FIRST INTERNATIONAL CONFERENCE ON THE COQUI FROG

February 7 – 9 , 2008
Hilo, HI

Naniloa Volcanoes Resort

Coqui Frog Working Group, Hawai'i Island

County of Hawai'i Mayor's Office | State of Hawai'i Dept of Agriculture | University of Hawai`i C T A H R | State of Hawai`i D L N R Forestry & Wildlife, Big Island Inv Sp Comm | University of Hawai'i at Hilo Biology Dept | US Dept of Agriculture Wildlife Services

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- University of Hawaiʻi at Hilo, Biology Department
- United States Department of Agriculture, Animal & Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center

These county, state and federal agencies are equal opportunity institutions.

Registration

The registration desk will be open from 4:00 pm on Thursday afternoon. An opening reception will be held in the Crown Room beginning at 6:00 pm until 8:00 pm. Registration will also be available on Friday morning starting at 7:30 am, and on Saturday morning starting at 8:30 am.

Poster Session

The poster session will be from 6:20 to 7:00 pm on Thursday evening during the reception in the Crown Room. Posters will be available for viewing throughout duration of the conference. Presenters will have access to the poster display area from 4:00 pm on Thursday. Please take down posters on Saturday at 11:30 am at the end of the conference.

Meals

Registration for all three days of the conference covers the opening reception (heavy pupu / appetizers, no-host bar), lunch on Friday, continental breakfast on Friday (from 7:30 am) and Saturday (from 8:15 am), and all refreshment breaks (beverages). Registration for Thursday only includes the opening reception. Registration for Friday only includes continental breakfast, lunch and refreshment break. Registration for Saturday only includes continental breakfast and a morning break. *Your name tag issued at registration will be your meal ticket during the conference – please bring it with you each day.*

Emergency Contact Information

Naniloa Volcanoes Resort phone: 808-969-3333

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MAYOR'S MESSAGE

On behalf of the County of Hawai'i, I extend a warm welcome to all of the participants of the First International Conference on the Coqui Frog being held on the Island of Hawai'i in Hilo on February 7-9, 2008.

We are honored to host such a significant gathering to share the most current research in herpetology, ecology, biology, and invasive species control being conducted world-wide to address the impact of the coqui frog within our county and across the state.

We commend the conference sponsors, planning committee, and the agencies of the Coqui Frog Working Group, who have stepped forward to assist our communities. We especially thank those individuals who have worked tirelessly in their own neighborhoods organizing work teams, writing for grant support, and looking out for neighbors who need assistance.

Thank you for coming to our islands and contributing to our understanding of the coqui frog. During your stay, we sincerely hope you will be able to take time to tour the beautiful Island of Hawai'i and enjoy the warm aloha of our people.

Aloha,

Harry Kim

Harry Kim
Mayor, County of Hawai'i

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HOUSE OF REPRESENTATIVES

STATE OF HAWAII
STATE CAPITOL
HONOLULU, HAWAII 96813

February 7, 2008
Honolulu

MESSAGE FROM REPRESENTATIVE CLIFT TSUJI TO THE ATTENDEES OF THE FIRST INTERNATIONAL CONFERENCE ON THE COQUI FROG

Aloha! I regret that legislative duties prevent me from joining all of you today at the First International Conference on the Coqui Frog.

This is a wonderful occasion to acknowledge the continuing commitment by researchers and concerned citizens to manage the coqui frog in Hawai'i and the world.

The House of Representatives recognizes the threat of invasive species and strives to be proactive in this regard. I am pleased that one of the top priorities of the 2008 Session is agriculture and invasive species. Current proposals would fund the biosecurity program within the Department of Agriculture to fight invasive species on several fronts, including administering pre-entry measures, conducting port of entry inspections, and mitigating the establishment of pests within the state. Another measure would fund the design and construction of joint biosecurity inspection facilities at Honolulu International Airport to provide inspection services for prevention of invasive species entry and destruction of Hawai'i's environment.

I would like to extend my warmest aloha to all the invited speakers, researchers, property management professionals, and concerned citizens here today. Your collective participation is a positive step in the effort to protect Hilo and the rest of Hawai'i from the coqui frog.

CLIFT TSUJI
Hawaii State Representative, Third District

FIRST INTERNATIONAL CONFERENCE ON THE COQUI FROG

Naniloa Volcanoes Resort ❧ Hilo, Hawai‘i USA ☙ February 7 -9, 2008

CONFERENCE PROGRAM

Thursday, February 7

4:00–8:00 pm	Registration Location: Crown Room entranceway
6:00–8:00 pm	OPENING RECEPTION Location: Crown Room (Heavy pupu / appetizers; No-host Bar)
6:00–7:00 pm	Welcome, Introductions, and Opening Remarks William Mautz, Coqui Frog Working Group, University of Hawai‘i at Hilo Lyle Wong, Hawai‘i Department of Agriculture William P. Kenoi
7:00-7:30 pm	Poster Session Location: Crown Room
7:45–8:00 pm	Reception Closing and Announcements

Your name tag issued at registration will be your meal ticket during the conference – please bring it with you each day.

