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Economic Impacts of *E. Coqui* frogs in Hawaii

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1. Introduction

Hawaii's geographical isolation has resulted in the development of unique and fragile ecosystems in which the arrival of a new species may create dramatic changes in the ecology, and now the economy, of the islands. Successful establishment rates for new species before the arrival of humans in the early 1st millennium AD may have been as low as one new species every 10,000 years (Loope, 1997). Only one terrestrial mammal, a bat (now extinct), reached the island chain without human assistance. Many other suborders are unrepresented; for example, the islands have no native snakes or frogs.

Today, combined purposeful and accidental arrival and establishment rates are in the order of hundreds per annum. The coqui (*Eleutherodactylus coqui*) is one of two species of small tree frogs that has arrived and become established in Hawaii since the 1980s. The frog has no predators and the islands are postulating both ecological and economic impacts. The male emits a loud "ko-kee" mating call at night that dominates the audioscape where it occurs. We describe the anticipated effects and quantify a lower bound estimate of damages generated by reductions in property values due to the current invasion.

2. Background and Methodology

The primary economic effect of the frog is noise pollution. The combined lack of predation and competition for resources has resulted in densities reaching 55,000 frogs per hectare¹, more than double the highest densities in the frog's native Puerto Rico (Beard & Pitt, 2005). The males' calls, which are individually between 80-90 dBA at 0.5 m, now extend from an hour before sunset until dawn. The Hawaii Department of Health sets the threshold for minimizing impacts to human health and welfare at only 70 dBA (Department of Health, Hawaii Revised Statutes Section 324F-1). We concentrate on elucidating these damages through changes in property values. Economic theory suggests that property values for locations with noise pollution should be lower than comparable properties without. Since the frog's calls reach approximately 500 to 800 meters, we investigate whether properties within this range of a registered coqui complaint trade at lower prices than those beyond that perimeter.

A secondary economic effect with concentrated impacts on one important Hawaiian industry comes from losses to the nursery industry. The suspected entrance vector for the frog to Hawaii is in plant media transported in the nursery trade; regardless, many nurseries have frogs present now. Demand for frog-free certification is increasing among both local and off-island customers. Informal surveys of island nurseries indicate both that sales revenues are declining and costs are rising as nurseries try to accommodate the frog's presence. The sales value of floricultural products in Hawaii has increased from \$68.2 million in 1995 to \$92.9 million in 2004, though this is down about 4.5% from 2003's level of \$97.0 million (Jerardo, 2005). Greenhouse/ nursery products are the largest agricultural commodity for the state, accounting for 15% of Hawaii's \$621.6 million agricultural output (www.bea.gov). The big island of Hawaii (Hawaii county)

¹ Densities of up to 133,000 per ha have been recorded on the island of Hawaii.

accounts for the majority of this production (\$50.5 million for 2004); of the 2,415 acres devoted to greenhouse and nursery products in Hawaii county, only 530 acres are not open field (Hawaii Agricultural Statistics Service, 2005). Protecting these open field nurseries from frog infestation and re-infestation thus is expected to be quite costly.

The primary expected ecological effect stems from the anticipated increase in biomass. There is concern that the frog preys on native arthropods already experiencing pressures from non-native bird species, and perhaps more importantly, creates a prey base capable of sustaining juvenile Brown treesnake (*Boiga irregularis*) populations. The imminent threat of arrival of the BTS to Hawaii² now has a significantly increased probability of establishing and causing significant economic damages. Elsewhere, we have estimated the damages from an optimally controlled snake invasion, in which populations are maintained through vigilant search and removal at very low levels, at \$17.8 million, and the costs of an uncontrolled invasion at \$138 billion (Burnett et al. 2006). If the presence of the frog increases the probability of the establishment of a viable snake population by even so little as 1%, the frog is essentially contributing \$1.8 million in expected present value damages to Hawaii's economy from this increased risk under the best case scenario in which the snake population is caught and regulated early.

