui forage mostly in leaf litter (Beard, 2007; Choi and Beard, in press), and both adult and juvenile coqui are found using leaf litter during the night for feeding areas (Beard et al., 2003; Beard, 2007). Leaf litter manipulations have been found to alter invertebrate abundance in Hawaii (Tuttle et al., 2009). In Puerto Rico *E. coqui* are mostly consuming foliage invertebrates (Stewart and Woolbright, 1996); in Hawaii the frogs are also consuming foliage invertebrates, but sampling may limit our ability to detect the actual consumption compared to other invertebrates in the environment (Beard, 2007; Choi and Beard, in press).

In addition, altering habitat structure may affect microclimate, such as humidity and temperature, which in turn could change the invertebrate community (Richardson et al., 2000; Vargas et al., 2001; Nakamura et al., 2009; Robson et al., 2009), and available suitable frog habitat (Woolbright, 1991; Pounds and Crump, 1994). Leaf litter acts as a protective layer on soil surface and also affects microclimate (Sayer, 2006).

While natural and artificial variation of habitat structure in Puerto Rico and Hawaii has been shown to affect *E. coqui* density (Stewart and Pough, 1983; Woolbright, 1991, 1996), the potential direct and indirect mechanisms linking habitat structure to these changes are presently unclear (Beard et al., 2008). The objective of this study was to determine the effect of habitat structure manipulation on both predator (coqui) and potential prey (invertebrate) abundances in a novel, altered ecosystem in Hawaii by examining both direct and indirect linkages (see Figure 4.1). Because both leaf litter and vegetation serve as sources of habitat structure for *E. coqui*, we manipulated both. We determined whether the removal of leaf litter or vegetation resulted in changes in predator (coqui) density or potential prey (invertebrate) abundance. We further examined potential mechanisms affecting predator and prey availability by determining the effect of habitat manipulations on microclimate and habitat usage by the predator in our experimental design.

2. MATERIALS AND METHODS

2.1. Study site

We conducted research in the Nanawale Forest Reserve (19°28’ N, 154°54’ W; elevation 230 m), in the southeast region of the island of Hawaii. Mean annual precipitation is 300-400 cm, with peak rainfall occurring between November and April (Giambelluca et al., 1986). Mean annual temperature is 23˚C (Nullet and Sanderson, 1993) and there is little seasonal variation (Price, 1983). The substrate is rough a’a lava

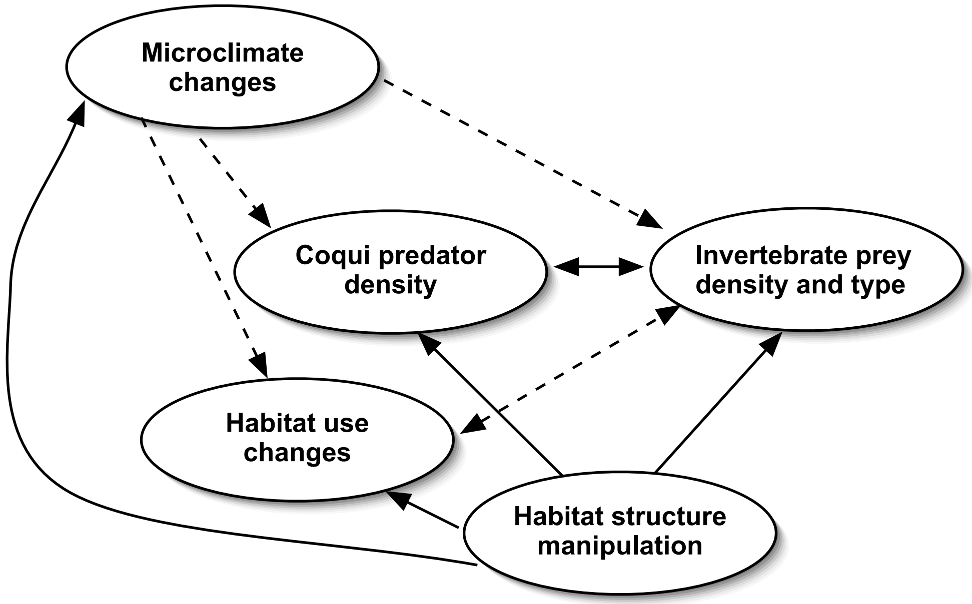

Fig. 4.1. Conceptual model guiding experimental manipulation of habitat structure (foraging substrate and calling/mating sites) on the densities of *Eleutherodactylus coqui*, and its prey (leaf litter, flying, and foliage invertebrates). Dotted lines refer to indirect effects of habitat structure disturbance, while solid lines are direct effects.

flow, approximately 400 years old (Wolfe and Morris, 1996). The reserve has extremely high *E. coqui* densities, estimated to be up to 89,000 frogs/ha (Woolbright et al., 2006; Beard et al., 2008). Dominant overstory trees include: non-native *Psidium cattleianum* Sabine, *Falcataria moluccana* (Miquel) Barneby and Grimes, and *Cecropia obtusifolia* Bertol. Dominant understory includes native *Cibotium* sp., and non-native *Melastoma candidum* D. Don, and *Clidemia hirta* (L.) D. Don. (Tuttle et al., 2009). Mean percent canopy cover in our study site was 99%. As a result of the influx of non-native under- and overstory vegetation in this forest reserve, endemic *Metrosideros polymorpha* and *Cibotium* sp. no longer dominate the vegetation and the ecosystem has moved into a novel, non-historic composition.

2.2. Experimental design

We used a completely randomized design consisting of five, 20 m x 20 m experimental plots, four treatments and a control plot, in four replicate blocks, for a total of 20 plots. The coqui are highly territorial and will remain within 20 m x 20 m areas (Woolbright 1985, 2005). The four treatments consisted of two vegetation treatments (50% and 100% removal of vegetation with diameter at breast height < 5 cm) and two leaf litter treatments (50% and 100% removal). Plots were at least 15 m apart, and blocks were from 500 m to 950 m apart. We took pre-treatment measurements in January and February 2010. We imposed treatments at the beginning of the study (February to March), two months later (April to May) and then one month later (June), for a total of three treatment applications (hereafter referred to as treatment applications 1, 2, and 3). After initial treatment, the two subsequent treatment applications were used as maintenance treatments due to the high litterfall and vegetation re-growth in this area.

Each plot was divided into 16, 5 m x 5 m subplots. For the 50% leaf litter removal treatment, we removed litter from eight of those subplots, resulting in a checkerboard pattern of removal. Removing litter in this way allowed us to maintain treatments in subsequent treatment applications. For the 100% removal treatment, we removed litter from all 16 subplots. We removed litter by hand. All of the litter removed from each of the 5 m x 5 m subplots was weighed. We developed wet to dry weight conversions using four, 3 kg subsamples from each leaf litter removal plot, dried in a drying oven at 50º C until constant weight (R^2 leaf litter = 0.81).

For the 50% vegetation removal treatment, we removed all vegetation with diameter at breast height <5 cm from eight subplots, resulting in a checkerboard pattern of removal. For the 100% vegetation removal treatment, we removed all vegetation with diameter at breast height <5 cm from all 16 subplots. We removed vegetation using machetes and hand pulling. We weighed all vegetation removed from four 5 m x 5 m subplots in each of the vegetation removal plots, and estimated the total amount removed per plot. We developed a wet to dry weight conversion using four, 3 kg subsamples from each vegetation removal plot, dried at 50º C until constant weight (R^2 vegetation = 0.61). Pictures of examples of what the plots looked like pre- and post-treatment can be seen in Figure 4.2.

A. Leaf litter pre-treatment

C. Vegetation pre-treatment

B. Leaf litter post-treatment

D. Vegetation post-treatment

Fig. 4.2. Pictures of example treatment plots pre- and post-treatment.

2.3. E. coqui density

We estimated *E. coqui* density using standard line transect distance sampling (Buckland et al., 2005). We divided our plots into four, 5 m x 20 m sections. Two researchers walked in parallel transects 5 m apart, through each of the plots, for the length of the plot. The transects started and ended 2.5 m from the edge of the plot and ran parallel to each other and the edge of the plot. We walked slowly for 30 minutes with headlamps, surveying for all frogs in each transect. We recorded all frogs (both seen and/or heard), distance from observer, height off the forest floor to the nearest 0.1 m, and type of structure used by the frog (leaves > 1m off the forest floor; forest floor (including soil, rocks, downed vegetation); trees; leaves < 1 m off the forest floor (mostly forbs, grass, fern). We completed each block in two consecutive nights, and we completed all four blocks in an eight-night period. We began surveying at 1900 hour and it lasted for 1 hour per plot. We conducted distance sampling prior to treatment application 1 and then 2 days following the last day of treatment application following treatment applications 1, 2, and 3.

2.4. Invertebrates

All invertebrate sampling occurred once pre-treatment and immediately following treatment applications 2 and 3. Four samples were collected from each plot during each sampling period, one from each of the 5 m x 20 m transects. To make sure invertebrate samples were representative of treatments, in the 50% removal treatments half the samples were collected in 5 m x 5 m subplots where removals had occurred and half were collected in subplots where removals had not occurred.

After sundown, we collected leaf litter invertebrates by collecting leaf litter from four 0.5 m x 0.5 m areas in each plot. Leaf litter was placed in Berlese-Tullgren funnels within 2 hours of collection to extract the invertebrates, which were then stored in 70% ethanol for later identification. We collected flying invertebrates from four 10 cm x 18 cm sticky traps placed vertically 0.75 m off the forest floor in each plot (as in Beard et al., 2003). Sticky traps were left in the plots for one week, wrapped in plastic wrap, and stored in the freezer for later identification. We collected foliage invertebrates using vacuum sampling. A modified hand-held vacuum (Black and Decker, Townson, MD, USA) was run for 90 seconds along all vegetation in a 1 m x 1 m area from 0.5 m off the forest floor to 2 m, in a slow steady pace. In the 100% removal plots, we ran the vacuum for 90 seconds in the air or along any vegetation that was not removed (i.e., dbh>5 cm). In the 50% removal plots, half of the samples were collected by running the vacuum in the air, and the other half of the samples were collected by running the vacuum along vegetation for 90 seconds. Collected invertebrates were placed in 70% ethanol for later identification. All collected invertebrates were later counted and identified to scientific order in the laboratory.

2.5. Environmental variables

We measured temperature and relative humidity using HOBOs (Pro Series H08-032-08, Onset Computer Corporation, Pocasset, MA), placed in each plot within one block for 4 days to 2 weeks at a time, taking readings once every minute, and then rotated to the next block to take measurements throughout the length of the experiment. We took temperature and relative humidity readings for a total of 37 to 46 days including pre- and post-treatment measures. For our analyses, we selected 3 days of readings for each plot within a location and time period (i.e., pre-treatment and after each treatment application), because this was the maximum number of days that could be selected consistently across treatment applications. The actual days selected were those closest to when the treatments were conducted and as close as possible to when data was collected in the other blocks. We placed the HOBOs on the forest floor, because both subadult and adult *E. coqui* can be found at this height at different times (Beard et al., 2003; Beard, 2007).

2.6. Statistical analyses

To test for treatment effectiveness (i.e., biomass and leaf litter removed) in our treatment plots, we conducted a two-way factorial analysis of variance (mixed model ANOVA) with location and location x treatment interaction as the random variables.

We analyzed distance sampling data with program DISTANCE (Buckland et al., 2005; Thomas et al., 2006), whereby we used the perpendicular distance from the transect line to the recorded frog to calculate a probability density function that models the decreased likelihood of observing animals with increasing distance from the transect line. This function is then used to correct the counts and estimate the density of frogs and the associated 95% confidence interval. Data were fit to key detection functions (half-normal or hazard-rate) and a cosine series expansion, which provided a better fit to the data than other functions (based on Akaike Information Criterion- AICs).

To assess the effects of treatment, we conducted a two-way factorial analysis of covariance (ANCOVA), with pre-treatment measures as the covariate, location and the location x treatment interaction as the random variables. We also assessed whether there were pre-treatment differences in the variables measured using one-way ANOVAs.

These tests revealed that pre-treatment there were no significant differences among sets of plots subsequently assigned to different treatments, and are thus not presented (see Appendix D). Even though we found no differences pre-treatment, we included pre-treatment measures as a covariate in our post-treatment tests to account for any pre-treatment variability. In these tests, pre-treatment was only found to be significant in temperature and humidity data.

We used the ANCOVA model structure to assess the effects of treatment on density of *E. coqui* frogs and on our other response variables: invertebrates collected from leaf litter sampling, invertebrates collected from sticky trap sampling, and invertebrates collected from vacuum sampling, diurnal (600 h to 1859 h) and nocturnal (i.e., 1900 h to 559 h) temperature and relative humidity, and height of frogs off the forest floor. We averaged the height used by the *E. coqui* pre-treatment and after each treatment application for each treatment type.

To assess differences in vegetation used by the *E. coqui* post-treatment applications, we performed a single sample chi-square test with a Bonferroni adjustment.

To meet the assumptions of normality and homogeneity of variance for these tests, we cube root transformed *E. coqui* distance data, and vacuum, sticky trap, and leaf litter collected invertebrates.

All ANOVAs and ANCOVAs were conducted using SAS v 9.2 for Windows (SAS Institute, Cary, North Carolina). ANOVAs were conducted using PROC MIXED, and ANCOVAs were conducted using PROC GLIMMIX (Appendix E). We followed these analyses with Holm's step-down Bonferroni *post hoc* multiple comparisons (Appendix F).

We considered $P<0.05$ significant for all statistical analyses.

3. RESULTS

3.1. Treatment effectiveness

We removed a total of 696 kg dry wt from the 100% leaf litter plots, 425 kg dry wt from the 50% leaf litter removal plots, 915 kg dry wt from the 100% vegetation removal plots, and 217 kg dry wt from the 50% vegetation removal plots. The amount of vegetation removed varied by treatment ($F_{4,42}$=4.28, P=0.0054) and treatment application ($F_{2,42}$=10.67, P=0.0002), with the most material removed from the 100% vegetation removal, followed by the 100% leaf litter removal, the 50% leaf litter removal, and the 50% vegetation removal. Most vegetation was removed during the first treatment application, with less being removed in treatment applications 2 and 3 (Figure 4.3).

There was a difference in understory density by treatment ($F_{4,14}$=118.75, P=<0.0001), where understory density includes all understory vegetation. The percent understory density initially in the 100% vegetation removal plots was much higher (M=86.5, SD=8.28) than post treatment (M=7.38, SD=1.94). The percent understory density initially in the 50% vegetation removal plots was also higher (M=79.01, SD=10.26) than post treatment (M=36.51, SD=7.71).

3.2. E. coqui density

There was an overall interaction between treatment application and treatments ($F_{8,34.92}$=2.87, P=0.01). After treatment application 3, the 100% leaf litter removal and the 100% vegetation removal plots had lower *E. coqui* densities than control plots; densities were much higher after this treatment application overall (Figure 4.4).

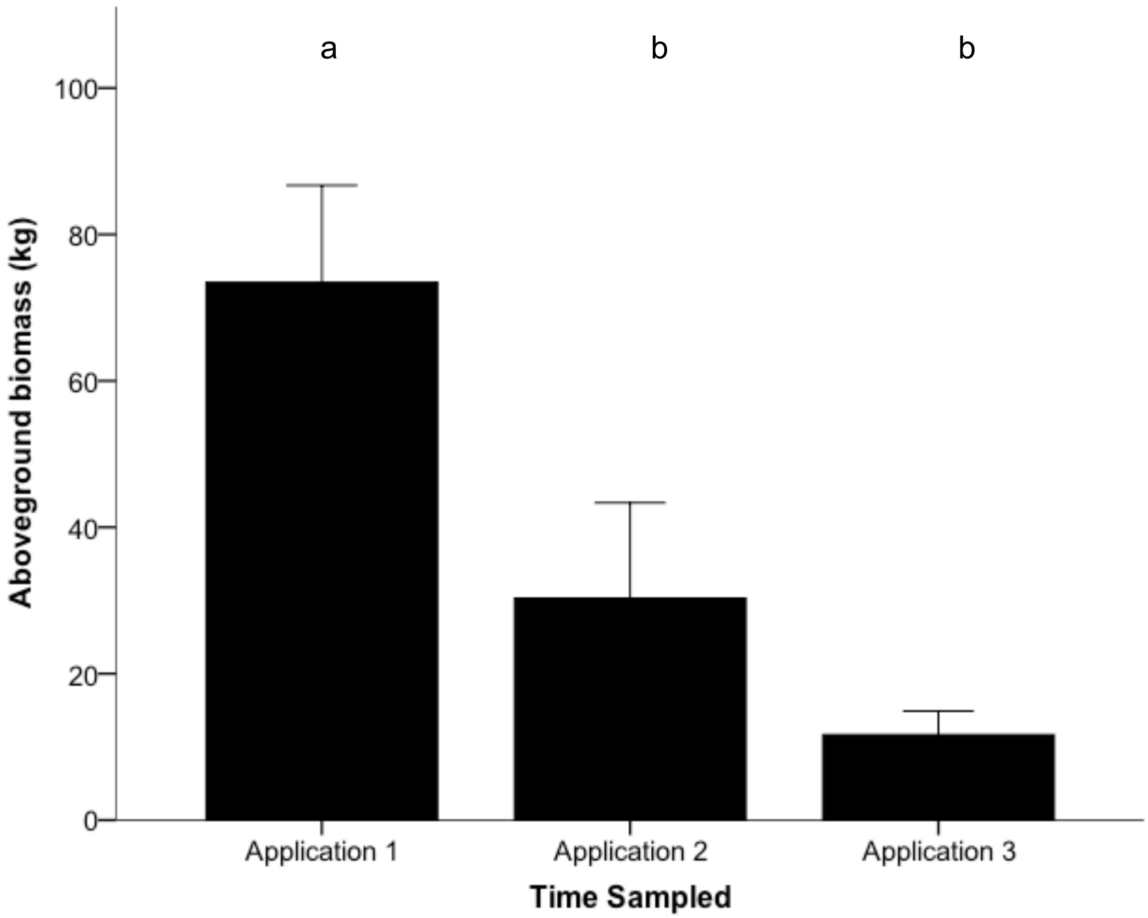

Fig. 4.3. Mean aboveground biomass removed (kg) (±1 SE) during each treatment application (N = 20 plots total). Letters indicate significant differences by treatment application (P<0.05). Treatment Application 1 = Feb 19 to Mar 4, Treatment Application 2 = Apr 28 to May 12, and Treatment 3 Application = June 8 to June 22.