Friday, February 8

PLENARY SESSION: Moderators: Christopher Jacobsen, Rogelio Doratt, and Shenandoah Marr

Location: Crown Room

8:00–8:30 am	Welcome, Announcements, and Pule (Registration desk and Continental breakfast available at 7:30 am) Harry Kim, Mayor, County of Hawai‘i
8:30–9:15 am	**The Cuban Treefrog in Florida: Ecology, Impacts, and Management** **Steve Johnson, Gulf Coast Res. and Ed. Center & Dept. of Wildlife Ecology and Conservation, Univ. of Florida, Plant City, FL**
9:15–9:40 am	The Unusual Development of *Eleutherodactylus coqui* Richard P. Elinson, Dept of Biological Sci., Duquesne Univ., Pittsburgh, PA
9:40–10:05 am	Population Density, Growth Rates, and Diets of *Eleutherodactylus coqui* at Eight Sites on the Island of Hawai‘i Karen Beard, Dept of Wildland Res. & the Ecology Center, Utah State Univ., Logan, UT

10:05–10:30 am	Color Pattern Polymorphism In *Eleutherodactylus coqui:* Evidence for Selection in Puerto Rico and Founder Effects in Hawai'i Eric O'Neil, Dept of Biology, Utah State Univ., Logan, UT
10:30–10:50 am	MORNING BREAK (beverages) Viewing of Poster Presentations
10:50–11:35 am	**The Cane Toad in Australia: Invasion Biology and Control Efforts** **Ross Alford, Marine & Tropical Biology, James Cook Univ. Townsville, Australia**
11:35 – 12:00 pm	Relation of Coqui Frog, *Eleutherodactylus coqui,* Population Density to Shrub and Forb Vegetation Structure in Hawaiian Forests William Mautz, Biology Dept., Univ. of Hawai'i at Hilo, HI
12:00 – 12:50 pm	LUNCH Crown Room Buffet Viewing of Poster presentations
12:50 – 1:50 pm	Panel Discussion of Coqui Frog (*Eleutherodactylus coqui*) Management Efforts in Hawai'i Moderator: Teya Penniman, Maui Invasive Species Committee (MISC) Brian Caleda, O'ahu Invasive Species Committee (OISC) Keren Gundersen, Kaua'i Invasive Species Committee (KISC) Adam Radford, Maui Invasive Species Committee (MISC) Hans Sin, State of HI, Dept of Land & Natural Res., Div. of Forestry & Wildlife, Hilo, HI
1:50–2:15 pm	To Use or Not To Use the Chytrid Pathogen, *Batrachochytrium dendrobatidis,* to Attempt to Eradicate Coqui Frogs from Hawaii Cynthia Carey, Dept of Integrative Physiology, Univ. of Colorado, Boulder, CO
2:15-2:40 pm	The Effects of Skin Hydration on the Susceptibility of the Frog, *Eleutherodactylus coqui*, to Citric Acid as a Control Agent Rogelio Doratt, Biology Dept., Univ. of Hawai'i at Hilo, HI
2:40–3:00 pm	AFTERNOON BREAK (beverages) Viewing of Poster presentations
3:00–3:45 pm	**Effect of Habitat Structure on Population Density of E*leutherodactylus coqui*** **Lawrence Woolbright, Siena College, Biology Dept, Loudonville, NY**
3:45–3:50 pm	Session Closing and Announcements

Friday Evening, February 8

4:30 pm	Depart for Field tour of coqui frog infestations Meet in the hotel parking lot for transportation Location: Lava Tree State Monument, Pāhoa, HI (see map at back) (Light refreshments will be available at the park)
8:00 pm	Return to Naniloa Volcano Resorts hotel