3. Model

We use a standard hedonic pricing model to evaluate the effect of registered coqui complaints on property values. Using this theory, we consider that individuals buy and sell properties as bundles of characteristics, such as zoning, improvements, and location, and these characteristics are what generate the economic value of the property. Using a subset of real estate transactions from 1995 to 2005 for Hawaii county, we parse the price of the properties by their characteristics, or hedonic attributes. Though price is clearly a function of many attributes, using the tax authority's myriad delineations of neighborhood (N), we are able to isolate the impact of the frogs (F), not yet included in the value assessments, from the other defining characteristics of property values about which we are not particularly concerned. Thus, the price of a property can be considered as a function of the district, the acreage, the proximity of frog complaints, the year of the transaction, whether the property has housing structures, broad zoning class, and finely gradated neighborhoods:

$$P_i = f(D_i, F5_i, F8_i, A_i, M_t, L_i, Y_i, Z_i, N_i),$$

Where P_i = natural log of sales price of transaction i ,

D_i = district (Puna, South Hilo, North Hilo, Hamakua, North Kohala, South Kohala, North Kona, South Kona, Kau),

$F5_i$ = indicator variable for frog complaint within 500 m previous to sale,

$F8_i$ = indicator variable for frog complaint between 500-800 m previous to sale,

A_i = natural log of acres for property i ,

M_t = natural log of average mortgage rate for month of transaction,

² Eight known cases of Brown treesnakes arriving in Hawaii have occurred since 1988.

Li = indicator variable for housing structures on property,
Yi = year of transaction,
Zi = zoning class (agriculture, apartment, unimproved residential, improved residential, conservation, industrial, resort, commercial)
Ni = tax assessor's neighborhood classification (1736 groupings).

We have data from the Hawaii County Tax Assessor's office on 50,033 real estate transactions and properties from 1995-2005, shown in Figure 1. We omit unvalidated sales and sales that fall within the lowest 1% or highest 1% of prices to eliminate outliers and pricing irregularities. This results in 37,228 properties, each of which changes hands between 1 and 6 times (average 1.2 times), for a total of 46,405 transactions. Figure 2 shows a close-up of the Puna district to provide additional clarity.

The presence of the frogs is not evenly distributed across districts, nor are districts expected to be similar (see Table 1). For these reasons, we explore the effect of district. As is clear in Table 1, Puna and Kau, adjacent districts within the immediate path of the active volcano Kilauea and fairly undeveloped, have considerably lower mean property prices than the other districts. The Hilo districts and Hamakua are on the wetter side of the island and have not had the real estate growth that the drier Kona and Kohala districts have experienced over the past two decades. We expect frog complaints to have a larger negative effect in districts where the frog is more prevalent, thus we expect Puna, South Hilo, and North Kona to show significant negative impacts from the frogs. The other districts may not yet be feeling the effects at measurable levels. Figure 1 illustrates the transactions by district.

We expect that frog complaints cause a greater reduction in property values the closer they are. Currently, we have frog complaints reported to USDA/APHIS or the Big Island Invasive Species Committee (BIISC) from 1997-2001. Unfortunately, the data after 2001 is not yet available in a format that provides sufficiently precise information about the location of the complaints. Thus, we use geographical information systems (GIS) software (ArcView) to match the verified frog complaints to property transactions, and generate indicator variables for whether a property is within 500m of a previous complaint and whether it is within 800m of a previous complaint. We then generate an indicator variable for whether a property is between 500-800m of a previous complaint. Though we would prefer to have data through 2005 to more closely match the transactions data, because the frogs are extremely difficult to eradicate, previous frog complaints should be highly indicative of future frog problems.

The remaining variables control for other characteristics of properties affecting their value. We expect that larger properties will trade at higher prices, but that these prices will not increase evenly across districts due to the differing uses and availability of large land tracts. In the more developed areas, we expect that increasing acreage does not have as significant an effect on price because the smaller home properties are more valuable. To allow the effect of acreage to vary by district, we interact the district with the acreage.