3.3. Invertebrates

We found an effect of treatment application and treatment on invertebrates collected from leaf litter ($F_{1,143.1}$=7.69, P=0.006 and $F_{4,143.2}$=5.19, P=0.0006, respectively). The number of invertebrates collected from leaf litter was higher in the 100% vegetation removal plot than in the other treatments (Figure 4.5). Overall, more invertebrates were found in samples after treatment application 2 than after treatment application 3 (Figure 4.6). To determine if the increase in invertebrates was not simply

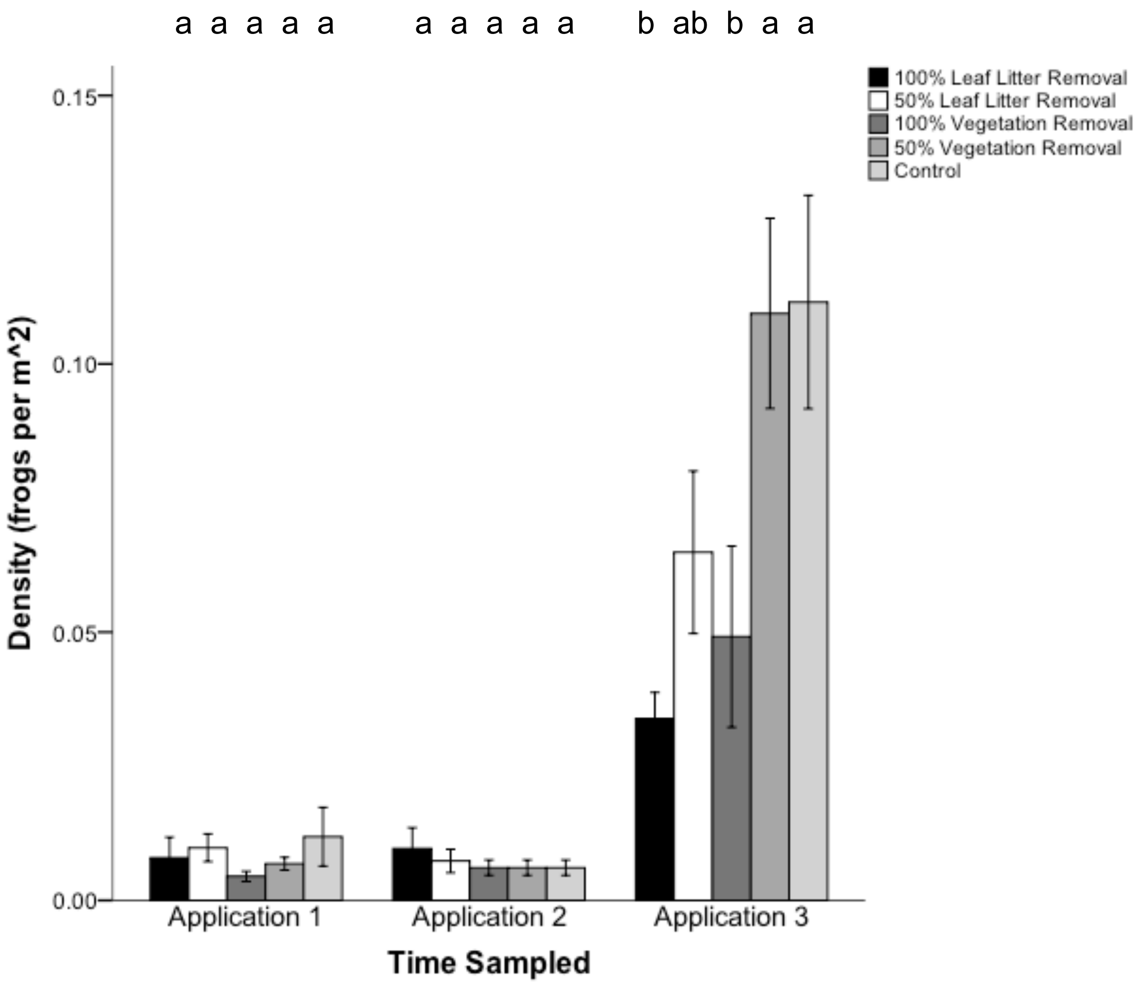

Fig. 4.4. Mean density of coqui (#/ m^2) (±1 SE) post-treatment application (N= 20 plots total). Letters indicate significant differences by treatment within each treatment application from post-hoc Holm's step-down Bonferroni (P<0.05).

due to an increase in leaf litter being produced in the vegetation removal plots, we ran an ANOVA on the leaf litter weights we removed from the plots and used in the Berlese funnels to extract invertebrates. We found no treatment effect on leaf litter weights ($F_{4,14.5}$=0.59, P=0.6743), suggesting a high litterfall rate in these plots.

The number of invertebrates collected from sticky traps was higher in the 100% vegetation removal plots than the other treatments ($F_{4,11.7}$=9.87 P=0.001; Figure 4.7).

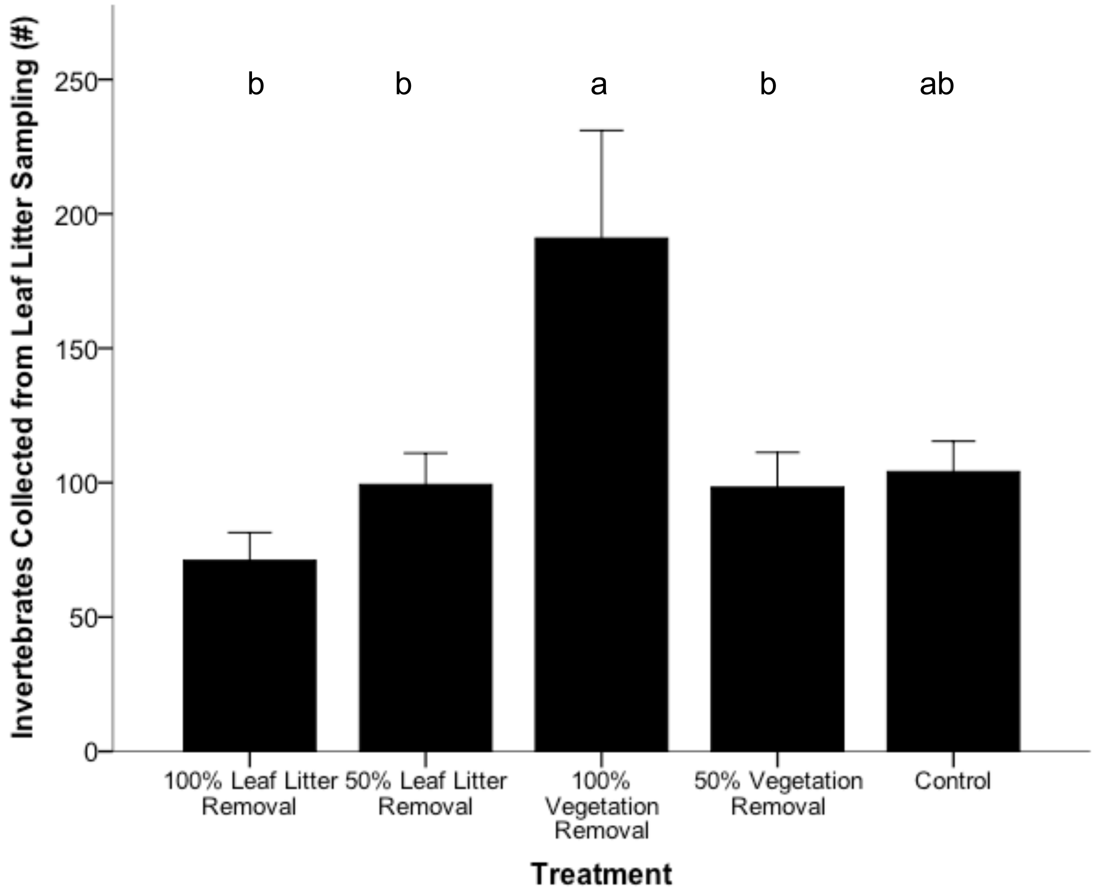

Fig. 4.5. Mean total number of invertebrates collected from leaf litter sampling (#) (±1 SE) by treatment (N = 4 replicate plots for each treatment). Letters indicate significant differences from post-hoc Holm's step-down Bonferroni (P<0.05).

We found an interaction between treatment application and treatments on invertebrates collected from vacuum sampling ($F_{4,133.7}$=4.08, P=0.004). Both the 50% and 100% vegetation removal plots had fewer invertebrates following treatment application 2, but only the 100% vegetation removal plot still had fewer invertebrates following treatment application 3 (Figure 4.8).

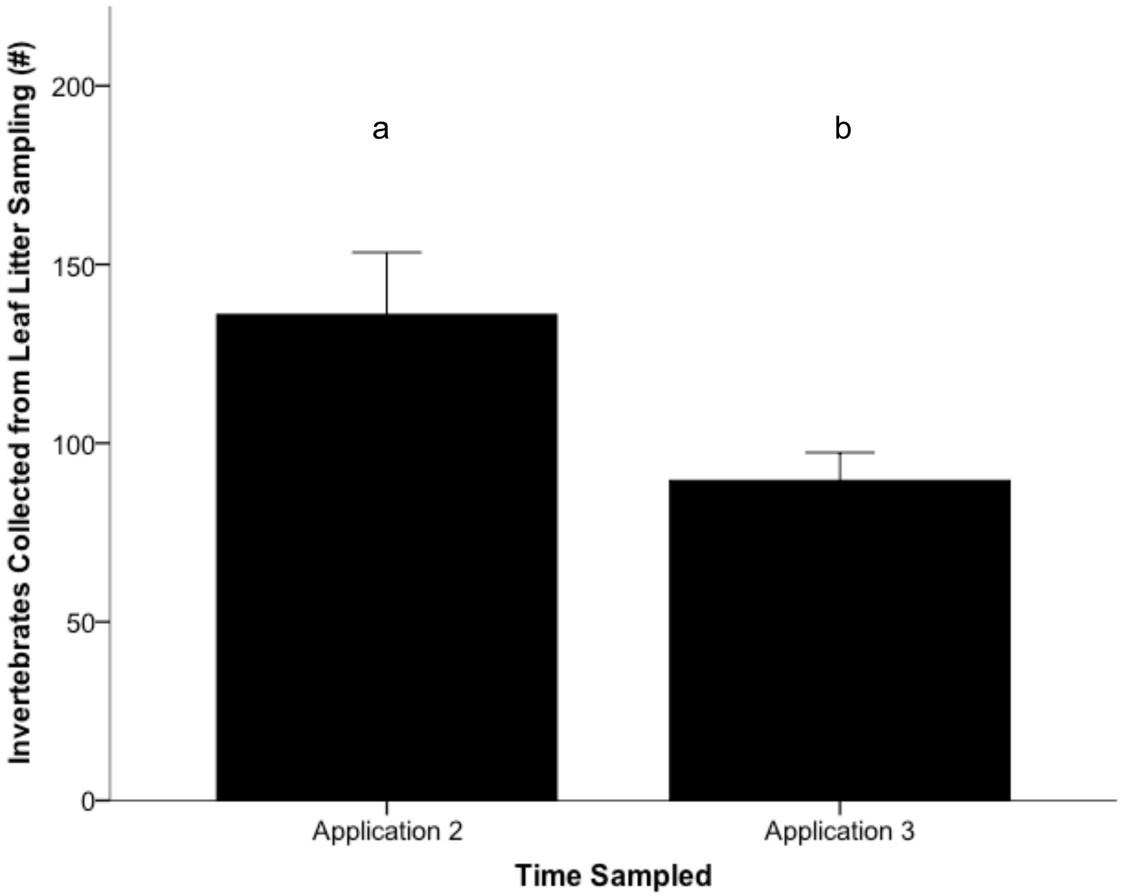

Fig. 4.6. Mean total number of invertebrates collected from leaf litter sampling (#) (±1 SE) by treatment application (N = 20 plots total). Letters indicate significant differences from post-hoc Holm's step-down Bonferroni (*P*<0.05).

3.4. Habitat usage by E. coqui frogs

We found an effect of treatment application on height off the forest floor where *E. coqui* were observed ($F_{2,39}$=4.15 *P*=0.0231). Height off the forest floor was higher after treatment application 2 than after treatment application 3 (Figure 4.9).

E. coqui were found on different vegetation post-treatment application periods 1, 2, and 3 ($F_{437,12}$=42.883, *P*<0.0001; $F_{515,12}$=74.943, *P*<0.0001; $F_{435,12}$=79.960, *P*<0.0001).

After all treatment applications, more frogs from the 100% vegetation removal plots were found on the forest floor than in leaf litter removal or control plots. Differences in leaf

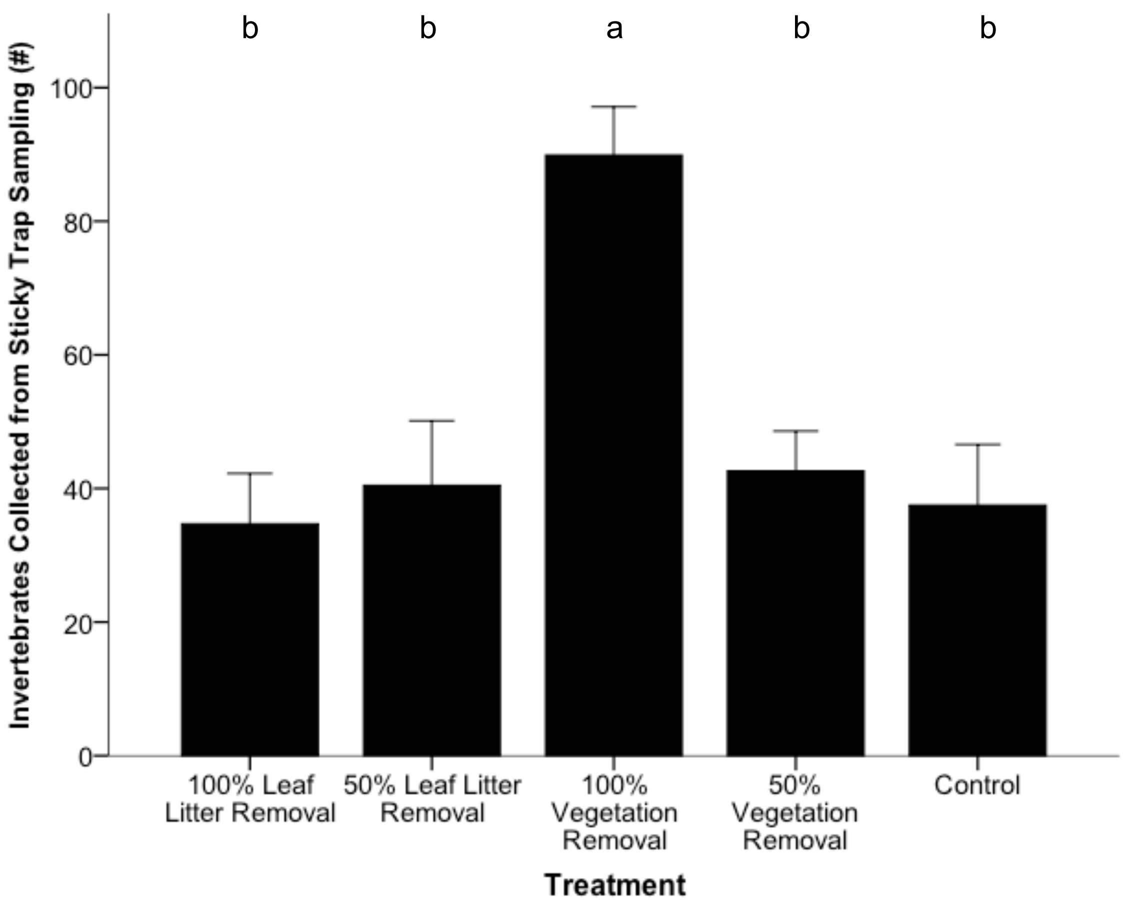

Fig. 4.7. Mean total number of invertebrates collected from sticky trap sampling (#) (±1 SE) by treatment (N = 4 replicate plots for each treatment). Letters indicate significant differences from post-hoc Holm's step-down Bonferroni (P<0.05).

litter removal plots, i.e., 100% leaf litter removal plots with more frogs >1 m off the ground than 50% vegetation removal after application 1, were no longer seen after treatment application 3 (Figure 4.10, A, B, and C).