Saturday Morning, February 9

PLENARY SESSION: Moderators: Hans Sin and William Mautz
Location: Crown Room

8:45–9:00 am	Welcome and Announcements (Registration desk and Continental breakfast available at 8:15 am)
9:00–9:25 am	Sound Pressure Levels of Overnight Vocalization by Coqui Frogs (*Eleutherodactylus coqui*) Francis Benevides, Jr, Biology Dept., Univ. of Hawai'i at Hilo, HI
9:25–9:50 am	The Effect of Environmental Variables on Sound Pressure Levels of Chorusing Male *Eleutherodactylus coqui* Miya Warrington, Biology Dept., Univ. of Hawai'i at Hilo, HI
9:50-10:15 am	Does the Invasive Tree, *Falcataria moluccana*, Facilitate a Large Population Density of the Invasive Puerto Rican Treefrog, *Eleutherodactylus coqui*? Raymond McGuire, Biology Dept., Univ. of Hawaiʻi at Hilo, HI
10:15–10:35 am	BREAK (beverages) Viewing of Poster presentations
10:35–11:00 am	Parasite Loss and Introduced Species: A Comparison of the Parasites of the Puerto Rican Tree Frog, (*Eleutherodactylus coqui*), in its Native and Introduced Ranges with Comments on Potential Biological Control Shenandoah Marr, Coll. of Trop. Agric. and Human Resource, Univ. of Hawaii at Manoa, Hilo, HI
11:00–11:25 am	Mechanisms behind the Successful Invasion of Bullfrogs (*Rana catesbeiana*) in the Northwest United States Tiffany Garcia, Fisheries & Wildlife Dept, Oregon State Univ., Corvallis OR
11:25–11:50 am	A Sprayable Formulation for Humane Lethal Control of Cane Toads David J.Dall, Pestat Pty Ltd, University of Canberra, Bruce ACT 2617 Australia
11:50 – 12:00 pm	Evaluation and Closing

END OF CONFERENCE

Mahalo!

POSTER PRESENTATIONS

1. Effects of Pesticide Exposure on Native and Invasive Amphibians: A Synthesis through Meta-analysis
   Nick Baker, Dept of Fisheries & Wildlife, Oregon State University, Corvallis, OR

2. Acidic Calcium Sulfate (ACS-P) as a Non-toxic Agent for use in Controlling Coqui Frogs: A Product Introduction Field Study
   David P. Davis, Ono Loa Orchards, LLC, PO Box 1229, Kurtistown, HI

3. Predicting Niche Conservatism or Niche Divergence in *Eleutherodactylus coqui* using Ecological Niche Modeling
   Sarah Glavan, Dept of Biology, Univ. of La Verne, La Verne, CA

4. Distribution of Native and Invasive Crayfishes in Oregon's Willamette Valley: Exploring Synergy Between Invasive Crayfish and Bullfrogs
   Brett Hanshew, Dept of Fisheries & Wildlife, Oregon State Univ., Corvallis, OR

5. Control of the Coqui Frog, *Eleutherodactylus coqui*, (Anura: Leptodactylidae) in Plant Nurseries
   Arnold Hara, Coll. of Trop. Agric. and Human Resources, Univ. of Hawaii at Manoa, Hilo, HI

6. Impacts of "Vegetation Management" and "Trapping" on Coqui Frog Density and Behavior
   Christopher Jacobsen, Coll. of Trop. Agric. and Human Resources, Univ. of Hawaii at Manoa, Hilo, HI

7. What about the people? The importance of understanding human attitudes, knowledge, and behavior in control of *Eleutherodactylus coqui*
   Emily Price, Dept of Environment and Society & the Ecology Center, Utah State Univ., Logan, UT

Poster set up is Thursday, February 7 from 4:00 pm to 6:00 pm. Please be available for discussion and questions during the Poster Session from 6:20 – 7:00 pm that evening. The posters will be on view until 11:30 am on Saturday, February 9.

ORAL PRESENTATION ABSTRACTS

(*denotes presenter among multiple authors)

The cane toad in Australia: Invasion biology and control efforts

Alford, Ross A.
School of Marine and Tropical Biology, James Cook University, Townsville, Queensland 4811, Australia, Ross.Alford@jcu.edu.au

Approximately 100 cane toads (*Chaunus* (*Bufo) marinus*) were imported to Australia in 1935. In 1936 and 1937 their offspring were deliberately dispersed at numerous locations on the Queensland coast; their range has rapidly expanded to the north and west and more slowly to the south. Our best estimate of the present Australian population is approximately 2×10^8. Cane toads are relatively poorly adapted to the seasonal tropical environments they occupy in Australia, but are successful invaders because they are nomadic and highly fecund, and because all life history stages are toxic to many predators. Their nomadism causes high rates of invasion of new habitats: individuals do not adopt permanent home ranges, but move across the landscape at variable rates, which are controlled in part by their physiology and by seasonal changes in the availability of water. Toads at the invasion front differ in many aspects of their biology from toads in established populations, suggesting that natural selection over the history of the invasion may have produced a class of hyper-dispersive individuals. Female toads lay 7000 or more eggs each time they breed, can breed in any season, and may breed more than once per year. Survival from egg to adult is highly variable, with strong evidence for intraspecific density dependence. Mean survival is very low, with an overall average since introduction no greater than 0.038%. Efforts to control cane toads were initiated in the mid 1980s. Control efforts originally focused on finding self-replicating pathogens that could be introduced or dispersed on a large scale. No pathogens have thus far been found that do not also threaten native frogs. Work on locating potential pathogens is ongoing. Substantial research has also been directed at developing genetically modified viruses that could disrupt highly toad-specific pathways; very preliminary results show some promise but development is likely to require substantial time and additional funding. Recent research and conservation efforts have been more concentrated on two aspects of the problem: understanding how toads affect native organisms and systems and preventing or mitigating these effects, and slowing the natural rate of spread of toads and preventing accidental introductions. Mitigation efforts have focused on native marsupial predators, and have thus far included establishing relocated predator populations on toad-free islands. There have also been proposals for creating zones of low toad density using a combination of hand collection and trapping. Preliminary work in the Northern Territory suggests that it may be possible to do this, although continuing effort is required to maintain low densities. In Western Australia, a combination of volunteer citizens groups and government agencies has been working with some success to reduce the rate of spread of toads along their natural invasion front and prevent the accidental transport of toads into new areas ahead of the invasion front. Their methods include hand collection, large-scale spraying of postmetamorphic toads, trapping, and the use of sniffer dogs to detect toads that are being accidentally transported in vehicles.