Higher mortgage rates should negatively affect the demand for real estate. Since we do not know the financial particulars of each transaction, we account for the anticipated availability of funds here by using the regional 30 year fixed mortgage rate reported to the St. Louis Federal Reserve for the month in which the transaction occurred.³

Only 32% of the transactions have residential structures present on the property at the time of the transaction. Properties with and without structures are expected to differ significantly in their prices, with structures adding considerably to the value. The influence on price of the characteristics of the structures such as square footage or structural age, however, is not considered independently identifiable from the tax assessor's neighborhood classifications, which consider these factors in determining the coding. Thus we collapse the variety of details pertaining to housing and community value into the 1,736 "neighborhoods" and an indicator variable for whether or not a property has a residential structure.

The year of the transaction is included to account for the increasing trend in real estate prices in Hawaii. The prices are in real (1992) dollars, so this does not pick up inflation effects, rather a positive relationship between year and price will indicate growth in the real estate market in general.

The zoning classes are included with the expectation that agricultural and conservation land will garner lower prices than other land, that apartments and unimproved residential will have lower prices than improved residential, and that commercial, industrial and resort properties will have higher prices.

4. Results

Table 2 shows the results for the regression including all of the districts (neighborhood controls not reported). Note that Puna is the omitted district and agriculture is the omitted zoning, so that the interpretation of the dummy variables is relative to the constant term representing Puna agricultural land transactions. Since we have transformed the continuous variables into logs, the results of our analysis will estimate elasticities. Thus, a one percent change in acreage, for example, will generate an estimated percent change in price indicated by the coefficient in column 2, Table 2, or 0.43 percent.

From the table, we see that most variables have the expected sign and influence on price. Virtually all variables are significantly different than zero at the 99% level (P-value < 0.01). The overall fit of the regression is quite good, with an R^2 of 0.86. Due to the wide variation across districts, heteroskedasticity was suspected. The Breusch-Pagan test for linear heteroskedasticity indicated its presence and the Huber-White robust standard errors thus were used for correcting the errors.

³ <http://research.stlouisfed.org/fred2/series/MORTG/>

The impacts are in general fairly small⁴, with only the residential structure and industrial property indicators, in addition to some neighborhood indicators (not reported), generating impacts on price greater than 1%.

The presence of frogs, however, does have a significant negative impact on property values. For properties within 500 meters of a complaint, property values decline 0.16%, or about 1/3 as much as values decline from a 1% increase in mortgage rates (-0.45%). For properties within 800m but not within 500 meters, property values decline less severely, at 0.12%. This is about 1/4 of the drop from a 1% increase in mortgage rates.

For additional perspective, we consider the effect of acreage by district. To interpret these coefficients, recall that Puna is the omitted district, so that the coefficient on log acres (0.46) corresponds to Puna, and that the interaction terms are the change in slope from that coefficient for the other districts. The drop in property values from complaints within 500m is just slightly lower in magnitude than the increase in property values from a 1% increase in acreage of land included in a sale in North Kona (0.17%) or South Kohala (0.19%), the most expensive districts. The drop in property values from complaints between 500m and 800m is approximately the same as a 1% increase in acreage of land included in a sale in South Kona (0.12%).

Hawaii county reports a median value of owner-occupied housing of \$153,700 for the year 2000 across 29,914 specified owner-occupied housing units (US Census Bureau, 2000a). Considering just this limited definition for those receiving damages from the frogs (excluding rental properties, commercial, industrial, or agricultural properties, or tourism), the total is estimated at \$7.4 million dollars in direct property value loss if the frogs were within 500m of all owner-occupied properties. In 2000, there were also a reported 16,183 renter-occupied housing units with monthly median contract rents of \$553 (US Census Bureau, 2000b). This adds another potential \$0.2 million in direct damages if rents reflect the property value and drop accordingly in the presence of frogs.

5. Conclusions and Extensions

We find that the presence of the noisy coqui frog in Hawaii county has begun to lower property values. An official complaint of the frog within 500m reduces property values 0.16% and between 500m and 800m reduces property values 0.12%.

If the frog spreads across all residential properties, direct damages to property values are estimated at a minimum of \$7.6 million. Since agricultural lands are also included in the data, we consider the lower property values in the presence of frogs to reflect expected losses in profitability for floriculture and nursery products. With annual sales values of \$50.5 million in these commodities, a loss of 0.16% per annum results in another \$81,000 in losses per year for the county.