3.5. Effect of treatment on temperature and humidity

Temperature and humidity were affected by treatment application and daytime versus nighttime measures ($F_{2,64.8}$=50.94, P<0.0001; $F_{2,62.22}$=60.81, P<0.0001,

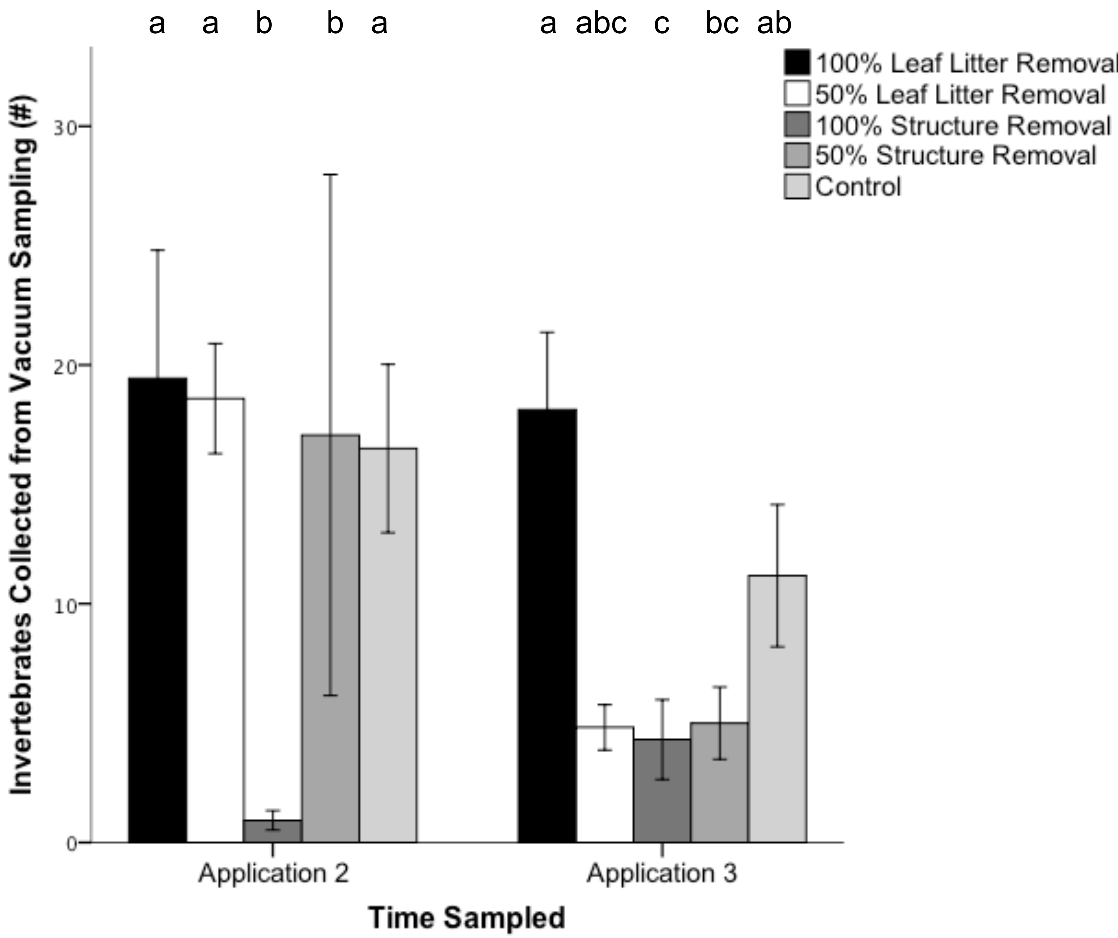

Fig. 4.8. Mean total number of invertebrates collected from vacuum sampling (#) (±1 SE) by treatment application (N = 20 plots total). Letters indicate significant differences from post-hoc Holm's step-down Bonferroni ($P<0.05$).

respectively). Treatment application 3 had the highest overall temperature during the daytime, while nighttime temperatures stayed relatively constant over time (Figure 4.11). The same pattern was observed with the humidity measurements (Figure 4.12).

4. DISCUSSION

Overall, after 6 months we removed a total of 2,253 kg dry weight from our plots over three treatment applications. The amount of vegetation removed varied by treatment and by treatment application. Initially we found no differences between our plots with

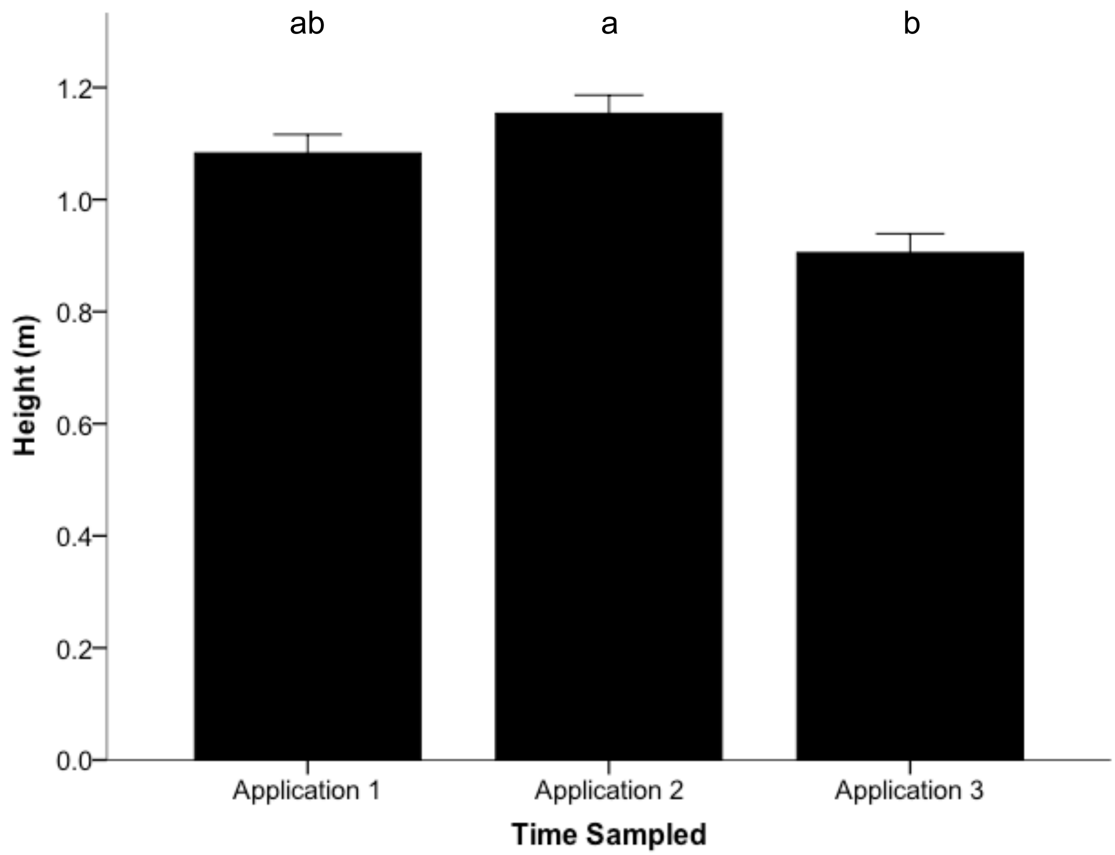

Fig. 4.9. Mean differences in coqui height above forest floor (m) (±1 SE) by treatment application (N = 20 plots total). Letters indicate significant differences from post-hoc Holm's step-down Bonferroni (P<0.05).

respect to coqui density, invertebrate abundance, or heights of vegetation used by *E. coqui*.

Coqui density was most affected by our 100% vegetation and leaf litter removal plots, where there was a lower predator (i.e., coqui) density than in the control plot. Potential invertebrate prey density (i.e., invertebrates collected from leaf litter, sticky traps, and vacuum sampling) was most affected by removing 100% of the understory vegetation. Invertebrates collected from leaf litter sampling were found in lower quantities in the 100% and 50% leaf litter removal plot and the 50% vegetation removal

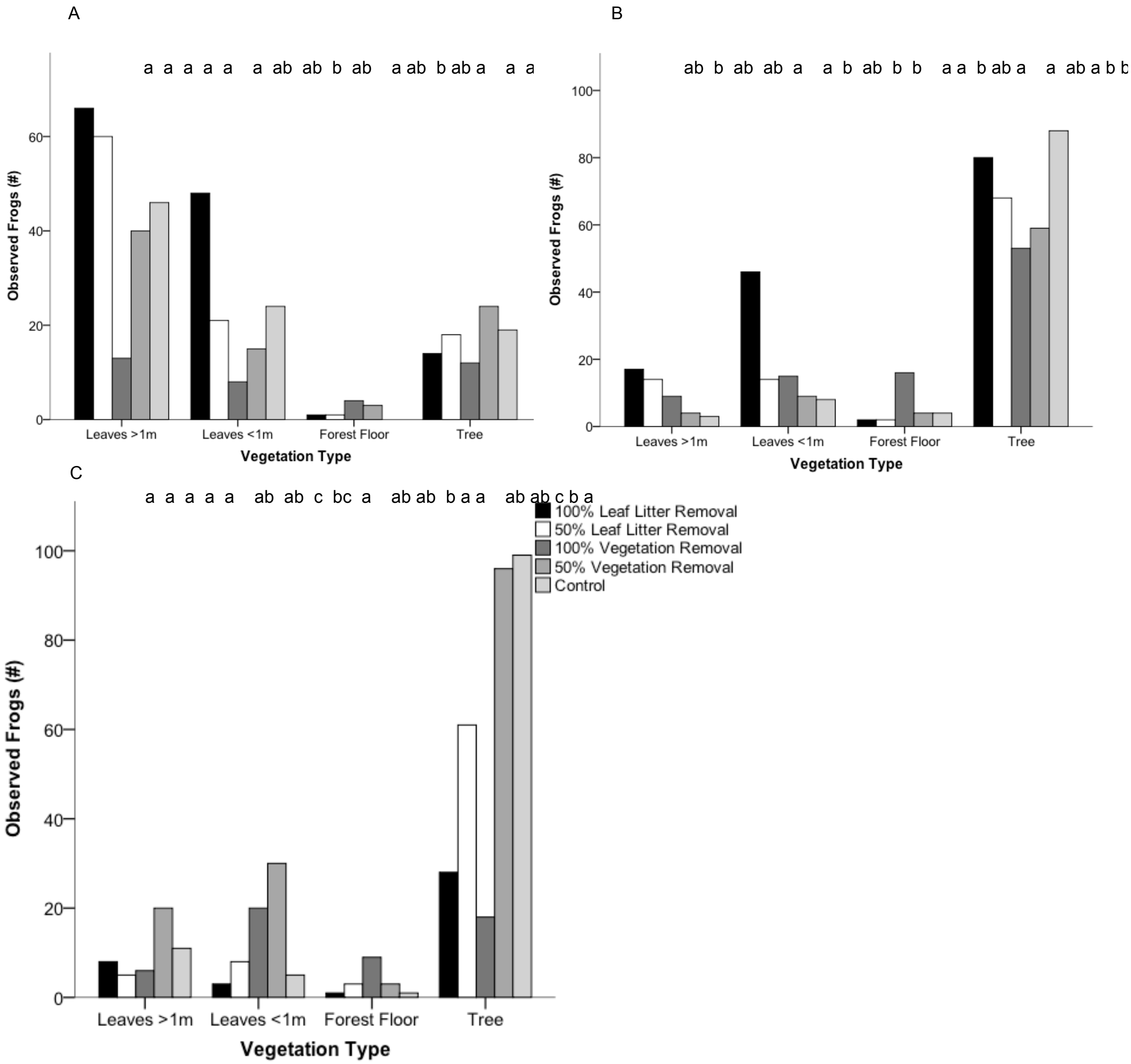

Fig. 4.10 A-C. Observed counts of frogs found on each vegetation type in each treatment plot, after the three treatment applications, labeled 1, 2, and 3 (N = 437; N = 515; N = 435 total frogs observed, respectively). Letters indicate significant differences ($P<0.05$).

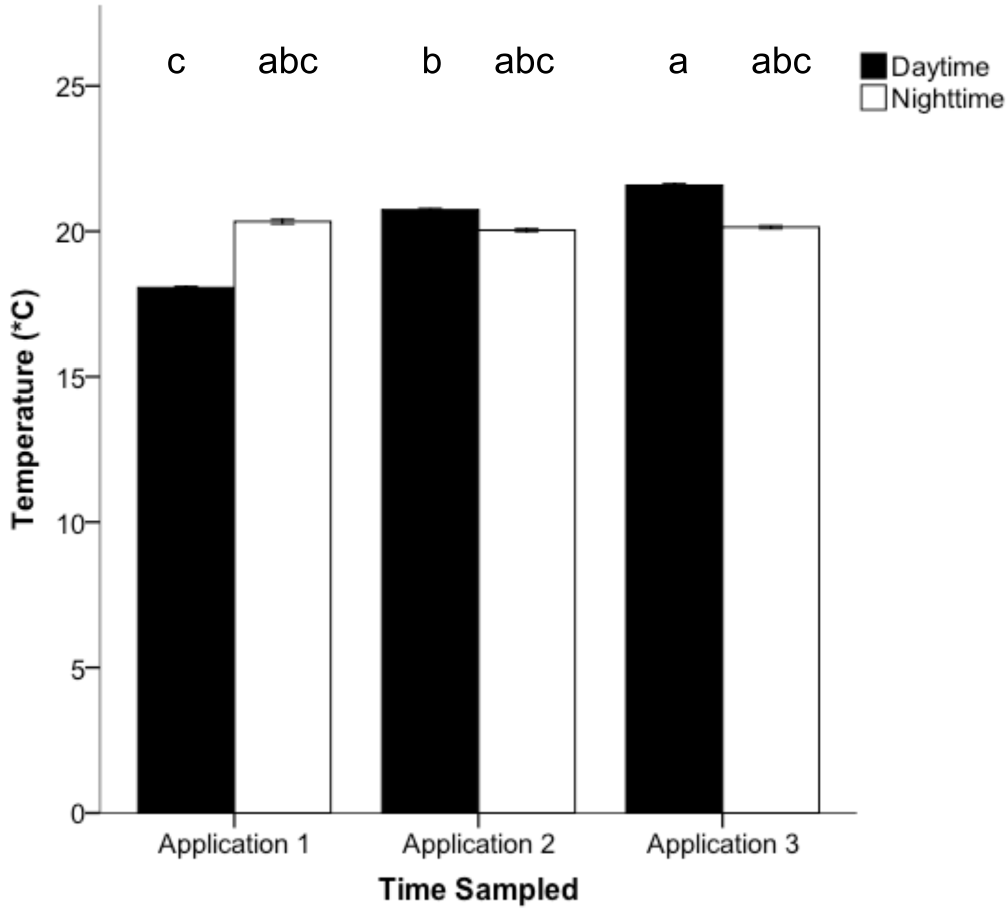

Fig. 4.11. Mean comparisons (±1 SE) for differences in temperature (*C) by treatment applications and daytime versus nighttime (N = 20 plots total). Letters indicate significant differences from post-hoc Holm's step-down Bonferroni (*P*<0.05).

compared with the 100% vegetation removal plot. Fewer invertebrates collected from leaf litter sampling were counted over time. More of these invertebrates were found in the vegetation removal plot, which may correspond to a reduction in predation pressure by *E. coqui*. More invertebrates collected from sticky trap sampling were counted in the 100% vegetation-removal plot than any other, perhaps due to the overall reduction of coqui density due to this treatment, and thus likely reduction in predation pressure.

Similarly, we found invertebrates collected from vacuum sampling to be most affected by 100% and 50% vegetation removal plots. However, after treatment application 3, only

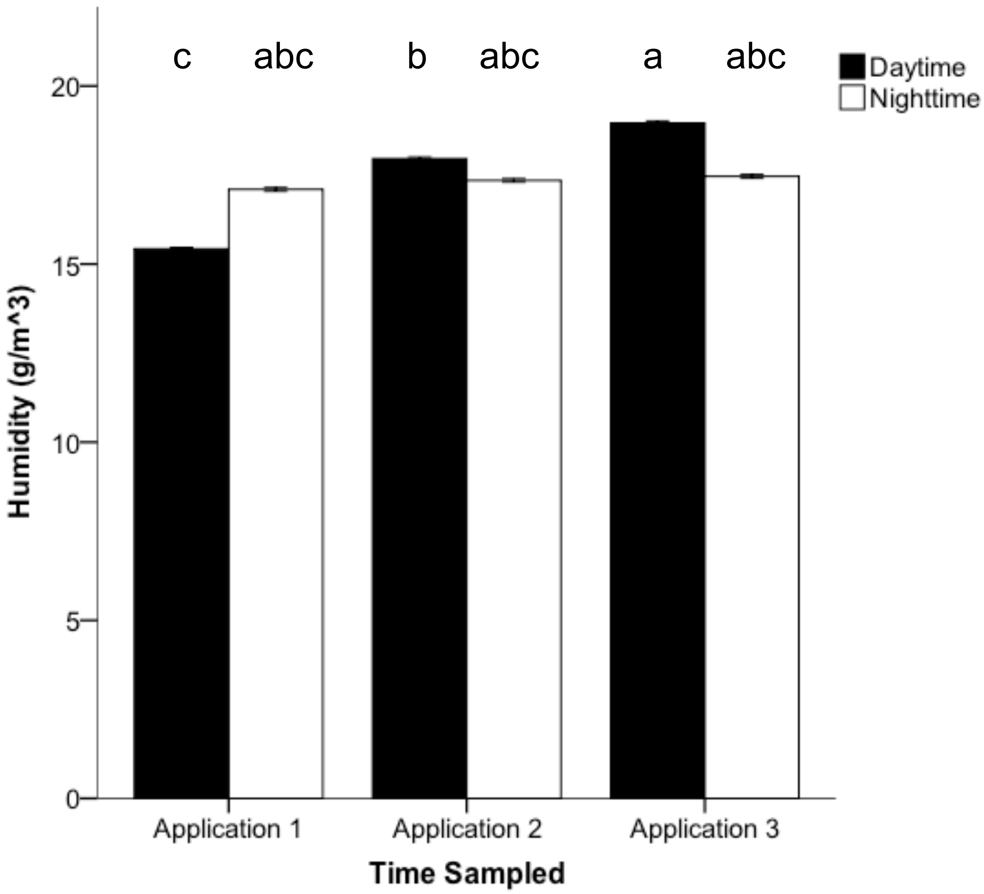

Fig. 4.12. Mean comparisons (±1 SE) for differences in humidity level (g/m^3) by treatment applications and daytime versus nighttime (N = 20 plots total). Letters indicate significant differences from post-hoc Holm's step-down Bonferroni (P<0.05).

the 100% vegetation-removal plots still showed a reduction in these invertebrates.

Vegetation removal also affected the microclimate, the heights at which *E. coqui* were found and the type of structure the frogs were using after treatment. *E. coqui* were found at lower heights in the 100% vegetation removal plot than the control, and post-treatment frogs in the 100% vegetation plots were moving down to the forest floor, and leaf litter removal plots showed frogs moving up into trees. Temperature and humidity generally increased over time, with the differences seen in the daytime readings, but not at night.

Based on these findings, we suggest that structure modification affected both potential invertebrate prey and predator abundances. Specifically, reducing habitat structure by close to 100% in a 20 m x 20 m area in a tropical forest resulted in increased densities of invertebrates collected from leaf litter and sticky trap sampling, but decreased invertebrates collected from vacuum sampling, as well as a change in how structure was used by predators.