Population density, growth rates, and diets of *Eleutherodactylus coqui* at eight sites on the Island of Hawaii

Beard, Karen H.
Department of Wildland Resources and the Ecology Center, Utah State University, Logan, UT 84322-5230, karen.beard@usu.edu

Critical components for determining invasion potential and mechanisms of control are robust estimates of densities and vital rates, and factors limiting densities across habitat types. To address this lack of information for *Eleutherodactylus coqui* on the Island of Hawaii, I studied eight separate populations for the past three years. Using mark-recapture methods, I estimated *E. coqui* densities, survival rates, and growth rates of adult frogs. In addition, I investigated the rate and impact of *E. coqui* invertebrate consumption at each site. Finally, to identify factors that potentially limit *E. coqui* densities, I related densities to snout-vent length (SVL), invertebrate abundance, and habitat structure in the understory. I found that for all sites surveyed, except for Waipio Overlook and Kalopa State Park, mean adult estimates were greater, and three times greater (100 adults/100 m^2) at three of the sites, Lava Tree State Park, Manuka Natural Area Reserve (NAR), and Paradise Park, than the highest long-term estimates from Puerto Rico (33 adults/100 m^2). Total (adult and subadult) *E. coqui* density ranged from 2,200 to 50,000 frogs/ha across the sites, and at four of the eight study sites total densities were at least 1.7 times greater (35,000 frogs/ha) than mean long-term, total density estimates from Puerto Rico (20,570/frogs ha). The highest total density estimate was for Manuka NAR in 2004 (91,000 frogs/ha). Across sites, survival rate ranged from 0.10 to 0.47, and mean growth rate was 0.0078 mm/day (± 0.007 SD, n = 87) for males and 0.0097 mm/day (± 0.0088 SD, n = 11) for females. Multivariate analyses of diet content and invertebrates collected at each site suggest that most prey was from the leaf litter. Because frogs contained 7.6 ± 7.6 SD prey items per stomach (n = 696 frogs), *E. coqui* are estimated to be consuming over 650,000 prey items/ha/night at high density sites. Non-native ants (Hymenoptera: Formicidae) and amphipods (Amphipoda: Talitridae) comprised 30% and 22%, respectively, of the total prey items consumed, and were more abundant in stomachs than in the environment indicating a preference for these prey. Arthropod orders containing endemic species that appear most vulnerable to *E. coqui* predation included Acarina (mites), Coleoptera (beetles), Collembola (springtails), and Diptera (flies), which each made up > 2% of the diet of *E. coqui*. Dominant prey items differed among study sites suggesting that frogs are opportunistic and forage on abundant prey. Across sites, there was a negative relationship between *E. coqui* SVL and density, suggesting that resources are limiting. There was a positive relationship between *E. coqui* density and invertebrate abundance, but it was not significant. There was a strong, positive relationship between *E. coqui* density and understory structure suggesting that control should be targeted to areas with great understory structure and that removing understory structure should reduce *E. coqui* densities.

Sound Pressure Levels of Overnight Vocalization by Coqui Frogs (*Eleutherodactylus coqui*

Benevides, Francis L. Jr.*, William J. Mautz, and Miyako Warrington
University of Hawai'i at Hilo, HI, 200 W. Kawili St., Hilo, HI 96720-4091, fb2@aloha.net