⁴ The large negative constant reflects the sale year starting at 1995.

The frog has already spread to three other Hawaiian islands: Maui, Oahu, and Kauai. Populations on these islands are currently small but rapidly expanding. Real estate values on Oahu and Maui are considerably higher than the Big Island, and the additional threat presented by the ecological damages is significant.

Changes in property values such as those found here frequently reflect the widespread and diverse economic losses due to invasive species. The changes in price due to the invasive frog in the Hawaii case are similar though smaller than the estimated impacts on price calculated in a hedonic study of property values reduced by the defoliation of hemlock trees due to the presence of hemlock woolly adelgids (HWA) in northern New Jersey. This study finds that the deterioration in aesthetic values from the defoliation to be between 0.7% and 0.95% of the property's values. (Holmes et al, 2005).

Continued research using hedonic pricing methodology may begin to identify standard parameters for damages to a variety of environmental damages. The evolution of GIS technology and the increasing ability to pair spatial and economic data is starting to simplify the quantification of previously unidentifiable losses. The availability of such damage estimates is the first step in dramatically increasing the quality of policy debates regarding the provision of environmental goods and services, including efforts to prevent and control invasive species.

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Figure 1

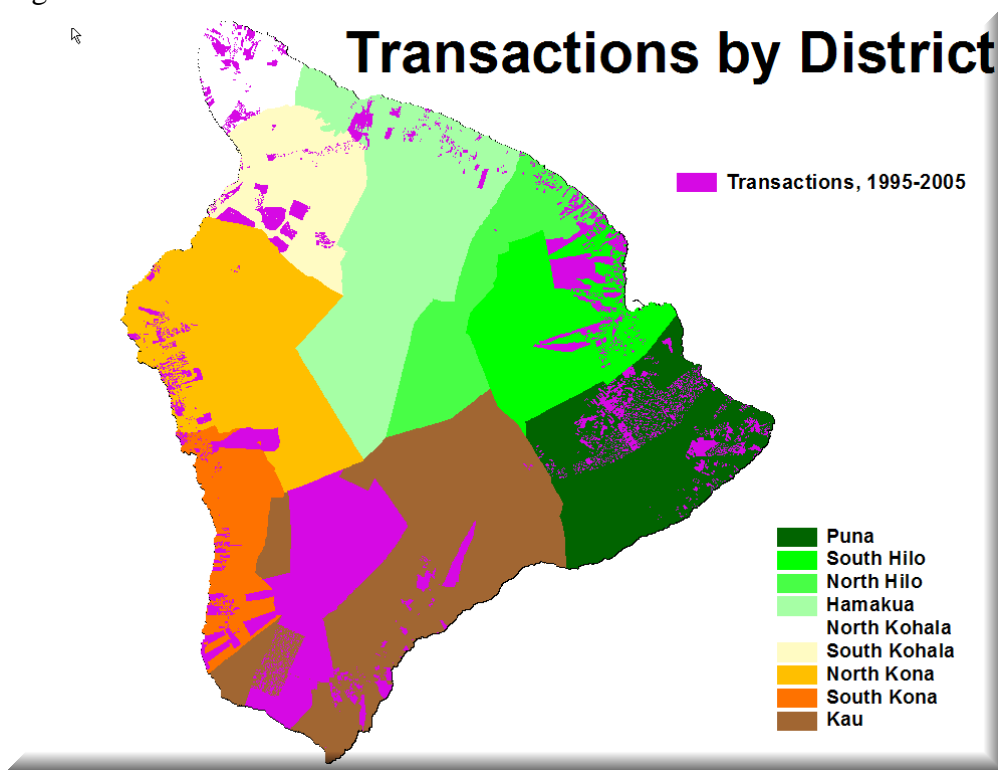


Figure 2

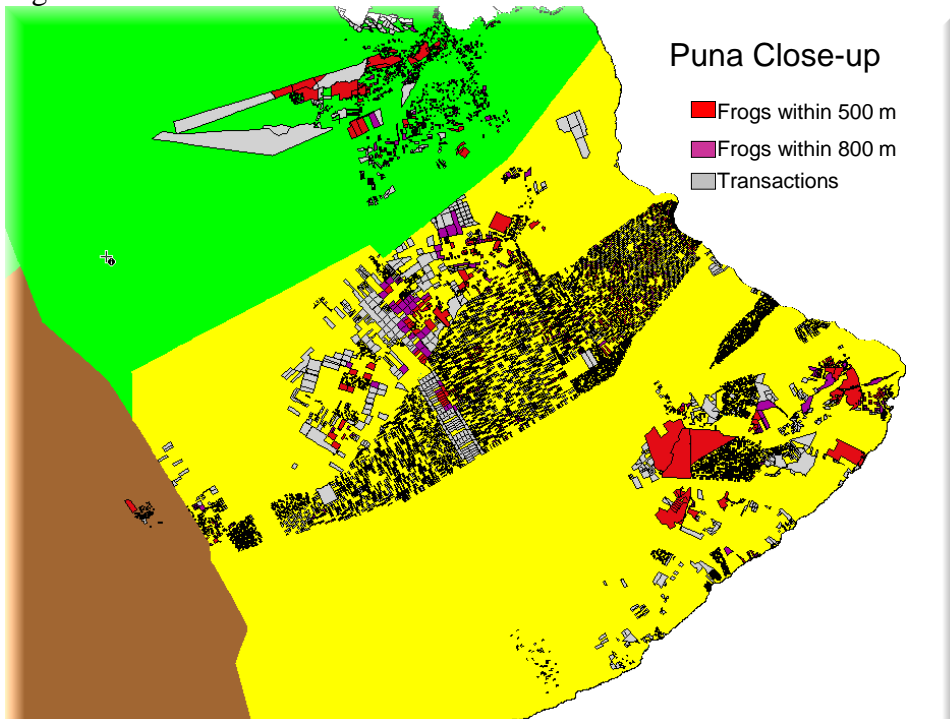


Table 1. District Level Summary Statistics

District	Number of transactions	Mean Transaction Price (\$) (standard error)	Mean fraction of properties within 500m of frog complaints (standard error)
Puna	20,914	25,912 (40,177)	0.17 (0.38)
South Hilo	4,163	99,130 (81,389)	0.37 (0.48)
North Hilo	412	128,321 (110,007)	0.00 (0)
Hamakua	683	123,091 (109,196)	0.02 (0.13)
North Kohala	1,452	179,028 (153,884)	0.01 (0.09)
South Kohala	4,595	197,095 (176,779)	0.21 (0.41)
North Kona	7,871	187,438 (150,954)	0.33 (0.47)
South Kona	1,427	124,315 (154,234)	0.14 (0.35)
Kau	5,049	23,362 (43,874)	0.00 (0.04)

Table 2. Regression Results (dependent variable: Log Price)

Variable	Coefficient	Standard error	P-value
Frog500m	-0.16	0.01	0.00
Frog800m	-0.12	0.01	0.00
Log Acres	0.43	0.02	0.00
S_hilo_acres	-0.12	0.04	0.00
N_Hilo_acres	-0.15	0.07	0.03
Hamakua_acres	-0.06	0.04	0.09
N_Kohala_acres	-0.08	0.03	0.01
S_Kohala_acres	-0.24	0.03	0.00
N_Kona_acres	-0.26	0.03	0.00
S_Kona_acres	-0.31	0.05	0.00
Kau_acres	0.17	0.07	0.02
Log mortgage rate	-0.45	0.04	0.00
Residential structure	1.27	0.01	0.00
Year of sale	0.07	0.00	0.00
Improved Residential	0.23	0.14	0.10
Apartment	0.31	0.17	0.07
Commercial	0.14	0.26	0.58
Industrial	1.98	0.17	0.00
Conservation	-0.19	0.20	0.34
Resort	0.32	0.19	0.09
Unimproved Residential	0.53	0.33	0.11
Constant	-139.57	4.51	0.00