While microclimate was affected by structure, the change in temperature and humidity is not likely to be as important for coqui density as for potential prey density, because there was no change in microclimate variability when the frog was active (nighttime).

However, when considering the above findings, it is important to notice that coqui density was only affected after treatment application 3. In this treatment application period there were more coquis found across all treatment plots. While we are unable to say for certain why this might be the case, several potential reasons come to mind. The density sampling done following treatment application 3 was done at the end of June to early July, when we measured ambient temperatures as consistently higher in all of our control plots. Higher temperatures in Puerto Rico have been shown to result in greater coqui activity (Townsend and Stewart, 1994); however, there is little seasonal variation in temperature in Hawaii (Price, 1983).

In addition to adding to a growing body of literature of empirical studies examining the effect of habitat modification on community structure in novel, altered ecosystems (Seastedt et al., 2008), these findings are particularly important in Hawaii where management suggestions for *E. coqui* frog include vegetation removal (Beard et al., 2009). Vegetation removal may not only be effective at reducing coqui, but may also alter the invertebrate community in this novel ecosystem. In Hawaii where coqui are already expected to reduce invertebrates through direct predation (Sin et al., 2008; Choi and Beard, in press), and where much of the invertebrates are endemic to the island (Gange and Christensen, 1985), managers may want to reconsider the best way to manage the frog while limiting the effect on other community dynamics.

Overall, we found that a reduction in habitat structure in a novel ecosystem resulted in changes in both predator and its potential prey abundance. These changes appear to be a direct result of the habitat manipulation, as well as a result in changing the community composition. In the case of a novel ecosystem that has already changed as a result of invasive plants, changes in abundance of an introduced frog appear to further drive community composition changes. In this way, the frogs can be seen as directly affecting the development of an altered ecosystem (Seastedt et al., 2008).

The novel ecosystem approach to managing invasive species has not been documented much in the literature, but may lead toward more efficient and cost-effective long-term management with decreases in undesirable direct or indirect consequences (Seastedt et al., 2008; Hobbs et al., 2006). Given that habitat structure manipulations are currently being suggested in Hawaii as a way to manage for the frogs, it is important for public management campaigners to recognize that this management is likely to affect the distribution of the frogs, as well as the prey community.

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CHAPTER 5

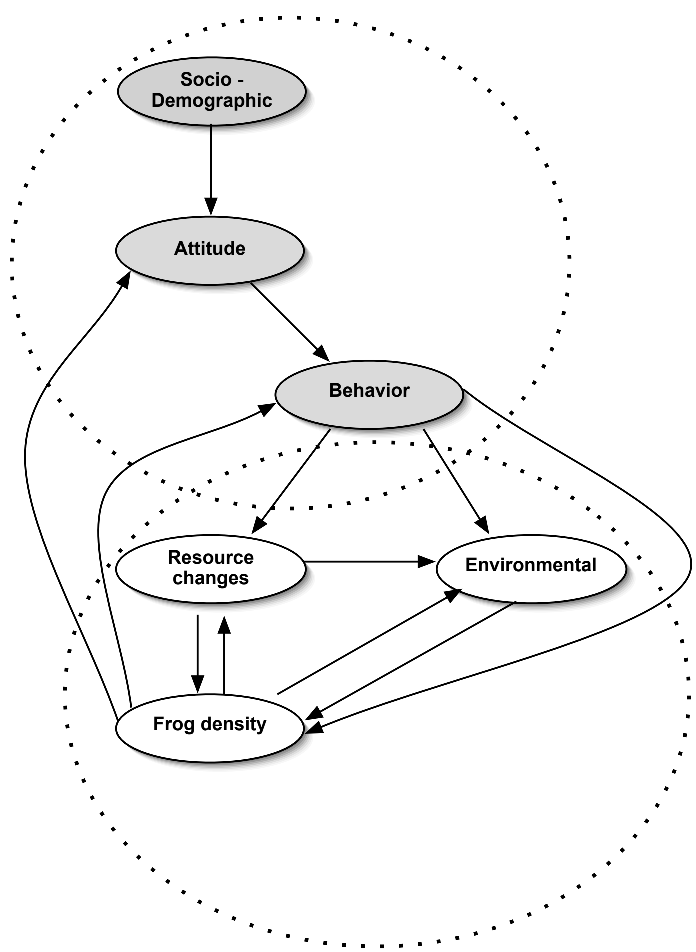
CONCLUSIONS

IMPLICATIONS OF THE STUDY

I chose to focus my study on the *Eleutherodactylus coqui* frog invasion in Hawaii, because there appears to be a tight coupling of both natural and social variables surrounding the invasion, making the invasion the center of conflict, debate, and discussion in recent years (Singer and Grismaijer 2005, Beard et al. 2009). The overall objective of my research was to take a coupled human and natural systems (CHANS) approach to understand the frog invasion as an exemplar of social-ecological system dynamics in a novel ecosystem. In each of the three research chapters, I examined a portion of the CHANS model depicted in Figure 5.1. I found that coqui density is affected by landowners' attitudes and subsequent management behavior, but the frog's density also influences these attitudes and behaviors. Examining the interactions and feedbacks that exist between important variables in the system follows complexity theory and is likely to produce increased predictability (Bennett and McGinnis 2008). This approach was useful for piecing apart the important components for *E. coqui* in Hawaii and should be more broadly applicable to predicting the invasion success of other invasive species, as well as aiding in maintenance of biodiversity in complex, novel ecosystems. Specifically, starting with the overall coupled model I have provided, researchers can modify it to fit their specific study system.

Novel ecosystems occur as the result of new combinations of species and conditions that are currently present, but were not previously occurring (Hobbs et al. 2006, Seastedt et al. 2008). Novel ecosystems are largely occurring as the result of

Fig. 5.1. Coupled human and natural systems model to understanding factors affecting an invasive frog's density. Gray ovals represent social constructs while white ovals are natural constructs. Overlapping dotted circles represent the intersection of the social and natural variables, and the elements that would be included if a researcher was taking a more traditional approach to either understanding the social or natural components of the system.



human influences. Increases in invasive species are one such potential result of human influences (Seastedt et al., 2008).

The standard tenets of invasion ecology suggest that colonization pressure, resource availability, competitive advantage, mutualisms, disturbance, and niche requirements are all important variables to consider for predicting the potential success of an invader (Shea and Chesson 2002, Lockwood et al. 2007, 2009). While it is well understood that humans play a role in the invasion process (Lockwood et al. 2007), the human dimensions of the system are often excluded from the predictive model or underplayed in attempts to understand invasion ecology (McNeely 2001). By following a CHANS approach to examining the *E. coqui* frog invasion in Hawaii, I was able to piece apart some of the complexity surrounding the invasion and develop a relatively straightforward model that other invasion ecologists could use when trying to incorporate a CHANS approach in similar novel ecosystems (see Figure 5.1). While this model is very rudimentary, it provides an easier, more accessible starting point for researchers than other similar research utilizing more cumbersome computer simulations (Rebaudo et al. 2011). However, future research on invasive species using a CHANS approach should seek to provide for more predictive models.

While the need for educational campaigns to elicit public support for management of invasive species is often encouraged (Epanchin-Niell et al. 2010), a one-size-fits-all message is not likely to be as effective as it could be. With costs for invasive control and management already quite high (Pimentel et al. 2005), the more targeted the education campaign is, the better (Witmer et al. 2009, Gherardi et al. 2011, Shine and Doody 2011, Vanderhoeven et al. 2011). The results from my study suggest that managers should target their educational messages to the stage of the invasion and the general public's experience with the invader.

My findings were consistent with previous research showing a connection between socio-demographic variables and a person's attitude toward managing for that species (Miller and Jones 2005, 2006, Fitzgerald et al. 2007). However, I also found that attitudes were stronger in individuals who had less direct experience with the invasive frog. This finding is in contrast to other research, suggesting that the more directly an invasive species impacts a person, the more likely they will be to care about management programs designed to eradicate the species (Fraser 2006). This finding is important for education campaigns designed to elicit attitude or behavioral change and is likely to be similar for other invasive species where the fear or threat of the species precedes it (Gobster 2005).

Focusing educational messages on social norms (i.e., working together as a community for a common goal) may work best when trying to elicit management behavior in individuals who have limited direct experience with the invasive. Once individuals have more experience with the invasive, managers may want to focus on messages designed to result in attitudinal changes, as my research found this to be more important in guiding management behavior in these individuals.

I also studied the role played by habitat modification in driving community structure in areas where the coqui frog is found in high densities. Seastedt et al. (2008) suggest a need for understanding how to manage novel ecosystems, and my findings point to the need for further empirical study. Of particular interest in this particular novel ecosystem is the observation that a commonly-suggested form of control for an invasive frog, i.e., habitat modification, is affecting the frogs as well as the microclimate and the invertebrate community. Because habitat modification used to control for coqui results in unintended consequences for the ecosystem (namely altering microclimate and changing invertebrate abundance), the frog plays a role in development of an altered ecosystem (Seastedt et al. 2008). More generally, my findings suggest that managers need to consider the unintended consequences resulting from suggested control strategies for an invasive species, as the impacts may affect community composition as well as public willingness to participate in the management.

Specific Management Recommendations for *E. coqui* in Hawaii

Overall, my research suggests the need for multi-stage educational campaigns, as well as potential changes to one of the suggested forms of management by the people of Hawaii. Current control efforts consist of a mix of chemical, mechanical, and agricultural methods. All are activities landowners can do themselves. Control efforts have eradicated the coqui from Oahu and reduced coquis to one small (6 ha) and one larger (87 ha) population on Kauai and Maui, respectively (Anonymous 2010), and current management efforts on these islands are focused on eradicating the frog (Anonymous 2010). Many of the control efforts on the island of Hawaii are conducted by volunteer community groups (Anonymous 2010). Currently the only approved and recommended chemical control consists of direct application of citric acid to frogs and/or frog eggs. Mechanical control, including hand-capture, traps, barriers, and hot water treatments, has mostly been employed in smaller, high-risk settings such as nurseries. Cultural control includes checking plants at the nursery for coqui eggs or frogs before purchasing, and removing vegetation on a property because of frogs. Property owners are encouraged to spray suspected frog habitats directly with citric acid, eliminate frog habitat, inspect potted plants, and treat coqui-infested green waste (Bertelmann n.d.). Based on my research findings, it appears current recommendations for structure removal may not only be effective at reducing coqui density, but may also alter the invertebrate community. In Hawaii, where coqui are already expected to reduce invertebrates through direct predation (Sin et al. 2008, Choi and Beard, in press) and where many of the invertebrates are endemic to the island (Gange and Christensen 1985), managers may want to reconsider the best way to manage the frog while limiting the impact on other community dynamics.

Also, unless the landowner is interested in removing close to 100% of the habitat structure for the frogs (i.e., removing the leaf litter and/or vegetation with diameter at breast height< 5 cm), their time may be better spent on preventing frogs from invading new areas rather than attempting to eliminate coqui habitat.

While managers on the island of Hawaii have tried to encourage homeowners to control for the frogs on their property (Bertelmann n.d.), my research suggests the educational campaign is currently not enough to elicit behavior change. For individuals living on the island of Hawaii, I would recommend managers use targeted campaigns directed at positive attitude change toward coqui management behaviors. Because a large portion of my participants appeared to accept that the frogs were going to be a fact of life, and therefore are not engaged in management, managers may wish to trigger attitudes directed at preventing further spread of the frogs, i.e., preventative control methods management. In the case of individuals living on Kauai, Maui, or Oahu, managers should continue to focus on prevention by directing their messages to the social norm, i.e., "your neighbor is interested in preventing coqui frog spread, so you should too."

Future Research

Future research on the coqui frog invasion could benefit by more directly examining the feedback loops in my proposed model (Figure 5.1). The next step could include designing educational campaigns to change attitudes or behaviors in Hawaii. Multiple approaches could be used and the resulting changes in behaviors measured. Further, directly measuring people's actual behavior and the relationship to frog density on a given property would be useful. Eventually, using the property-level data in the current model should be expandable to a large-scale predictive model both for the coqui frog and, more generally, for other invasive species.

Future research on novel ecosystems resulting from an invasive species could benefit by taking a similar approach to my research. Specifically, taking a multi-level, CHANS approach, focused both on the individual and community level, for both social and natural variables, will help elucidate the most important drivers of the system. Understanding the linkages between the social and biological variables is important for successful management of the novel ecosystem (Seastedt et al. 2008).

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APPENDICES

APPENDIX A

Demographic survey and interview questions for Chapter 1

Please answer the following questions. We would like to know some basic information about you. The questions asked are used for statistical purposes only and are strictly confidential.

1. How old are you?
   _______ years

2. Are you…
   ___Male? ___Female?

3. What is the highest level of education you have completed?
   ___Some high school
   ___High-school graduate
   ___Some college
   ___Earned 2-year college degree
   ___Earned 4-year college degree
   ___Earned advanced college degree

4. What is your primary occupation?
   ___Farmer
   ___Employed full-time with a company
   ___Employed part-time with a company
   ___Self-employed
   ___Retired
   ___Student
   ___Other _________________________

5. What is your total family income?
   ___less than $10,000
   ___$10,000 to $24,999
   ___$25,000 to $49,999
   ___$50,000 to $74,999
   ___$75,000 to $99,999
   ___$100,000 or more
   ___Prefer not to say

6. How long have you lived at your current property in Hawai'i?
   ____

7. Do you....
   ___Rent or ___Own your property in Hawai'i?

8. Were you born in Hawai'i?

___No Where were you born? _________________ (Answer question 9, but **skip** 10)
___Yes (Skip to question 10)

9. If you were NOT born in Hawai'i, how long have you lived in Hawai'i for? _______________

10. If you WERE born in Hawai'i, have you lived anywhere other than Hawai'i?
___No ___Yes Where & how long? _________________________

11. People around the world are generally concerned about environmental problems because of the consequences that result from harming nature. However, people differ in the consequences that concern them the most.

    Please rate **each** of the following items from 1 (not important) to 7 (supreme importance) in response to the following question:

    I am concerned about environmental problems because of the consequences for___.

___Plants	___Me	___People in the community
___Marine life	___My lifestyle	___All people
___Birds	___My health	___Children
___Animals	___My future	___Future generations

<u>Interview questions for property owners in Hawai'i</u>

Time of Interview:
Date:
Interviewee:

I am going to ask you some questions about your experiences with the coqui frog and living in Hawai'i. There are no right or wrong answers. I ask only that you answer as honestly and completely as you can. If you don't understand something, please ask. Ready?

1. How would you describe the coqui frog to someone who doesn't know what it is?

2. How did you first learn about the coqui frog?

3. In your opinion, what are some positive and negative aspects of the coqui frog?

(anything specific to their property, i.e. property value, etc.?)

4. What , if any, types of things do you, or members of your household do to take care of your property? (i.e. lawn mowing, fertilizing, pruning, etc.)

5. Do you, or members of your household do anything on your property for the coqui frog? (If yes… please describe- i.e. spraying with citric acid, clearing understory, etc.; If no… any reason why you don't?)

6. Did you receive information on these activities? (if yes… from where?) (if no… what prompted you to participate in them?)

7. If you wanted to get your neighbors or community to change how they care for their land, with respect to the coqui frog, what would you do?

8. Do you and your neighbors talk about the coqui frogs? (if yes… what do you talk about?) (if no… any reason why you don't?)

9. This next question asks for you to estimate approximately how many coqui frogs you think are found on your property on any given night. If you had to guess, how many frogs would you say are out in your yard?

10. Have you lost sleep because of the coqui frog? (if yes… how much) (if no… do you just not hear them?)

11. What do you think the county should do about the coqui frogs? What do you think you, or your household should do about the coqui frogs?

12. What does it mean to you if something is described as being an “invasive species”?

13. Is there anything else you would like to say about the coqui frog?

Thanks again for your time! We will now be assessing your landscape characteristics and will be back during the evening to collect coqui sound data (and abundance).

APPENDIX B

Descriptive statistics for Chapter 2

Table B-1 Self-reported highest level of education completed.

Response	Frequency
Some high school	1
High-school graduate	22
Some college	15
Earned 2-year college degree	8
Earned 4-year college degree	19
Earned advanced college degree	22

Table B-2 Self-reported whether born in Hawaii or not.

Response	Frequency
Born in Hawaii	24
Not born in Hawaii	63

Table B-3 Self-reported gender breakdown.

Response	Frequency
Male	40
Female	47

Table B-4 Self-reported whether rent or own the property they were interviewed on.

Response	Frequency
Rent	15
Own	70
Blank	2

Table B-5 Which side of the island the participants were from.

Side of island	Frequency
East	35
West	52

Table B-6 Self-reported total family income.

Response	Frequency
Less than $10,000	5
$10,000 to $24,999	4
$25,000 to $49,999	17
$50,000 to $74,999	22
$75,000 to $99,999	13
$100,000 or more	14
Prefer not to say	12

Table B-7 Self-reported number of coqui on their property.

Response	Frequency
Zero frogs	37
One or two	4
>2 and <100	22
Hundreds	19
Thousands	5

Table B-8 Self-reported whether person participates in any form of management for the coqui on their property.

Response	Frequency
Yes	20
No	67

Table B-9 Self-reported whether the person has knowledge of types of management he/she could be doing on his/her property.

Response	Frequency
Yes	72
No	14

Table B-10 Self-reported opinion toward the coqui frog.

Side of island	Frequency
Negative	50
Positive	6
Neutral	31

Table B-11 Self-reported age of participants.

Mean	Std. Deviation	Minimum	Maximum
53.17	14.13	28	89

Table B-12 Logistic regression output for predicting attitude toward coqui from abundance of frogs on a property.

	B	S.E.	Wald	df	Sig.	Exp(B)
Frogs abundance	0.57	0.24	5.85	1	0.016	1.763
Constant	-0.70	0.28	6.40	1	0.011	0.497

APPENDIX C

Mail survey for Chapter 3

Thank you for participating in this survey. Several questions in this survey use a rating scale; please circle the number that best describes your opinion. For example, if you were asked to rate the effect of vog on your mood on such a scale, the 7 places should be interpreted as follows:

I feel happy when the vog is light
definitely true:___3___:__2__:___1___:___0__;__-1__;__-2__;__-3__:definitely false
extremely quite slightly neither slightly quite extremely

If you feel extremely happy when the vog is light, then you would circle the number 3, as follows:
definitely true:___(3)___:__2__:___1___:___0__;__-1__;__-2__;__-3__:definitely false
extremely quite slightly neither slightly quite extremely

Please remember the following:
*Be sure to answer all of the items- do not skip any
*Do not circle more than one number on the same scale

First we would like to ask you some questions about your property in Hawaii. Please read each question carefully and answer it to the best of your ability. There are no right or wrong answers; we are just interested in your own point of view.