The nighttime chorus of the invasive Puerto Rican coqui frog (*Eleutherodactylus coqui*) is a new prominent feature in Hawaii. We characterized the overnight progression of sound pressure level (SPL) of male coqui frog populations in Hawaii (34 data sets) and Puerto Rico (4 data sets) using data logging SPL meters. Sound measurement was equivalent continuous sound, $L_{Aeq(1sec)}$. A bandpass filter range of 1 – 3.15 kHz was selected to encompass the coqui audio spectrum and to exclude most of the sound energy emanating from other sources. We also made simultaneous audio recordings along with SPL to help detect and identify other noise sources. The coqui chorus rises from daylight ambient SPL shortly before sunset. This SPL rise is relatively rapid until a plateau phase when SPL is relatively constant (within 1 dB of maximum SPL). The plateau phase is followed by a relatively slow decline in SPL until ambient daytime levels are reached shortly after sunrise. We applied a two pass moving average filter in the pressure domain (anti-logarithm of dB) to derive reference points and parameters of the chorus phases. Moving averaged data converted back to the dB domain were then used to define a piece-wise linear SPL model of the chorus phases: ambient daytime, rise, plateau, and fall. The plateau phase, duration from 0.38 ± 0.22 SD h to 1.78 ± 0.68 SD hours after sunset, appears to be the best opportunity to study coqui behavior consistent with the highest (68.1 ± 3.2 SD dB) levels of male vocalization.

Panel Discussion of Coqui Frog (*Eleutherodactylus coqui*) Management Efforts in Hawai'i

Caleda, Brian[1]*, Keren Gundersen[2]*, Adam Radford[3]*, and Hans Sin[4]*
[1]O'ahu Invasive Species Committee, 2551 Waimano Home Road, Building 202, Pearl City, HI 96782, bcaleda@hawaii.edu
[2]Kaua'i Invasive Species Committee, P.O. Box 1998, Lihue, HI 96766, keren.kisc@hawaiiantel.net
[3]Maui Invasive Species Committee, P.O. Box 983, Makawao, HI 96768, aradford@hawaii.edu
[4]State of Hawai'i, Department of Land and Natural Resources, Division of Forestry and Wildlife, 19 East Kawili Street, Hilo, HI 96720, hsin@dofawha.org

The coqui frog (*Eleutherodactylus coqui*) is native to Puerto Rico and was accidentally introduced to the State of Hawai'i through contaminated nursery products from the Caribbean. Since its introduction in the late 1980s, coqui have become widely dispersed, and in some areas population densities have reached 55,000 frogs/ha. Subsequently, the number of reported locations has steadily increased since the early 1990s. Surveys indicate that coqui populations have become established in nurseries, parks, residential communities, resort areas, and lowland forest habitats. However, substantial progress has been made on each of the infested Hawaiian Islands to mitigate the impacts of this invasive species. On

the island of Hawai‘i, the coqui is widely established and inter-agency efforts to manage population centers and distribute resources to community groups are ongoing. Eradication of the coqui frog is not considered attainable on the island of Hawai‘i and efforts there are focused on high-value areas. On Maui, nine naturalized populations are actively being controlled or monitored, while five populations are considered eradicated. One coqui population has been controlled on the island of O‘ahu with no coqui heard since November of 2006. One population of coqui frogs is actively being controlled on the island of Kaua‘i and eradication seems likely. Unfortunately, reintroduction of the species, public relations issues, terrain hurdles and more have hampered control efforts. This panel will focus on the current status of statewide management efforts and creative solutions to overcoming complex management issues.

To use or not to use the Chytrid Pathogen, *Batrachochytrium dendrobatidis,* to Attempt to Eradicate Coqui Frogs from Hawaii

Carey, Cynthia* and Lauren Livo
Department of Integrative Physiology, University of Colorado, Boulder, CO 80309-0354, careyc@colorado.edu

The economic devastation brought by coqui frogs *(Eleuthrodactylus coqui)* in Hawaii has raised the question concerning whether eradication of the frogs might be achieved by release of the chytrid pathogen, *Batrachochytrium dendrobatidis,* in Hawaii. This fungal pathogen has caused declines of amphibian populations and a few species extinctions world-wide. Although some amphibian species appear to be resistant to this pathogen, species from a wide variety of taxonomic groups, mostly of anurans, have proven variably susceptible. Declines in some populations of coqui in Puerto Rico have been linked to chytridiomycosis.
The purpose of this study was to test experimentally the susceptibility of coqui captured in Hawaii to this pathogen. After transport by air to the University of Colorado, groups of coqui were exposed for 24 hrs to 0 (control), 40, 100, 1000, or 1 M zoospores of isolate JEL#275 of *B. dendrobatidis.* Each individual was exposed in a separate container. Following exposures, they were held individually in 20% Holtfreter's solution and observed daily for deaths. To ensure that our culture of *B. dendrobatidis* was still virulent and had not become attenuated by culture in the laboratory, 9 yearling boreal toad *(Bufo boreas)* toadlets, were split into control and exposed groups. The exposed group was exposed to 1 M zoospores in the same solutions used for the coqui exposures.
All five of the boreal toads exposed to 1 M zoospores died within 31 days after exposure to *B. dendrobatidis* than 7 days following exposure tested highly positive at the time of death for *B. dendrobatidis* DNA, as judged by PCR. These results were very similar to previous studies in our laboratory in which all boreal toads exposed to 1 M zoospores for 24 hr died within an average of 26 days. These findings give us confidence that the culture of *B. dendrobatidis* in our lab had not attenuated by frequent passage to fresh broth. In contrast, coqui proved quite resistant to exposure to *B. dendrobatidis.* Although there was some mortality in each group, the pattern of mortality did not differ significantly among dosage exposures, as judged by the Mantel-Cox log-rank test ($P = 0.5770$). The major reason for the lack of mortality in exposure groups were that many of the exposed coqui did not test positive for *B. dendrobatidis* DNA, indicating that they were not