1. Do you currently own land in Hawaii?
___Yes ___No
If you answered No, please return this survey in the enclosed envelope without completing any of the remaining questions.

2. Which island is your land on?
___Hawai'i ___Maui ___Kaua'i ___O'ahu ___Other:___________

3. How many acres of land do you own in Hawaii?
___Less than ½ acre ____3 to 9.5 acres ___30 to 49.5 acres
___½ acre to 2.5 acres____10 to 29.5 acres ___50 or more acres

4. What is the *primary* make-up of your land in Hawaii?
___Wooded ___Dense understory
___Lava rock ___Grassy
___Landscaped ___Other:___________________________

5. To what extent do you do the following things on your land in Hawaii?

Irrigation/watering	Never	Sometimes	All the time
Lawn mowing	Never	Sometimes	All the time
Clear understory...............	Never	Sometimes	All the time
Spray pesticides	Never	Sometimes	All the time
Trim trees	Never	Sometimes	All the time
Spray insecticides.............	Never	Sometimes	All the time

Use herbicides..................	Never	Sometimes	All the time
Garden..............................	Never	Sometimes	All the time
Plant trees.........................	Never	Sometimes	All the time
Exclude wildlife w/fences	Never	Sometimes	All the time

6. What is the *primary* type of vegetation on your property?

___Ohia trees ___Albizia trees ___Other:_____________
___Fruit trees ___Coffee ___Shrubs
___Nut trees ___Grasses ___Bare ground or lava

7. Which of the following do you *regularly* find on your property in Hawaii (Please check all that apply):

___Coqui frogs ___Nettle caterpillar ___Feral pigs
___Giant snails ___Cane toad ___Biting flies
___Fire ant ___Greenhouse frog ___Cane spiders
___Geckos/Chameleons ___Mongoose ___Chickens
___Centipedes ___Mosquitoes ___Rats
___Cockroaches ___Myna birds ___None of these

8. In general, what is your opinion of the following animals (please check appropriate box):

	Don't know what it is	Strongly dislike	Dislike	Neutral	Like	Strongly like
Coqui frogs						
Giant snails						
Fire ants						
Geckos or Chameleons						
Centipedes						
Cockroaches						
Nettle caterpillars						
Cane toads						
Greenhouse frogs						
Mosquitoes						
Myna birds						
Chickens						
Mongoose						
Biting flies						
Cane spiders						
Hoary bat						

Feral pigs						
Rats						

Next we would like to know more about the management of your land in Hawaii for the coqui frog.

1. Which of the following statements best describes how you try to manage your property for the coqui frog?
   ___I try to reduce the number of coqui frogs on my land
   ___I try to increase the number of coqui frogs on my land
   ___I don't try to change the number of coqui frogs on my land at all

2. Have you heard or read about things you could do on your property to manage for the coqui frog?
   ___Yes
   ___ No (please skip to question 4)

3. Please check *all* of the following things you have heard or read could be done to manage for coqui frogs:
   ___ Spray with hydrated lime ___ Hand capture
   ___ Spray with citric acid ___ Dust with baking soda
   ___ Spray with caffeine ___ Clear vegetation on property
   ___ Spray with something else ___ Increase vegetation on property
   please list:______________ ___ Other please list:____________

4. Please rate your agreement with this statement: The County or State should require people to manage for coqui on their property:
   ___Strongly Agree ___Don't care/neutral ___Strongly disagree
   ___Agree ___Disagree

5. Do you, or members of your household do anything on your property to manage for the coqui frog?
   ___Yes
   ___No (please go to question 8)
   ___We don't have any coquis on our property (please go to question 8)

6. On average, how often are the following things currently being done on your property to manage for coqui:

	Never	One time	1-3 times/ month	4-12 times/ month	13-27 times/ month	Every day
Hand capture	☐	☐	☐	☐	☐	☐
Spray with hydrated lime	☐	☐	☐	☐	☐	☐
Catch with coqui wand/trap	☐	☐	☐	☐	☐	☐

Spray with caffeine	☐	☐	☐	☐	☐	☐
Dust with baking soda	☐	☐	☐	☐	☐	☐
Spray with citric acid	☐	☐	☐	☐	☐	☐
Clear vegetation	☐	☐	☐	☐	☐	☐
Supply habitat for coqui	☐	☐	☐	☐	☐	☐
Supply food for coqui	☐	☐	☐	☐	☐	☐
Other- please list:_________	☐	☐	☐	☐	☐	☐

7. What would you estimate has been your total cost of managing for the coqui?
   ___Nothing ___$101 to $1,000
   ___$1 to $50 ___$1,001 to $5,000
   ___$51 to $100 ___greater than $5,001;how much?________

8. In the last 12 months…(please circle yes or no)

Have you removed a plant because coquis seemed to like it?	Y	N
Have you chosen to purchase a landscaping plant because you'd heard coquis *didn't* like it?	Y	N
Have you stopped purchasing plants from a nursery because you heard they had coquis?	Y	N
Have you stopped purchasing plants from any/all nurseries because you've heard they are thought to aid in spreading coquis?	Y	N
Have you participated in a coqui working group?	Y	N
Have you hired someone to manage coquis on your property?	Y	N
Have you felt like giving up on trying to manage for coquis on your property?	Y	N
Have you felt alone in your efforts to manage for coquis?	Y	N
Did you have a landscaper modify your land? *If "Yes", how so?*______________________	Y	N
Have you worried the coquis would come to your area (if they aren't already), or increase in number (if they are there already)?	Y	N
Have you introduced an animal to your property to manage for the coqui?	Y	N

Please answer the following questions *whether or not* you have coqui on your property by selecting the best response based on your opinion.

9. If managing coqui frogs required a large time commitment it would be extremely good:__3_:_2_:_1_:_0_:_-1_:_-2_:_-3_: extremely bad

10. Managing my property for coqui frogs on a regular basis will help me have better control over the coqui frog on my property

extremely likely:__3_:_2_:_1_:_0_:_-1_:_-2_:_-3_: extremely unlikely

11. Managing my property for coqui frogs on a regular basis will cause me to use more chemicals on my property
extremely likely:__3_:_2_:_1_:_0_:_-1_:_-2_:_-3_: extremely unlikely

12. Having better control over the coqui frog on my property is
extremely bad:_-3_:_-2_:_-1_:_0_:_1_:_2_:_3_: extremely good

13. Interacting more with my neighbors or other individuals in my community is
extremely bad:_-3_:_-2_:_-1_:_0_:_1_:_2_:_3_: extremely good

14. Using more chemicals of any kind on my property is
extremely good:__3_:_2_:_1_:_0_:_-1_:_-2_:_-3_: extremely bad

15. Managing my property for coqui frogs on a regular basis will give me an opportunity to interact with my neighbors and other individuals in my community
extremely unlikely:_-3_:_-2_:_-1_:_0_:_1_:_2_:_3_: extremely likely

16. Managing my property for coqui frogs on a regular basis will cause me to spend a lot of money
extremely likely:__3_:_2_:_1_:_0_:_-1_:_-2_:_-3_: extremely unlikely

17. Managing my property for coqui frogs on a regular basis will result in a large time commitment
extremely unlikely:_-3_:_-2_:_-1_:_0_:_1_:_2_:_3_: extremely likely

18. Spending lots of my money to manage for coqui frogs is
extremely good:__3_:_2_:_1_:_0_:_-1_:_-2_:_-3_: extremely bad

---

Next we would like to ask you a few questions about your experiences with the coqui frog.

1. Please circle True or False:
The coqui is an insect..True False
The coqui is native to Hawaii ....True False
The coqui is gray or brown in color.....................True False
The coqui is larger than a baseball.......................True False
The coqui has a tadpole stage ....True False
The coqui is poisonous..True False
The coqui eats mosquitoes...................................True False
The coqui calls more at night than during the dayTrue False

2. Have you heard the coqui frog call?
___Yes ___No

3. Have you seen the coqui frog?
   ___Yes ___No

Please answer the following questions whether or not you have coqui on your property by selecting the best response based on your opinion.

4. My neighbor thinks that I should manage my property for coqui frogs on a regular basis
   extremely likely:__3_:_2_:_1_:_0_:_-1_:_-2_:_-3_: extremely unlikely

5. Not receiving enough education on management activities for the coqui would make it much more difficult :_-3_:_-2_:_-1_:_0_:_1_:_2_:_3_: much easier
   for me to manage my property for coqui frogs on a regular basis

6. How often do you have less spending money than you had hoped for?
   very rarely:_-3_:_-2_:_-1_:_0_:_1_:_2_:_3_: very frequently

7. Generally speaking, how much do you want to do what the county or state thinks you should do?
   not at all:_-3_:_-2_:_-1_:_0_:_1_:_2_:_3_: very much

8. For me to manage my property for coqui frogs on a regular basis is
   extremely good:__3_:_2_:_1_:_0_:_-1_:_-2_:_-3_: extremely bad

9. If I felt ill, tired, or old, it would make it more difficult for me to manage my property for coqui frogs on a regular basis
   strongly agree: _3_:_2_:_1_:_0_:_-1_:_-2_:_-3_: strongly disagree

10. I plan to manage my property for coqui frogs on a regular basis
    extremely likely:__3_:_2_:_1_:_0_:_-1_:_-2_:_-3_: extremely unlikely

11. How often do you feel that your neighbors manage their land in a way that negatively affects you?
    very rarely:_-3_:_-2_:_-1_:_0_:_1_:_2_:_3_: very frequently

12. For me to manage my property for coqui frogs on a regular basis is
    impossible:_-3_:_-2_:_-1_:_0_:_1_:_2_:_3_: possible

13. Whether or not I manage my property for coqui frogs on a regular basis is completely up to me
    strongly disagree:_-3_:_-2_:_-1_:_0_:_1_:_2_:_3_: strongly agree

14. Most people who are important to me manage their properties for coqui frogs on a regular basis
    definitely true:__3_:_2_:_1_:_0_:_-1_:_-2_:_-3_: definitely false

15. For me to manage my property for coqui frogs on a regular basis is
extremely valuable:__3_:_2_:_1_:_0_:_-1_:_-2_:_-3_: extremely worthless

16. I am confident that if I wanted to I could manage my property for coqui frogs on a regular basis
definitely true:__3_:_2_:_1_:_0_:_-1_:_-2_:_-3_: definitely false

17. It is expected of me that I manage my property for coqui frogs on a regular basis
definitely true:__3_:_2_:_1_:_0_:_-1_:_-2_:_-3_: definitely false

18. If I have less spending money than I hoped for, it would make it more difficult for me to manage my property for coqui frogs on a regular basis
strongly agree: _3_:_2_:_1_:_0_:_-1_:_-2_:_-3_: strongly disagree

19. I will make an effort to manage my property for coqui frogs on a regular basis
I definitely will:__3_:_2_:_1_:_0_:_-1_:_-2_:_-3_: I definitely will not

20. How often do you feel ill, tired, or old?
very rarely:_-3_:_-2_:_-1_:_0_:_1_:_2_:_3_: very frequently

21. Generally speaking, how much do you want to do what your neighbor thinks you should do?
not at all:_-3_:_-2_:_-1_:_0_:_1_:_2_:_3_: very much

22. Unanticipated demands on my time would make it
much more difficult :_-3_:_-2_:_-1_:_0_:_1_:_2_:_3_: much easier
for me to manage my property for coqui frogs on a regular basis

23. For me to manage my property for coqui on a regular basis is
energizing:__3_:_2_:_1_:_0_:_-1_:_-2_:_-3_: tiring

24. I intend to manage my property for coqui frogs on a regular basis
strongly agree: _3_:_2_:_1_:_0_:_-1_:_-2_:_-3_: strongly disagree

25. How often do you have unanticipated demands on your time?
very rarely:_-3_:_-2_:_-1_:_0_:_1_:_2_:_3_: very frequently

26. The county or state thinks that I should manage my property for coqui frogs on a regular basis
extremely likely:__3_:_2_:_1_:_0_:_-1_:_-2_:_-3_: extremely unlikely

27. My neighbors managing their land in a way that negatively affects me would make it
much more difficult :_-3_:_-2_:_-1_:_0_:_1_:_2_:_3_: much easier
for me to manage my property for coqui frogs on a regular basis

28. How often do you feel that you do not receive enough education on management

activities for the coqui frog?
very rarely:_-3_:_-2_:_-1_:_0_:_1_:_2_:_3_: very frequently

29. Suppose that coqui frogs were expected to have a large increase in population size such that they will migrate to areas where they are currently not found, and increase in areas where they are already found, until all areas of the island you live on have coqui. If you knew that control of the coqui would be possible with intensive management practices across the island, would you be willing to contribute $5 a month to be sure the management was possible?
___Yes ___No

Next we would like to know where you receive information on the coqui.

1. Which of the following is your *primary* source of information about managing your property for coqui frogs? (Please check **only one**).
___Don't know information on coqui management
___Community group
___Radio
___Word of mouth
___Documentary
___Agricultural office
___University/college
___Other:__________________
___Newspaper
___News
___Internet
___State/county
___Brochure/pamphlet
___Classes or workshops
___Book
___Personal Knowledge

2. How satisfied are you with your current sources of information on coqui frog management?
___Highly satisfied
___Satisfied
___Dissatisfied
___Highly dissatisfied
___Neither satisfied nor dissatisfied (neutral)

3. Please **rank** the following educational methods from **1 to 9** with 1 being your *most* preferred method for learning more about managing your land for coqui frogs and 9 being *least* preferred
___Brochures, pamphlets, fact sheets
___Books from the library
___Radio broadcasts
___TV news series
___Personal assistance from a trained manager
___The Internet
___Periodic newsletters
___Classes or workshops
___Other:______________ ___________________

4. Besides the people you live with, do you talk with others about coqui frogs?
___Yes; who (i.e. friends, family, etc.):_____________________________
___No

Next we would like to know some general information about coqui frogs on your property.

1. Approximately how many frogs would you say you are hearing around your property on an average night?
   ___Zero (skip to question 3)
   ___One or two
   ___3 to 50
   ___51 to 100
   ___101 to 1000
   ___Thousands
   ___Millions
   ___Don't know

2. In the last 12 months, would you say the coqui frogs on your property are:
   ___Increasing in numbers
   ___Decreasing in numbers
   ___Staying the same

3. Have you ever lost sleep because of hearing a coqui frog?
   ___ Yes
   ___ No
   ___ Never been in an area with coqui frogs at night (skip to question 5)

4. How long would you say the coquis typically call at night?
   ___Don't know ___Until 12 a.m. ___All night
   ___Until 10 p.m. ___Until 2 a.m.

5. Have you ever had a coqui on your car?
   ___Yes ___No

6. Please check the appropriate box responding to how your opinion of the coqui would change if….

	Dislike a lot more	Dislike a little more	No change	Like a little more	Like a lot more
The coquis did not call at night					
The coqui was native to Hawaii					
The coqui was not native to Hawaii					
The coqui consumed native insects					
The coqui consumed non-native insects					
The coqui negatively affected my property value					
The coqui positively affected my property value					

Finally, we would like to know some basic information about you. The questions asked are used for statistical purposes only and are strictly confidential.

1. How old are you?
   _______ years

2. What is your gender?
   ___ Male ___ Female

3. What is the highest level of education you have completed?
   ___Some high school ___Earned 2-year college degree
   ___High-school graduate ___Earned 4-year college degree
   ___Some college ___Earned advanced college degree

4. What is your primary occupation?
   ___Farmer or rancher ___Retired
   ___Employed full-time ___Employed part-time
   ___Self-employed ___Student
   ___Other:_________________________

5. How long have you lived at your current property in Hawaii?
   __________ weeks/months/years (circle which is appropriate)

6. What is your total family income?
   ___Less than $10,000 ___$75,000 to $99,999
   ___$10,000 to $24,999 ___$100,000 or more
   ___$25,000 to $49,999 ___Prefer not to say
   ___$50,000 to $74,999

7. What is your primary place of residence on your property in Hawaii?
   ___House ___Apartment ___Mobile home
   ___Other:_______

8. Is this house, apartment, or mobile home:
   ___Owned by you or someone in this household
   ___Rented by you or someone in this household

8. Were you born in Hawaii?
   ___No; *Where were you born?* _________________ (Answer 9, but **skip** 10)
   ___Yes (Skip to question 10)

9. If you were NOT born in Hawaii, how long have you lived in Hawaii for?
   ____

10. If you WERE born in Hawaii, have you lived anywhere other than Hawaii?

___No ___Yes Where & How long? ________________________

We would like to talk to you further about your experiences with the coqui frog. If you would be willing to participate in a follow-up interview or request for information, please provide your **name** and **phone number** or **email address** for us to reach you:

____

Thank you again for your participation in our survey. If you have any additional comments about your experience with coqui frogs, please write them below and return the survey in the postage-paid envelope provided.

If you have any questions, please contact Emily Price at (435) 797-2458 or CoquiSurvey@gmail.com

APPENDIX D

Descriptive statistics for Chapter 3

Table D-1 Descriptive statistics for "Which island is your land on?"

Island	Frequency
Hawai'i	591
Maui	138
Kaua'i	98
O'ahu	90
Multiple islands	14
Blank	94

Table D-2 Descriptive statistics for "How many acres of land do you own in Hawaii?"

Acreage	Frequency
Less than ½ acre	430
½ acre to 2.5 acres	331
3 to 9.5 acres	121
10 to 29.5 acres	26
30 to 49.5 acres	5
50 or more acres	6
Multiple sizes	3
Blank	103

Table D-3 Descriptive statistics for "What is the ***primary*** make-up of your land in Hawaii?"

Vegetation type	Frequency
Wooded	73
Lava rock	71
Landscaped	412
Dense understory	16
Grassy	193
Other	87
Blank	104
Multiple	69

Table D-4 Descriptive statistics for "To what extent do you do the following things on your land in Hawaii?"

General management	Never	Sometimes	All the time	Blank
Irrigation/watering	219	429	220	157
Lawn mowing	95	269	545	116
Clear understory	274	425	113	213
Spray pesticides	311	516	52	146
Trim trees	65	685	147	128
Spray insecticides	308	515	35	167
Use herbicides	276	522	52	175
Garden	100	447	313	165
Plant trees	174	615	77	159
Exclude wildlife with fences	564	148	123	190

Table D-5 Descriptive statistics for "What is the *primary* type of vegetation on your property?"

Vegetation	Frequency
Ohia trees	62
Fruit trees	90
Nut trees	3
Albizia trees	4
Coffee	5
Grasses	262
Shrubs	75
Bare ground or lava	11
Multiple types / other	513

Table D-6 Descriptive statistics for "In general, what is your opinion of the following animals (please check appropriate box):"

Animal	Don't know what it is	Strongly dislike	Dislike	Neutral	Like	Strongly like	Blank
Coqui frogs	37	555	172	98	18	8	137
Giant snails	40	377	283	154	11	0	160
Fire ants	35	659	124	18	3	4	182
Geckos or Chameleons	1	91	131	273	233	158	138
Centipedes	1	625	192	59	7	3	138
Cockroaches	2	660	195	28	1	3	136
Nettle caterpillars	255	330	121	106	8	1	204
Cane toads	144	207	180	214	55	25	200
Greenhouse frogs	247	155	136	219	34	13	221
Mosquitoes	1	667	197	20	2	4	134
Myna birds	4	104	151	366	176	56	168
Chickens	1	102	160	370	163	45	184
Mongoose	11	253	218	302	57	20	164
Biting flies	61	589	152	28	2	3	190
Cane spiders	98	321	202	187	38	11	168
Hoary bat	299	116	53	215	74	58	210
Feral pigs	19	285	221	258	44	15	183

Rats	4	738	117	23	1	5	137

Table D-7 Descriptive statistics for "Which of the following statements best describes how you try to manage your property for the coqui frog?"

Management statement	Frequency
I try to reduce the number of coqui frogs on my land	423
I try to increase the number of coqui frogs on my land	2
I don't try to change the number of coqui frogs on my land at all	352
Don't have coqui	28
Blank	220

Table D-8 Descriptive statistics for "Have you heard or read about things you could do on your property to manage for the coqui frog?"

Response	Frequency
Yes	627
No	245
Blank	153

Table D-9 Descriptive statistics for “Please check *all* of the following things you have heard or read could be done to manage for coqui frogs:”

Management type	Frequency
Spray with hydrated lime	462
Spray with citric acid	515
Spray with caffeine	402
Spray with something else	67
Hand capture	372
Dust with baking soda	222
Clear vegetation on property	365
Increase vegetation on property	8
Other	45
Blank	389

Table D-10 Descriptive statistics for “Please rate your agreement with this statement: The County or State should require people to manage for coqui on their property:”

Response	Frequency
Strongly agree	281
Agree	250
Don’t care/neutral	125
Disagree	124
Strongly disagree	91
Blank	154

Table D-11 Descriptive statistics for "Do you, or members of your household do anything on your property to manage for the coqui frog?"

Response	Frequency
Yes	239
No	260
We don't have any coquis on our property	391
Blank	135

Table D-12 Descriptive statistics for "On average, how often are the following things currently being done on your property to manage for coqui?"

Management	Never	One time	1-3 times /month	4-12 times /month	13-27 times /month	Every day	Blank
Hand capture	151	46	75	27	9	6	711
Spray with hydrated lime	198	63	26	8	0	1	729
Catch with coqui wand/trap	264	10	5	2	0	3	741
Spray with caffeine	253	20	11	3	1	1	736
Dust with baking soda	233	25	25	6	2	1	733
Spray with citric acid	203	52	33	8	3	0	726
Clear vegetation	126	39	97	25	9	3	726
Supply habitat for coqui	266	4	4	0	0	2	749
Supply food for coqui	270	3	0	0	0	1	751
Other	53	7	6	7	0	9	946

Table D-13 Descriptive statistics for "What would you estimate has been your total cost of managing for the coqui?"

Cost estimate	Frequency
Nothing	176
$1 to $50	84
$51 to $100	44
$101 to $1,000	42
$1,001 to $5,000	10
Greater than $5,001	3
Blank	666

Table D-14 Descriptive statistics for “In the last 12 months…(please circle yes or no).

Statement	Yes	No	Blank
Have you removed a plant because coquis seemed to like it?	90	776	159
Have you chosen to purchase a landscaping plant because you’d heard coquis *didn’t* like it?	22	836	167
Have you stopped purchasing plants from a nursery because you heard they had coquis	256	608	161
Have you stopped purchasing plants from any/all nurseries because you’ve heard they are thought to aid in spreading coquis?	165	706	163
Have you participated in a coqui working group?	55	806	164
Have you hired someone to manage coquis on your property?	23	837	165
Have you felt like giving up on trying to manage for coquis on your property	178	677	170
Have you felt alone in your efforts to manage for coquis?	158	691	176
Did you have a landscaper modify your land?	41	822	162
Have you worried the coquis would come to your area (if they aren’t already), or increase in number (if they are there already?	585	282	158
Have you introduced an animal to your property to manage for the coqui?	36	830	159

Table D-15 Descriptive statistics for knowledge question on coqui frog: “Please circle True or False:”

Statement	True	False	Don’t know	Blank
The coqui is an insect	37	800	0	188
The coqui is native to Hawaii	15	868	1	141
The coqui is gray or brown in color	625	211	8	181
The coqui is larger than a baseball	7	866	3	149
The coqui has a tadpole stage	293	464	17	251
The coqui is poisonous	35	800	8	182
The coqui eats mosquitoes	384	361	23	257
The coqui calls more at night than during the day	837	30	3	155

Table D-16 Descriptive statistics for “Have you heard the coqui frog call?”

Response	Frequency
Yes	737
No	168
Blank	120

Table D-17 Descriptive statistics for “Have you seen the coqui frog?”

Response	Frequency
Yes	606
No	298
Blank	121

Table D-18 Descriptive statistics for willingness to pay question: “Suppose that the coqui frogs were expected to have a large increase in population size such that they will migrate to areas where they are currently not found, and increase in areas where they are already found, until all areas of the island you live on have coqui. If you knew that control of the coqui would be possible with intensive management practices across the island, would you be willing to contribute X amount a month to be sure the management was possible?”

Dollar amount	Yes	No	Blank
$5	80	46	899
$10	57	51	917
$25	35	89	901
$50	26	87	912
$100	17	107	901
$250	9	103	914
$500	13	119	893

Table D-19 Descriptive statistics for “How satisfied are you with your current sources of information on coqui frog management?”

Response	Frequency
Highly satisfied	69
Satisfied	279
Dissatisfied	138
Highly dissatisfied	45
Neither satisfied nor dissatisfied (neutral)	326
Blank	168

Table D-20 Descriptive statistics for “Please **rank** the following educational methods from **1 to 9** with 1 being your *most* preferred method for learning more about managing your land for coqui frogs and 9 being *least* preferred”

Information type	1	2	3	4	5	6	7	8	9	Blank
Brochures, pamphlets, fact sheets	227	129	106	61	49	25	18	11	25	374
Books from the library	20	15	21	34	68	98	110	155	92	412
Radio broadcasts	60	75	68	65	92	85	77	66	46	389
TV news series	165	84	87	68	82	59	35	24	32	389
Personal assistance from a trained manager	128	44	51	50	69	55	70	90	72	389
The Internet	121	73	72	86	93	39	58	35	48	400
Periodic newsletters	89	93	100	101	95	60	51	21	19	396
Classes or workshops	61	56	60	43	80	78	82	97	65	403
Other	19	9	10	8	6	2	12	11	194	754

Table D-21 Descriptive statistics for "Besides the people you live with, do you talk with others about coqui frogs?"

Response	Frequency
Yes	491
No	367
Blank	167

Table D-22 Descriptive statistics for "Approximately how many frogs would you say you are hearing around your property on an average night?"

Response	Frequency
Zero	473
One or two	78
3 to 50	188
51 to 100	37
101 to 1000	41
Thousands	22
Millions	3
Don't know	29
Blank	154

Table D-23 Descriptive statistics for "In the last 12 months, would you say the coqui frogs on your property are:"

Response	Frequency
Increasing in numbers	137
Decreasing in numbers	63
Staying the same	242
Blank	583

Table D-24 Descriptive statistics for "Have you ever lost sleep because of hearing a coqui frog?"

Response	Frequency
Yes	213
No	494
Never been in an area with coqui frogs at night	153
Blank	165

Table D-25 Descriptive statistics for "How long would you say the coquis typically call at night?"

Response	Frequency
Don't know	283
Until 10 p.m.	16
Until 12 a.m.	47
Until 2 a.m.	69
All night	287
Blank	323

Table D-26 Descriptive statistics for "Have you ever had a coqui on your car?"

Response	Frequency
Yes	151
No	709
Blank	165

Table D-27 Descriptive statistics for "Please check the appropriate box responding to how your opinion of the coqui would change if…"

Statement	Dislike a lot more	Dislike a little more	No change	Like a little more	Like a lot more	Blank
The coqui did not call at night	30	26	291	189	275	214
The coqui was native to Hawaii	129	27	448	115	83	223
The coqui was not native to Hawaii	186	54	462	15	80	228
The coqui consumed native insects	230	113	287	127	42	226
The coqui consumed non-native insects	54	66	331	233	111	230
The coqui negatively affected my property value	541	105	126	12	14	227
The coqui positively affected my property value	113	29	313	154	187	229

Table D-28 Descriptive statistics for "How old are you?"

Mean	Std. Deviation	Minimum	Maximum
59.54	13.047	18	94

Table D-29 Descriptive statistics for “What is your gender?”

Response	Frequency
Female	443
Male	435
Blank	146

Table D-30 Descriptive statistics for “What is the highest level of education you have completed?”

Response	Frequency
Less than high school	4
Some high school	26
High-school graduate	126
Some college	192
Earned 2-year college degree	119
Earned 4-year college degree	224
Earned advanced college degree	185
Blank	149

Table D-31 Descriptive statistics for “What is your primary occupation?”

Response	Frequency
Farmer or rancher	17
Employed full-time	266
Self-employed	127
Other	52
Retired	344
Employed part-time	35
Student	2
Multiple	32
Blank	150

Table D-32 Descriptive statistics for “How long have you lived at your current property in Hawaii?”

Mean	Std. Deviation	Minimum	Maximum
19.83	14.786	1	68

Table D-33 Descriptive statistics for "What is your total family income?"

Response	Frequency
Less than $10,000	23
$10,000 to $24,999	76
$25,000 to $49,999	170
$50,000 to $74,999	194
$75,000 to $99,999	113
$100,000 or more	143
Prefer not to say	132
Blank	174

Table D-34 Descriptive statistics for "What is your primary place of residence on your property in Hawaii?"

Response	Frequency
House	876
Apartment	3
Mobile home	0
Other	3
Blank	143

Table D-35 Descriptive statistics for “Is this house, apartment, or mobile home?”

Response	Frequency
Owned by you or someone in this household	865
Rented by you or someone in this household	4
Blank	156

Table D-36 Descriptive statistics for “Were you born in Hawaii?”

Response	Frequency
Yes	459
No	417
Blank	149

Table D-37 Descriptive statistics for “If you were NOT born in Hawaii, how long have you lived in Hawaii for?

Mean	Std. Deviation	Minimum	Maximum
21.79	14.163	1	66

Table D-38 Descriptive statistics for "If you WERE born in Hawaii, have you lived anywhere other than Hawaii?"

Response	Frequency
No	275
Yes	174
Blank	576

Table D-39a ANOVA results for comparing mean response to opinion toward the coqui frog, with 0 being "don't know what it is", 1 being "strongly dislike", 2 being "dislike", 3 being "neutral", 4 being "like", and 5 being "strongly like".

					95% Confidence Interval for Mean	
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound
Island of Hawaii	574	1.53	.895	.037	1.46	1.61
Other islands	308	1.36	.847	.048	1.26	1.45
Total	882	1.47	.882	.030	1.41	1.53

Table D-39b ANOVA results for comparing mean response to opinion toward the coqui frog, with 0 being "don't know what it is", 1 being "strongly dislike", 2 being "dislike", 3 being "neutral", 4 being "like", and 5 being "strongly like".

	Sum of Squares	df	Mean Square	F	Sig.
Between groups	6.321	1	6.321	8.190	.004
Within groups	679.192	880	.772		
Total	685.513	881			

APPENDIX E

ANOVA, ANCOVA, and Chi Square tables for Chapter 4

Table E-1. ANOVA results for vegetation removal.

Effect	Num DF	Den DF	F Value	Pr>F
Treatment	4	42	4.28	**0.0054**
Treatment application	2	42	10.67	**0.0002**
Treatment*Treatment application	8	42	1.05	0.4126

Table E-2. ANCOVA results % understory cover pre and post treatment (N=20).

Effect	Num DF	Den DF	F Value	Pr>F
Pre-Treatment	1	14	3.76	0.0730
Treatment	4	14	118.75	<0.0001

Table E-3. ANCOVA results for effects of treatment on the density of *Eleutherodactylus coqui*. Density was cube-root transformed (N=55 estimates, one for each plot, three times minus the last block during the last application).

Effect	Num DF	Den DF	F Value	Pr>F
Pre-treatment	1	37.8	3.28	0.0782
Treatment	4	35.25	3.98	**0.0091**
Treatment application	2	36.02	153.09	**<0.0001**
Treatment application*Treatment	8	34.92	2.87	**0.0145**

Table E-4. ANCOVA results for effects of treatment on leaf litter invertebrates. Leaf-litter invertebrates were cube-root transformed (N=159 total samples, one for each plot, four times).

Effect	Num DF	Den DF	F Value	Pr>F
Pre-treatment	1	145.7	1.79	0.1834
Treatment	4	143.2	5.19	**0.0006**
Treatment application	1	143.1	7.69	**0.0063**
Treatment application*Treatment	4	143.3	1.44	0.2254

Table E-5. ANCOVA results for effects of treatment on flying invertebrates. Flying invertebrates were cube-root transformed (N=162 total samples, one for each plot, four times).

Effect	Num DF	Den DF	F Value	Pr>F
Pre-treatment	1	100.2	0.18	0.6709
Treatment	4	11.71	9.87	**0.0010**
Treatment application	1	144	1.84	0.1766
Treatment application *Treatment	4	143.7	1.80	0.1329

Table E-6. ANCOVA results for effects of treatment on foliage invertebrates. Foliage invertebrates were cube-root transformed (N=159 total samples, one for each plot, four times).

Effect	Num DF	Den DF	F Value	Pr>F
Pre-treatment	1	66.83	1.58	0.2138
Treatment	4	11.71	11.46	**0.0005**
Treatment application	1	133.9	1.49	0.2243
Treatment application *Treatment	4	133.7	4.08	**0.0038**

Table E-7. ANCOVA results for effect of treatment on mean heights used by coqui (N=55).

Effect	Num DF	Den DF	F Value	Pr>F
Pre-treatment	1	39	2.39	0.1303
Treatment	4	39	2.36	0.0701
Treatment application	2	39	4.15	**0.0231**
Treatment application*Treatment	8	39	1.34	0.2517

Table E-8. ANCOVA results for effect of treatment on mean heights used by coqui (N=55).

Effect	Estimate	StdErr	DF	t value	Pr > |t|	Adj P
Application 1	-0.09538	0.08282	39	-10.76	0.2565	0.7695
Application 2	0.1643	0.09029	39	-11.49	0.0764	0.2293
Application 3	0.2597	0.09029	39	-0.18	0.0065	**0.0195**

Table E-9. ANCOVA results for effect of treatment on temperature recorded (N=108).

Effect	Num DF	Den DF	F Value	Pr>F
Pre-treatment	1	11.49	9.72	**0.0093**
Treatment	4	11.69	1.28	0.3330
NightDay	1	63.91	0.12	0.7267
Treatment*NightDay	4	63.61	0.02	0.9993
Application	2	65.6	36.85	**<0.0001**
Application*Treatment	8	67.68	0.66	0.7280
Application*NightDay	2	64.8	50.94	**<0.0001**
Application*Treatment*NightDay	8	63.61	0.30	0.9635

Table E-10. ANCOVA results for effect of treatment on humidity recorded (N=108).

Effect	Num DF	Den DF	F Value	Pr>F
Pre-treatment	1	7.548	12.23	0.0089
Treatment	4	9.963	0.96	0.4687
NightDay	1	62.44	1.36	0.2477
Treatment*NightDay	4	61.72	0.03	0.9983
Application	2	63.41	87.81	**<0.0001**
Application*Treatment	8	66.47	0.97	0.46660
Application*NightDay	2	62.22	60.81	**<0.0001**
Application*Treatment*NightDay	8	61.72	0.24	0.9812

Table E-11. Vegetation where coqui found before treatment. Cells include total counts for each treatment type before treatment application. Letters indicate significant differences (*P*<0.05).

	Treatment				
Vegetation	100% LL removal	50% LL removal	100% Vegetation removal	50% Vegetation removal	Control
Leaves >1m	90_{a}	$72_{a,b}$	135_{c}	$81_{b,c}$	57_{b}
Leaves <1m	101_{a}	38_{b}	26_{c}	14_{c}	$19_{b,c}$
Forest Floor	1_{a}	1_{a}	0_{a}	0_{a}	1_{a}
Trees	$5_{a,b}$	$10_{b,c}$	1_{a}	13_{c}	9_{c}

Table E-12. Vegetation where coqui found after treatment application 1. Letters indicate significant differences (*P*<0.05).

	Treatment				
Vegetation	100% LL removal	50% LL removal	100% Vegetation removal	50% Vegetation removal	Control
Leaves >1m	66_{a}	60_{a}	13_{a}	40_{a}	46_{a}
Leaves <1m	48_{a}	$21_{a,b}$	$8_{a,b}$	15_{b}	$24_{a,b}$
Forest Floor	1_{a}	$1_{a,b}$	4_{b}	$3_{a,b}$	0_{a}
Trees	14_{a}	$18_{a,b}$	12_{b}	24_{b}	$19_{a,b}$

Table E-13. Vegetation where coqui found after treatment application 2. Letters indicate significant differences (*P*<0.05).