successfully infected during the 24 hr exposure despite being forced to be in constant contact with the solution containing the zoospores. These data, along with the effects of temperature on the ability to cause amphibian deaths with exposure to *B. dendrobatidis* and the problems of releasing a pathogen with unknown other hosts into the environment, suggest that eradication efforts using *B. dendrobatidis* will not prove successful and could prove very harmful to ecosystems in Hawaii.

A Sprayable Formulation for Humane Lethal Control of Cane Toads

Dall, David J.*, Joan Dawes, Ricky J. Spencer and Sally J. Campbell
Pestat Pty Ltd, LPO Box 5055, University of Canberra, Bruce ACT 2617 Australia, david.dall@pestat.com.au

The cane toad (*Bufo* [*Chaunus*] *marinus*) has the status of a toxic invasive pest in many areas outside its natural range. Commencing from a small deliberate introduction in the 1930s the cane toad has colonized a large area of Australia, and continues to extend its geographic range and environmental impact. In addition to ‘landscape scale’ effects, there are now an estimated 1.3 million households in cane toad-infested areas of Australia, and this number is expected to increase in the future. Instances of poisoning of pet dogs and cats in Australia are widely reported, and the toads also present a potential safety hazard for small children. The objective of work reported here was to develop a chemical formulation that could be used to safely, effectively and humanely kill cane toads in domestic settings. We have now successfully tested a formulation that can be applied as a topical aerosol spray dispensed from a pressurized spraycan. The formulation contains materials that rapidly anaesthetize the toad and subsequently kill it. The formulation has been shown to be 100% effective in killing cane toads in field trial settings in Australia, across a sample of animals differing in size by more than an order of magnitude (25-320 grams) and sourced from widely separated geographic locations. In our trials toads treated with the spray ceased moving in an average time of less than one minute, and died in as little as 10 minutes, but on average, about 45-50 minutes after treatment. In the period between their cessation of movement and death, toads remained motionless and silent, and exhibited no sign of distress. We are now working towards registration of the formulation as a pesticide in Australia, and believe that its potential utility extends to other cane toad-infested areas of the world.

The Effects of Skin Hydration on the Susceptibility of the Frog, *Eleutherodactylus coqui*, to Citric Acid as a Control Agent

Doratt, Rogelio E.* and William J. Mautz
Department of Biology, University of Hawaii at Hilo, 200 West Kawili Street, Hilo, HI 96720, Rogelio.Doratt@aphis.usda.gov

In 2002, 16% citric acid solution was approved for general use in controlling the rapid spread of the invasive Caribbean tree frog, *Eleutherodactylus coqui,* in the Hawaiian Islands. Since then studies have shown large variation in mortality from citric acid, possibly related to frog acclimatization to drought conditions. We reevaluated the efficacy of citric acid treatment in controlled comparisons of frog hydration status. Frogs were exposed to high (99%) or low (23%) relative humidity air while in ventral contact with liquid water, so that low humidity would dehydrate the skin without affecting whole body hydration. Sixteen percent and 8% citric acid solutions produced 100% mortality in both low and high relative humidity groups, but at 4% citric acid, there was a significant difference in survival rates. Frogs exposed to low humidity air with dehydrated skin had 4% citric acid mortality rates of 90-100%, while frogs exposed to high humidity with moist skin had mortality rates of 60-65%. At 2% citric acid exposure, frog mortality showed a similar pattern with further reduction: frogs exposed at low humidity with dry skin had mortality rates of 10-40% while frogs exposed to high humidity with moist skin had 0% mortality. Frog plasma osmolality was analyzed to 1) verify that humidity treatment did not affect body hydration and 2) test whether citric acid exposure affected body hydration as a possible mechanism of toxicity. There were no significant differences in plasma osmolalities between frogs that were exposed to citric acid or distilled water or between frogs that lived or died. Environmental drought conditions, with lower relative humidity that dehydrates frog skin, is expected to make frogs more susceptible to citric acid exposure. However, dry conditions are likely to induce frogs to seek cover and thus avoid contact with citric acid sprays.