	Treatment				
Vegetation	100% LL removal	50% LL removal	100% Vegetation removal	50% Vegetation removal	Control
Leaves >1m	$17_{a,b}$	14_{b}	$9_{a,b}$	$4_{a,b}$	3_{a}
Leaves <1m	46_{a}	14_{b}	$15_{a,b}$	9_{b}	8_{b}
Forest Floor	2_{a}	2_{a}	16_{b}	$4_{a,b}$	4_{a}
Trees	80_{a}	$68_{a,b}$	53_{a}	59_{b}	88_{b}

Table E-14. Vegetation where coqui found after treatment application 3. Letters indicate significant differences (*P*<0.05).

	Treatment				
Vegetation	100% LL removal	50% LL removal	100% Vegetation removal	50% Vegetation removal	Control
Leaves >1m	8_{a}	5_{a}	6_{a}	20_{a}	11_{a}
Leaves <1m	$3_{a,b}$	$8_{a,b}$	20_{c}	$30_{b,c}$	5_{a}
Forest Floor	$1_{a,b}$	$3_{a,b}$	9_{b}	3_{a}	1_{a}
Trees	$28_{a,b}$	$61_{a,b}$	18_{c}	96_{b}	99_{a}

APPENDIX F

Post-Hoc mean comparisons for Chapter 4

Table F-1. Post-hoc mean comparisons for vegetation removal analysis by treatment. Raw_P = Unadjusted p value; stpbon = Holm's step-down Bonferroni.

Treatment	Treatment	Estimate	StdErr	Raw_P	stpbon_p
100% LL removal	50% LL removal	23.1327	17.7153	0.19873	0.59618
100% LL removal	100% Vegetation removal	-6.9068	17.7153	0.69860	1.00000
100% LL removal	50% Vegetation removal	26.7022	17.7153	0.13922	0.55688
100% LL removal	Control	58.8253	17.7153	0.00187	**0.01679**
50% LL removal	100% Vegetation removal	-30.0395	17.7153	0.09735	0.48674
50% LL removal	50% Vegetation removal	3.5695	17.7153	0.84128	1.00000
50% LL removal	Control	35.6926	17.7153	0.05036	0.40286
100% Vegetation removal	50% Vegetation removal	33.6090	17.7153	0.06469	0.45286
100% Vegetation removal	Control	65.7321	17.7153	0.00060	**0.00602**
50% Vegetation removal	Control	32.1231	17.7153	0.07694	0.46162

Table F-2 Post-hoc mean comparisons for vegetation removal analysis by treatment application. Raw_P = Unadjusted p value; stpbon = Holm's step-down Bonferroni.

Treatment application	Treatment application	Estimate	StdErr	Raw_P	stpbon_p
1	2	43.1460	13.7222	0.00305	**0.00611**
1	3	61.7950	13.7222	0.00005	**0.00016**
2	3	18.6491	13.7222	0.18139	0.18139

Table F-3. Post-hoc mean comparisons for frog density analysis for the treatment application and treatment interaction. Raw_P = Unadjusted p value; stpbon = Holm's step-down Bonferroni.

Application	Treatment	Application	Treatment	Estimate	stderr	raw_p	stpbon_p
2	100% LL removal	2	50% LL removal	-0.02259	0.02980	0.45363	1.00000
2	100% LL removal	2	100% Vegetation removal	0.02906	0.02999	0.33918	1.00000
2	100% LL removal	2	50% Vegetation removal	0.003523	0.03000	0.90720	1.00000
2	100% LL removal	2	Control	-0.02713	0.02981	0.36908	1.00000
2	100% LL removal	3	100% LL removal	-0.01333	0.02980	0.65732	1.00000
2	100% LL removal	3	50% LL removal	-0.00261	0.02980	0.93071	1.00000
2	100% LL removal	3	100% Vegetation removal	0.01160	0.02999	0.70130	1.00000
2	100% LL removal	3	50% Vegetation removal	0.01185	0.03000	0.69525	1.00000
2	100% LL removal	3	Control	0.003787	0.02981	0.89966	1.00000
2	100% LL removal	4	100% LL removal	-0.1492	0.03241	0.00005	**0.00313**
2	100% LL removal	4	50% LL removal	-0.2218	0.03234	0.00000	**0.00000**
2	100% LL removal	4	100% Vegetation removal	-0.1848	0.03250	0.00000	**0.00013**
2	100% LL removal	4	50% Vegetation removal	-0.2895	0.03268	0.00000	**0.00000**
2	100% LL removal	4	Control	-0.3047	0.03238	0.00000	**0.00000**
2	50% LL removal	2	100% Vegetation removal	0.05165	0.02993	0.09328	1.00000

Application	Treatment	Application	Treatment	Estimate	stderr	raw_p	stpbon_p
2	50% LL removal	2	50% Vegetation removal	0.02611	0.02995	0.38922	1.00000
2	50% LL removal	2	Control	-0.00454	0.02984	0.87985	1.00000
2	50% LL removal	3	100% LL removal	0.009253	0.02980	0.75805	1.00000
2	50% LL removal	3	50% LL removal	0.01998	0.02980	0.50704	1.00000
2	50% LL removal	3	100% Vegetation removal	0.03418	0.02993	0.26120	1.00000
2	50% LL removal	3	50% Vegetation removal	0.03444	0.02995	0.25795	1.00000
2	50% LL removal	3	Control	0.02637	0.02984	0.38277	1.00000
2	50% LL removal	4	100% LL removal	-0.1267	0.03245	0.00041	**0.02263**
2	50% LL removal	4	50% LL removal	-0.1992	0.03237	0.00000	**0.00004**
2	50% LL removal	4	100% Vegetation removal	-0.1623	0.03245	0.00002	**0.00100**
2	50% LL removal	4	50% Vegetation removal	-0.2669	0.03261	0.00000	**0.00000**
2	50% LL removal	4	Control	-0.2821	0.03242	0.00000	**0.00000**
2	100% Vegetation removal	2	50% Vegetation removal	-0.02554	0.02980	0.39732	1.00000
2	100% Vegetation removal	2	Control	-0.05619	0.03011	0.07038	1.00000
2	100% Vegetation removal	3	100% LL removal	-0.04239	0.02999	0.16629	1.00000
2	100% Vegetation removal	3	50% LL removal	-0.03167	0.02993	0.29729	1.00000

Application	Treatment	Application	Treatment	Estimate	stderr	raw_p	stpbon_p
2	100% Vegetation removal	3	100% Vegetation removal	-0.01746	0.02980	0.56165	1.00000
2	100% Vegetation removal	3	50% Vegetation removal	-0.01721	0.02980	0.56733	1.00000
2	100% Vegetation removal	3	Control	-0.02527	0.03011	0.40694	1.00000
2	100% Vegetation removal	4	100% LL removal	-0.1783	0.03283	0.00000	**0.00030**
2	100% Vegetation removal	4	50% LL removal	-0.2509	0.03264	0.00000	**0.00000**
2	100% Vegetation removal	4	100% Vegetation removal	-0.2139	0.03232	0.00000	**0.00001**
2	100% Vegetation removal	4	50% Vegetation removal	-0.3185	0.03235	0.00000	**0.00000**
2	100% Vegetation removal	4	Control	-0.3337	0.03277	0.00000	**0.00000**
2	50% Vegetation removal	2	Control	-0.03065	0.03013	0.31594	1.00000
2	50% Vegetation removal	3	100% LL removal	-0.01686	0.03000	0.57783	1.00000
2	50% Vegetation removal	3	50% LL removal	-0.00613	0.02995	0.83890	1.00000
2	50% Vegetation removal	3	100% Vegetation removal	0.008074	0.02980	0.78802	1.00000
2	50% Vegetation removal	3	50% Vegetation removal	0.008328	0.02980	0.78152	1.00000
2	50% Vegetation removal	3	Control	0.000264	0.03013	0.99307	1.00000

Application	Treatment	Application	Treatment	Estimate	stderr	raw_p	stpbon_p
2	50% Vegetation removal	4	100% LL removal	-0.1528	0.03286	0.00005	**0.00281**
2	50% Vegetation removal	4	50% LL removal	-0.2253	0.03266	0.00000	**0.00000**
2	50% Vegetation removal	4	100% Vegetation removal	-0.1884	0.03232	0.00000	**0.00009**
2	50% Vegetation removal	4	50% Vegetation removal	-0.2930	0.03235	0.00000	**0.00000**
2	50% Vegetation removal	4	Control	-0.3082	0.03279	0.00000	**0.00000**
2	Control	3	100% LL removal	0.01380	0.02981	0.64642	1.00000
2	Control	3	50% LL removal	0.02452	0.02984	0.41676	1.00000
2	Control	3	100% Vegetation removal	0.03873	0.03011	0.20678	1.00000
2	Control	3	50% Vegetation removal	0.03898	0.03013	0.20418	1.00000
2	Control	3	Control	0.03092	0.02980	0.30663	1.00000
2	Control	4	100% LL removal	-0.1221	0.03235	0.00059	**0.03195**
2	Control	4	50% LL removal	-0.1947	0.03232	0.00000	**0.00005**
2	Control	4	100% Vegetation removal	-0.1577	0.03261	0.00002	**0.00155**
2	Control	4	50% Vegetation removal	-0.2623	0.03284	0.00000	**0.00000**
2	Control	4	Control	-0.2775	0.03234	0.00000	**0.00000**
3	100% LL removal	3	50% LL removal	0.01072	0.02980	0.72117	1.00000

Application	Treatment	Application	Treatment	Estimate	stderr	raw_p	stpbon_p
3	100% LL removal	3	100% Vegetation removal	0.02493	0.02999	0.41141	1.00000
3	100% LL removal	3	50% Vegetation removal	0.02518	0.03000	0.40695	1.00000
3	100% LL removal	3	Control	0.01712	0.02981	0.56949	1.00000
3	100% LL removal	4	100% LL removal	-0.1359	0.03241	0.00018	**0.01006**
3	100% LL removal	4	50% LL removal	-0.2085	0.03234	0.00000	**0.00001**
3	100% LL removal	4	100% Vegetation removal	-0.1715	0.03250	0.00001	**0.00043**
3	100% LL removal	4	50% Vegetation removal	-0.2761	0.03268	0.00000	**0.00000**
3	100% LL removal	4	Control	-0.2913	0.03238	0.00000	**0.00000**
3	50% LL removal	3	100% Vegetation removal	0.01421	0.02993	0.63798	1.00000
3	50% LL removal	3	50% Vegetation removal	0.01446	0.02995	0.63216	1.00000
3	50% LL removal	3	Control	0.006397	0.02984	0.83147	1.00000
3	50% LL removal	4	100% LL removal	-0.1466	0.03245	0.00007	**0.00399**
3	50% LL removal	4	50% LL removal	-0.2192	0.03237	0.00000	**0.00001**
3	50% LL removal	4	100% Vegetation removal	-0.1822	0.03245	0.00000	**0.00016**
3	50% LL removal	4	50% Vegetation removal	-0.2869	0.03261	0.00000	**0.00000**
3	50% LL removal	4	Control	-0.3021	0.03242	0.00000	**0.00000**

Application	Treatment	Application	Treatment	Estimate	stderr	raw_p	stpbon_p
3	100% Vegetation removal	3	50% Vegetation removal	0.000254	0.02980	0.99325	1.00000
3	100% Vegetation removal	3	Control	-0.00781	0.03011	0.79683	1.00000
3	100% Vegetation removal	4	100% LL removal	-0.1608	0.03283	0.00002	**0.00140**
3	100% Vegetation removal	4	50% LL removal	-0.2334	0.03264	0.00000	**0.00000**
3	100% Vegetation removal	4	100% Vegetation removal	-0.1964	0.03232	0.00000	**0.00004**
3	100% Vegetation removal	4	50% Vegetation removal	-0.3011	0.03235	0.00000	**0.00000**
3	100% Vegetation removal	4	Control	-0.3163	0.03277	0.00000	**0.00000**
3	50% Vegetation removal	3	Control	-0.00806	0.03013	0.79052	1.00000
3	50% Vegetation removal	4	100% LL removal	-0.1611	0.03286	0.00002	**0.00140**
3	50% Vegetation removal	4	50% LL removal	-0.2337	0.03266	0.00000	**0.00000**
3	50% Vegetation removal	4	100% Vegetation removal	-0.1967	0.03232	0.00000	**0.00004**
3	50% Vegetation removal	4	50% Vegetation removal	-0.3013	0.03235	0.00000	**0.00000**
3	50% Vegetation removal	4	Control	-0.3165	0.03279	0.00000	**0.00000**
3	Control	4	100% LL removal	-0.1530	0.03235	0.00004	**0.00221**

Application	Treatment	Application	Treatment	Estimate	stderr	raw_p	stpbon_p
3	Control	4	50% LL removal	-0.2256	0.03232	0.00000	**0.00000**
3	Control	4	100% Vegetation removal	-0.1886	0.03261	0.00000	**0.00009**
3	Control	4	50% Vegetation removal	-0.2933	0.03284	0.00000	**0.00000**
3	Control	4	Control	-0.3085	0.03234	0.00000	**0.00000**
4	100% LL removal	4	50% LL removal	-0.07256	0.03443	0.04232	1.00000
4	100% LL removal	4	100% Vegetation removal	-0.03560	0.03489	0.31461	1.00000
4	100% LL removal	4	50% Vegetation removal	-0.1402	0.03517	0.00032	**0.01791**
4	100% LL removal	4	Control	-0.1554	0.03441	0.00007	**0.00399**
4	50% LL removal	4	100% Vegetation removal	0.03696	0.03471	0.29421	1.00000
4	50% LL removal	4	50% Vegetation removal	-0.06766	0.03494	0.06082	1.00000
4	50% LL removal	4	Control	-0.08287	0.03442	0.02148	1.00000
4	100% Vegetation removal	4	50% Vegetation removal	-0.1046	0.03444	0.00449	0.23333
4	100% Vegetation removal	4	Control	-0.1198	0.03484	0.00152	0.08032
4	50% Vegetation removal	4	Control	-0.01521	0.03509	0.66743	1.00000

Table F-4. Post-hoc mean comparisons for leaf litter invertebrates analysis by treatment. Raw_P = Unadjusted p value; stpbon = Holm's step-down Bonferroni.

Treatment	Treatment	Estimate	StdErr	Raw_P	stpbon_p
100% LL removal	50% LL removal	-0.4028	0.2990	0.18007	0.72027
100% LL removal	100% Vegetation removal	-1.3113	0.2974	0.00002	**0.00020**
100% LL removal	50% Vegetation removal	-0.4771	0.3035	0.11825	0.59124
100% LL removal	Control	-0.5362	0.2980	0.07410	0.44462
50% LL removal	100% Vegetation removal	-0.9085	0.2958	0.00255	**0.02297**
50% LL removal	50% Vegetation removal	-0.07427	0.2995	0.80450	1.00000
50% LL removal	Control	-0.1334	0.3027	0.66013	1.00000
100% Vegetation removal	50% Vegetation removal	0.8342	0.2969	0.00565	**0.04521**
100% Vegetation removal	Control	0.7751	0.3019	0.01128	0.07893
50% Vegetation removal	Control	-0.05913	0.3114	0.84966	1.00000

Table F-5. Post-hoc means comparison for leaf litter invertebrates analysis by treatment application. Raw_P = Unadjusted p value; stpbon = Holm's step-down Bonferroni.

Treatment application	Treatment application	Estimate	StdErr	Raw_P	stpbon_p
2	3	0.5198	0.1874	0.006282	**0.00628**

Table F-6. Post-hoc mean comparisons for flying invertebrates analysis by treatment. Raw_P = Unadjusted p value; stpbon = Holm's step-down Bonferroni.

Treatment	Treatment	Estimate	StdErr	Raw_P	stpbon_p
100% LL removal	50% LL removal	-0.1445	0.2444	0.56528	1.00000
100% LL removal	100% Vegetation removal	-1.2955	0.2408	0.00019	**0.00194**
100% LL removal	50% Vegetation removal	-0.2551	0.2453	0.31860	1.00000
100% LL removal	Control	-0.07417	0.2417	0.76432	1.00000
50% LL removal	100% Vegetation removal	-1.1509	0.2427	0.00052	**0.00417**
50% LL removal	50% Vegetation removal	-0.1106	0.2420	0.65620	1.00000
50% LL removal	Control	0.07037	0.2423	0.77663	1.00000
100% Vegetation removal	50% Vegetation removal	1.0404	0.2437	0.00113	**0.00794**
100% Vegetation removal	Control	1.2213	0.2408	0.00032	**0.00286**
50% Vegetation removal	Control	0.1809	0.2436	0.47204	1.00000

Table F-7. Post-hoc mean comparisons for foliage invertebrates analysis by the interaction between treatment and treatment application. Raw_P = Unadjusted p value; spbon = Holm's step-down Bonferroni.