The unusual development of *Eleutherodactylus coqui*

Elinson, Richard P.
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Like all members of the genus *Eleutherodactylus*, *E. coqui* is a direct developer. Mating occurs on land, and fertilization is internal. After laying, the large, 3.5 mm diameter eggs are brooded by the father for about three weeks, at which time free living froglets hatch from their jelly capsules. The elimination of the tadpole from the life history has led to radical alterations of development. With no larval feeding, more yolk is deposited in the egg to provide nutrition, and the addition of yolk has altered the structure of the egg. In *Xenopus laevis*, a frog with a tadpole, RNAs that are important for early embryo patterning are localized to the vegetal pole of the egg. In contrast, the orthologues of these RNAs are found near the opposite, animal pole of the *E. coqui* egg (Beckham, Nath, Elinson 2003 Evol Dev 5:562-71). Corresponding to this molecular shift, most of the tissues of the embryo's body arise near the animal pole (Ninomiya, Zhang, Elinson 2001 Dev

Biol 236:109-23). The yolk-rich vegetal region is solely for nutrition, much like the bird yolk. Unlike the bird yolk, the *E. coqui* yolk-rich region is divided into cells, and we named this novel tissue "nutritional endoderm" (Buchholz et al 2007 Dev Dyn 236:1259-72). After the yolk is used up, the nutritional endodermal cells die and disappear. Adult structures, like limbs and jaws develop early, giving the *E. coqui* embryo a frog-like appearance. Mechanisms of limb development appear conserved between *E. coqui* and other tetrapods, based on gene expression patterns and on the requirement for retinoic acid for forelimbs but not hindlimbs (Fang, Elinson 1996; Dev Biol 179:160-72; Lee, Elinson 2008 Applied Herp in press). Despite the early frog morphology, thyroid hormone is required for completion of development, as in species with metamorphosis from a tadpole to a frog (Callery, Elinson 2000 PNAS 97:2615-20). On the one hand, the unusual features of *E. coqui* development could provide targets for biological control measures. On the other hand, this derived development provides opportunities for teaching and research into how evolutionary change of embryos occurs. Education and advocacy could lead to a public acceptance and appreciation of this fascinating animal.

Mechanisms behind the successful invasion of Bullfrogs (*Rana catesbeiana*) in the Northwest United States.

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The question of what factors make some species successful invaders is one of the most pressing problems facing ecologists this century. Understanding the mechanisms that allow populations of some species to successfully expand in novel environments is essential for developing management strategies to limit the spread and ecological impact of biological invasions. Bullfrogs (*Rana catesbeiana*) are one of the 100 worst invasive species in the world and are involved in declines of many native species, particularly other amphibians, via predation and/or competition. Our research tests three general hypotheses for the invasion success of bullfrogs: 1) local adaptation to the new environment, 2) phenotypic plasticity in response to novel environmental conditions, and 3) bullfrogs act as a disease reservoir for a fungal pathogen, *Batrachochytrium dendrobatidis* (Bd), which has been implicated in catastrophic declines and extinctions of amphibians around the globe. These hypotheses link molecular genetics, controlled laboratory experiments, population modeling, and field surveys in a biogeographic framework in which the phenotypes and ecology of invasive bullfrogs will be compared to those of source populations in the native range. Molecular genetic tools have already been developed for bullfrogs, including a previous phylogeographic study in its native range and microsatellite primers. We have determined the source population of invasive bullfrogs in the Northwest United States bullfrogs using these molecular markers and comparing them with populations in their native range (Southeast United States). Determining source populations for the Northwest United States bullfrog complex allows us to now compare life history characteristics and measure trait divergence and/or plasticity in response to source vs. invasive environmental conditions.