Treatment application	Treatment	Treatment application	Treatment	Estimate	StdErr	Raw_P	stpbon_p
2	100% LL removal	2	50% LL removal	-0.1124	0.3713	0.76456	1.00000
2	100% LL removal	2	100% Vegetation removal	2.0014	0.3845	0.00001	**0.00060**
2	100% LL removal	2	50% Vegetation removal	1.2390	0.3741	0.00267	0.07746
2	100% LL removal	2	Control	0.003581	0.3741	0.99243	1.00000
2	100% LL removal	3	100% LL removal	-0.1012	0.3203	0.75255	1.00000
2	100% LL removal	3	50% LL removal	0.9677	0.3707	0.01490	0.37242
2	100% LL removal	3	100% Vegetation removal	1.3595	0.3740	0.00117	**0.04100**
2	100% LL removal	3	50% Vegetation removal	1.3595	0.3868	0.00146	**0.04602**
2	100% LL removal	3	Control	0.4138	0.3702	0.27409	1.00000
2	50% LL removal	2	100% Vegetation removal	2.1137	0.3845	0.00001	**0.00029**
2	50% LL removal	2	50% Vegetation removal	1.3514	0.3730	0.00124	**0.04159**
2	50% LL removal	2	Control	0.1160	0.3702	0.75667	1.00000
2	50% LL removal	3	100% LL removal	0.01118	0.3759	0.97649	1.00000
2	50% LL removal	3	50% LL removal	1.0801	0.3061	0.00057	**0.02237**
2	50% LL removal	3	100% Vegetation removal	1.4719	0.3728	0.00053	**0.02138**

2	50% LL removal	3	50% Vegetation removal	1.4719	0.3908	0.00074	**0.02737**
2	50% LL removal	3	Control	0.5262	0.3666	0.16381	1.00000
2	100% Vegetation removal	2	50% Vegetation removal	-0.7624	0.3836	0.05637	1.00000
2	100% Vegetation removal	2	Control	-1.9978	0.3862	0.00001	**0.00062**
2	100% Vegetation removal	3	100% LL removal	-2.1026	0.3891	0.00001	**0.00031**
2	100% Vegetation removal	3	50% LL removal	-1.0337	0.3833	0.01158	0.30116
2	100% Vegetation removal	3	100% Vegetation removal	-0.6418	0.3266	0.05148	1.00000
2	100% Vegetation removal	3	50% Vegetation removal	-0.6419	0.3913	0.11117	1.00000
2	100% Vegetation removal	3	Control	-1.5875	0.3821	0.00027	**0.01106**
2	50% Vegetation removal	2	Control	-1.2354	0.3752	0.00279	0.07804
2	50% Vegetation removal	3	100% LL removal	-1.3402	0.3787	0.00144	**0.04602**
2	50% Vegetation removal	3	50% LL removal	-0.2713	0.3721	0.47243	1.00000
2	50% Vegetation removal	3	100% Vegetation removal	0.1206	0.3737	0.74951	1.00000
2	50% Vegetation removal	3	50% Vegetation removal	0.1205	0.3267	0.71273	1.00000

2	50% Vegetation removal	3	Control	-0.8252	0.3712	0.03521	0.73945
2	Control	3	100% LL removal	-0.1048	0.3787	0.78408	1.00000
2	Control	3	50% LL removal	0.9641	0.3700	0.01510	0.37242
2	Control	3	100% Vegetation removal	1.3560	0.3751	0.00122	**0.04159**
2	Control	3	50% Vegetation removal	1.3559	0.3907	0.00160	**0.04812**
2	Control	3	Control	0.4102	0.3104	0.18856	1.00000
3	100% LL removal	3	50% LL removal	1.0689	0.3753	0.00835	0.22537
3	100% LL removal	3	100% Vegetation removal	1.4607	0.3787	0.00062	**0.02363**
3	100% LL removal	3	50% Vegetation removal	1.4607	0.3914	0.00079	**0.02829**
3	100% LL removal	3	Control	0.5150	0.3749	0.18095	1.00000
3	50% LL removal	3	100% Vegetation removal	0.3919	0.3719	0.30177	1.00000
3	50% LL removal	3	50% Vegetation removal	0.3918	0.3887	0.32172	1.00000
3	50% LL removal	3	Control	-0.5539	0.3663	0.14333	1.00000
3	100% Vegetation removal	3	50% Vegetation removal	-0.00004	0.3840	0.99992	1.00000
3	100% Vegetation removal	3	Control	-0.9457	0.3711	0.01714	0.39416
3	50% Vegetation removal	3	Control	-0.9457	0.3863	0.02072	0.45584

Table F-8. Post-hoc mean comparisons for temperature analysis by treatment. Bonferroni adjustment used for p values.

Simple Effect Level	Application	Application	Estimate	StdErr	DF	t value	Pr > |t|	Adj P
NightDay D	1	2	-5.1538	0.4788	64.27	-10.76	<.0001	**<.0001**
NightDay D	1	3	-5.9891	0.5213	65.79	-11.49	<.0001	**<.0001**
NightDay D	2	3	-0.8353	0.5310	66.47	-1.57	0.1204	0.3617
NightDay N	1	2	0.5016	0.4745	64.3	1.06	0.2944	0.8832
NightDay N	1	3	0.4071	0.5120	65.37	0.80	0.4294	1.0000
NightDay N	2	3	-0.09449	0.5193	66.29	-0.18	0.8562	1.0000

Table F-9. Post-hoc mean comparisons for humidity analysis by NightDay and treatment application. Bonferroni adjustment used for p-values.

Simple Effect Level	Application	Application	Estimate	StdErr	DF	t value	Pr > |t|	Adj P
NightDay D	1	2	-2.6456	0.2002	62.36	-13.21	<0.0001	**<0.0001**
NightDay D	1	3	-3.3818	0.2171	62.93	-15.58	<0.0001	**<0.0001**
NightDay D	2	3	-0.7362	0.2209	63.55	-3.33	0.0014	**0.0044**
NightDay N	1	2	-0.3122	0.1988	62.5	-1.57	0.1215	0.3646
NightDay N	1	3	-0.2943	0.2153	62.77	-1.37	0.1766	0.5298
NightDay N	2	3	0.01789	0.2187	63.73	0.08	0.9350	1.0000

CURRICULUM VITA

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EDUCATION

PhD in Ecology, Utah State University, Logan, UT, May 2012. Passed qualifying exam, April 2009, and defense December 2, 2011.
Thesis title: A Coupled Human and Natural Systems Approach to Understanding an Invasive Frog, *Eleutherodactylus Coqui*, in Hawaii
Thesis advisors: Mark Brunson and Karen Beard
Thesis committee members: Thomas Edwards, Jr., Edward (Ted) Evans, Christopher Monz

MS in Natural Resources and Environmental Sciences, University of Illinois at Urbana-Champaign, Urbana, IL, 2007
Thesis title: Environmentally Responsible Behavior Precursors: Influences from a Zoo-Based Non-Formal Environmental Education Program
Thesis advisor: Joanne Vining
Thesis committee members: Courtney Flint, Neil Knobloch, Carol Saunders

BS in Zoology, Psychology and Spanish, University of Wisconsin-Madison, Madison, WI, 2005
Independent Project title: Female preference for male body size in threespine stickleback
Project advisor: Janette (Jenny) Boughman

RESEARCH EXPERIENCE

PhD Candidate, Department of Environment and Society, Utah State University, 2007-2011

- Developed three research projects as part of my dissertation including two field studies in Hawaii, one large-scale experiment, and one large mailing survey

***PhD Student*,** Department of Environment and Society, Utah State University, 2007-2008

- Developed a survey to assess Utah rural landowners' knowledge, information sources, and management goals

MS Student, Department of Natural Resources and Environmental Sciences, University of Illinois at Urbana-Champaign, 2006-2007

- Assisted in projects related to the human-nature experience
- Conducted literature reviews, various statistical analyses and manuscript preparation

Department of Plant Biology, University of Illinois at Urbana-Champaign, 2005-2006

- Completed DNA extractions on loculoascomycete fungi
- Prepared samples for PCR analysis

Undergraduate Student, Department of Zoology, University of Wisconsin-Madison, 2003-2005

- Developed independent project examining female mating preference in threespine stickleback
- Awarded the prestigious Hilldale Undergraduate Research Fellowship for my independent project, 2004
- Awarded the Tri Beta (Biological Honor Society) Research Scholarship Foundation Grant for my independent project, 2003

GRANTS

Graduate Student Senate Project awards, Utah State University, Spring 2011, $1,000.

Ecology Center Graduate Research Support award, Utah State University, Summer 2010-Spring 2011, $4,000.

Ecology Center Graduate Research Support award, Utah State University, Summer 2009-Spring 2010, $3,000.

Vice President of Research Catalyst (RC) Seed Grant Program, Co-PI, "Behavioral, Attitudinal, and Ecological Factors Influencing the Management of Invasive Frogs in Hawaiian Agro Ecosystems", Spring 2009- Fall 2009, $20,000.

Ecology Center Graduate Research Support award, Utah State University, Summer 2008-Spring 2009, $4,000.

Tri Beta (Biological Honor Society) Research Scholarship Foundation Grant, University of Wisconsin-Madison, 2003- $500.00

FELLOWSHIPS AND SCHOLARSHIPS

Xi Sigma Pi Natural Resources Honor Society, inducted March 4, 2009.

Nominee, American Association for the Advancement of Science, Program for Excellence in Science, Fall 2008. Science subscription.

Ecology Center Travel Award, Utah State University, Spring 2008, $636.08.

Graduate Student Senate Travel Award, Utah State University, Fall 2007, $300.00.

S.J. Quinney Ph.D Fellowship, Utah State University, 2007-2011, $20,000 per year for four years ($80,000 total).

Stapp Scholarship for North American Association of Environmental Educators conference and research symposium, 2007, $340.00

Human Dimensions of Environmental Systems Scholar, University of Illinois at Urbana-Champaign, 2006-2007, $15,950.

Natural Resources and Environmental Sciences Educational Opportunity Travel Grant, University of Illinois at Urbana-Champaign, 2006, $350.00

Hilldale Undergraduate Research Fellowship, University of Wisconsin-Madison, 2004-Spring 2005, $4000.00

PUBLICATIONS (IN PRINT) *My name has legally changed from Emily A. Price to Emily A. Kalnicky

Vining, J., Merrick, M., and ***Price, E. A.** (2008). The distinction between humans and nature: Human perceptions of connectedness to nature and elements of the natural and unnatural. *Human Ecology Review*, *15*(1), 1-11.

Head, M. L., ***Price, E. A.**, Boughman, J. W. (2009) Body size differences do not arise from divergent mate preferences in a species pair of threespine stickleback, *Biology Letters*, 5(4): 517-520.

***Price, E. A.**, Vining, J., and Saunders, C. D. (2009). Intrinsic and extrinsic rewards in a non-formal environmental education program. *Journal of Zoo Biology*, 28: 361-376.

Beard, K. H., ***Price, E. A.,** and Pitt, W. C. (2009). Biology and Impacts of Pacific Island Invasive Species: 5. *Eleutherodactylus coqui*, the Coqui frog (Anura: *Leptodactylidae*). *Pacific Science* 63: 297-316.

Brunson, M., and ***Price, E. A.** (2009). Information use and delivery preferences among small-acreage owners in areas of rapid exurban population growth, *Journal of **Extension***, **47(5) Article 5FEA4. [Available online at http://www.joe.org/joe/2009october/a4.php].**

PUBLICATIONS (IN REVIEW OR PREPARATION)

Kalnicky, E. A., Beard, K. H., and Brunson, M. W. (2012). Community level response to habitat structure manipulations: An experimental case study in a tropical ecosystem. Manuscript in prep for submission to *Forest Ecology and Management*.

Kalnicky, E. A., Brunson, M. W., and Beard, K. H. (2012). Experience versus rumor: Management behavior for an invasive frog in Hawaii depends on exposure-level to the invader. Manuscript in prep for submission to *Environment and Behavior*.

Kalnicky, E. A., Brunson, M. W., and Beard, K. H. (2012). Learning to live with an invader: Hawaii coqui frog invasion as a complex social-ecological system. Manuscript in prep for submission to *Ecology and Society*.

Kalnicky, E. A., Vining, J., and Saunders, C. D. (2012). Connection with nature: A family pattern? Manuscript in review with *Environmental Education Research*.

Kalnicky, E. A., Vining, J., and Saunders, C. D. (2012). Program evaluation of zoo-based non-formal environmental education program designed to enhance participants' caring for nature. Manuscript in review with *Visitor Studies*.

CONFERENCE PRESENTATIONS *My name has legally changed from Emily A. Price to Emily A. Kalnicky

***Kalnicky, E. A.**, Beard, K. H., and Brunson, M. W. Resource availability and invasive frog (*Eleutherodactylus coqui*) density in Hawaii. 96th ESA Annual Meeting (August 7-12 2011), Austin, TX.

***Kalnicky, E. A.,** Beard, K. H., and Brunson, M. W. Encouraging Hawai'i landowners to participate in coqui management: Insights from a public attitude survey. Abstract submitted and accepted for 2011 HCC conference, Honolulu, HI.

***Kalnicky, E. A.**, Brunson, M. W., and Beard, K. H. How attitudes, social norms, and control are related to management behavior of an invasive frog (*Eleutherodactylus coqui*) in Hawaii. 17th International Symposium on Society and Resource Management, Madison, WI, June 4-8, 2011.

***Price, E. A**., Brunson, M. W., & Beard, K. H. What about the people? The importance of understanding human attitudes, knowledge, and behavior in control of *Eleutherodactylus coqui*. 1st International Conference on the coqui frog, Hilo, HI, February 7th, 2008.

***Price, E. A.** What's all the noise about? The human side of an invasive frog in Hawaii. EcoLunch, Utah State University, Logan, UT, January 18th, 2008.

***Price, E.** Environmentally Responsible Behavior Precursors: Influences from a Zoo-Based Non-Formal Environmental Education Program. 36th Annual Conference of the North American Association of Environmental Educators, Virginia Beach, Virginia, November 14th, 2007.

***Price, E.**, Vining, J. and Saunders, C. Conservation Behavior: The Role of a Non-formal Environmental Education Program and Intergenerational Influences on short and long-term behavior. 14th International Conference of the Society for Human Ecology, Bar Harbor, Maine, October 20, 2006

***Price, E. A.** Body Size and its Role in Speciation of Threespine Sticklebacks (*Gasterosteus spp*). Seventh Annual Undergraduate Symposium, University of Wisconsin-Madison, April 12, 2005

***Price, E. A.** Body Size and its Role in Speciation of Threespine Sticklebacks (*Gasterosteus spp*). Northcentral Tri-Beta District Convention, University of Wisconsin-Green Bay, April 23, 2005

- Awarded 2nd Place in the Frank G. Brooks Award for Excellence in Student Research

INVITED PRESENTATIONS *My name has legally changed from Emily A. Price to Emily A. Kalnicky

***Price, E. A.** The human side of the coqui frog invasion in Hawaii. The Rotary Club of South Hilo, HI, June 15, 2010.

***Price, E. A.** and Vining, J. Evaluation of the Nature Swap Program and its Relationship to Environmentally Responsible Behavior Precursors. Brookfield Zoo, Brookfield, IL, July 20, 2007.

TEACHING EXPERIENCE

Bilingual Substitute Teacher, *Madison Metropolitan School District, Madison, WI, 2011*

- Teaching pre-schoolers through highschoolers in all subject areas
- Flexibility in following lesson plans or coming up with lessons on short notice

Middle-school Afterschool Program Leader**,** *Madison School Community Recreation, Madison, WI, 2011*

- Responsible for leading afterschool activities for at-risk middle-school students 2 days a week
- Assisted unemployed adults with computer services as well as resume and job applications

Community Education Intern**,** Third Millennium Alliance, Camarones, Ecuador, 2011

- Designed curriculum for 1st through 7th graders to learn English
- Taught entirely in Spanish
- Organized and ran activities for women in the community

Teaching Assistant, Integrative Biology 100/101, University of Illinois at Urbana-Champaign, 2005-2006

- Conducted weekly discussion and laboratory sessions for 27 students Fall 2005 and 49 students Spring 2006
- Developed lesson plans from material provided by course coordinator
- Prepared and graded quizzes and out of class written assignments
- Received campus teaching awards based upon student evaluations of teaching performance for two consecutive terms
- Listed among top 10% of teachers rated at the university for Spring 2006 semester

Graduate Teaching Certificate (GTC), University of Illinois at Urbana-Champaign, 2005-2006

- Participated in over 9 hours of continuing education related to teaching
- Attended professional development seminars
- Participated in videotaped critiques of teaching
- Received student feedback and evaluations

Study Skills Assistant Coordinator**,** University of Wisconsin-Madison, 2004-2005

- Collaborated on the development, organization, and presentation of workshops for student organizations, residence halls, and other academic programs (groups of 5 to 20 students)
- Counseled students in one-on-one appointments on time management and other study skill techniques

PEOPLE (Pre-College Enrichment Opportunity for Learning Excellence) Animal Behavior Instructor, University of Wisconsin-Madison, 2003

- Designed and taught a one week summer course on animal behavior to 30 underrepresented students who had just completed the 9th grade
- Planned, designed, and implemented course content, objectives, and class activities in collaboration with local high school teacher

INFORMAL TEACHING ACTIVITIES

English Language Center Volunteer**,** English Language Center of Cache Valley, Logan, UT, 2008-2009

- Helped to lead conversation groups with various levels of students trying to learn English
- Worked as teacher's aide in completing activities designed to improve English with groups of 15 to 20 students

Convo Partner, University of Illinois at Urbana-Champaign, 2006-2007

- Worked weekly with two international students to aid in improving their English conversational skills

Education/Public Outreach Committee member**,** The Illinois Wildlife Society, University of Illinois at Urbana-Champaign, 2006-present

- Worked with a team to lead an initiative to establish newspaper recycling to support the veterinary sciences department on campus
- Attended monthly club and board meetings and presented education opportunities for club members

New TA Orientation Facilitator, University of Illinois at Urbana-Champaign, 2006

- Led small group sessions for new TAs in the college of ACES (Agriculture, Consumer and Environmental Sciences)
- Facilitated discussion in the topics of Getting started in the Classroom, Questioning Strategies and Planning a Class Session

PROFESSIONAL MEMBERSHIPS

Ecological Society of America
Xi Sigma Pi Natural Resources Honor Society
The Wildlife Society
Society for Human Ecology
Beta Beta Beta Biological Honor Society
Phi Eta Sigma Honor Society
Society for Conservation Biology
North American Association of Environmental Educators

UNIVERSITY SERVICE

Member of the College of Natural Resource's Graduate Student Council (GSC), 2007-2011
Environment and Society Graduate Student Representative to the GSC, 2007-2009

PROFESSIONAL SERVICE

Manuscript reviewer for *Environmental Education Research*
Co-Founder of nonprofit organization, Camarones Community Coalition, a partnership with a rural Ecuadorian community and groups in the United States

LANGUAGES/SKILLS

Fluent in Spanish
Proficient in website design through use of CSS, XHTML, HTML, and Dreamweaver
Proficient in statistical software programs SAS, SPSS, R, MARK, DISTANCE, AMOS
Proficient in Microsoft products including Word, Excel, PowerPoint