The Cuban Treefrog in Florida: Ecology, Impacts, and Management

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The Cuban Treefrog (*Osteopilus septentrionalis*) is an established, invasive amphibian in Florida, with the earliest confirmed records in the state dating to the late 1920's from the Florida Keys. To date, breeding populations of this species are found as far north as Cedar Key on Florida's Gulf Coast, Jacksonville on the Atlantic Coast, and Gainesville in North-central Florida. Cuban Treefrogs continue to expand their range and individuals have been documented recently in coastal Georgia, South Carolina, Alabama, and Texas, as well as in the panhandle of Florida. Cuban Treefrogs thrive in human-modified habitats and appear to be the most common species of treefrog in suburban settings in central and southern Florida. They also are able to invade a variety of native habitats and are the most frequently encountered species of hylid at two study sites in Central Florida. Cuban Treefrogs are predators of native treefrogs, and there is mounting evidence that Cuban Treefrogs may be negatively affecting populations of native treefrogs. Lab experiments have shown that Cuban Treefrog tadpoles are superior competitors to tadpoles of at least two species of native frogs. Cuban Treefrogs are generalist predators, consuming a great diversity of invertebrate prey; as such, competition with native vertebrates in Florida is possible. Cuban Treefrogs are also a nuisance and are having impacts on the quality of life of Floridians. They enter homes through plumbing systems and are known to clog sinks and turn up in toilets. Their feces is unsightly and may accumulate on windows and doors of homes. During the spring and summer breeding season their calls can be annoying, and they will breed in ornamental fish ponds and swimming pools that are not maintained. Cuban Treefrogs are also having negative economic impacts. They invade electrical utility equipment in Central Florida, causing short circuits and interruption of power to customers. This results in revenue loss to utility companies due to repair costs and service disruption. Presently, management options for Cuban Treefrogs are limited. They can be managed locally by hand capture followed by humane euthanization. PVC pipe refugia may be deployed to increase the likelihood of capturing frogs. A commercially available chemical deterrent (Sniff-n-Stop) has proven effective for excluding Cuban Treefrogs in a controlled setting and has great potential to alleviate problems for electrical utility companies. This product could also have application in residential settings.

Parasite Loss and Introduced Species: A Comparison of the Parasites of the Puerto Rican Tree Frog, (*Eleutherodactylus coqui*), in its Native and Introduced Ranges with Comments on Potential Biological Control

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The Puerto Rican frog, *Eleutherodactylus coqui*, has invaded Hawaii and reached densities far exceeding those in their native range. One possible explanation for the success of *E. coqui* in its introduced range is that it lost its co-evolved parasites in the process of the invasion. We compared the parasites of *E. coqui* in its native versus introduced range. We collected parasite data on 160 individual coqui frogs collected during January-April 2006 from eight populations in Puerto Rico and Hawaii and evaluated their potential for biological control. Puerto Rican coqui frogs had higher species richness of parasites than Hawaiian coqui frogs. Parasite prevalence and intensity were significantly higher in Hawaii, however this was likely a product of the life history of the dominant parasite and its minimal harm to the host. This suggests that the scarcity of parasites may be a factor contributing to the success of *E. coqui* in Hawaii. The nematode *Rhabdias sp.* was recovered from 30% of the frogs examined in Puerto Rico and could be a useful biological control. Studies conducted on common toads (*Bufo bufo*) and cane toads (*Bufo marinus*) found a significant decrease in growth, food intake, locomotory performance, and survival rates in *Rhabdias*-infected toads versus uninfected toads. The results from these studies are encouraging that *Rhabdias sp.* may be an effective tool in managing populations and the rate of expansion of *E. coqui* by reducing the frog's fitness.

Relation of Coqui Frog, *Eleutherodactylus coqui,* Population Density to Shrub and Forb Vegetation Structure in Hawaiian Forests

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The potential for coqui frog control by landscape modification was examined at 12 plots (20 x 20 m) in east Hawaii Island forests. Adult frog population density was measured by mark-recapture analysis (program MARK), and height above ground of all frogs encountered was measured. Perch site density, estimated as foliage density, in the forest shrub and forb understory was measured by counting leaf and branch contacts with a vertical rod over 0-3 m height at 0.5 m intervals ($n = 60$ samples per plot). Adult frog population density (range 1433 – 6276 frogs/ha) was significantly related to 0-3 m foliage density among the plots ($p < 0.35$) but not to density of individual taller trees. Within plots, vertical distribution of frogs (males, females, and juveniles) was not related to the vertical distribution of foliage density. Foliage density was generally maximal at 0-0.5 m, declined to a minimum at 1.5 - 2.5 m, and increased again at 2.5 - 3.0 m. Male frogs had a maximum count at 1.0 - 1.5 m, and female and juvenile frogs had maximum counts at 0.5 -

1.0 m. Average frog perch height for males, females and juveniles was not affected by plot frog population density. Frogs were rarely spotted or heard calling from above 3.0 m. Frogs appear to seek perch heights independent of variation in the vertical profile of foliage density, but frog population density increases with overall forb and shrub density over 0 – 3 m. Reduction of dense coqui frog populations may be achieved by removing shrubs between 0.5 – 2.0 m height. Taller shade trees and lower ground cover may be retained, and landscape modification with shrub removal will also facilitate additional frog controls such as spraying or hand capture.

Does the Invasive Tree, *Falcataria moluccana*, Facilitate a large Population Density of the Invasive Puerto Rican Treefrog, *Eleutherodactylus coqui*?

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Since introduction to Hawaii, the Puerto Rican treefrog, *Eleutherodactylus coqui*, has quickly spread to major Hawaiian Islands and throughout major parts of Hawaii Island. Hawaii's climate is similar to Puerto Rico, yet Hawaii's coqui population can reach three times the density of that found in Puerto Rico. Preliminary surveys suggested that *E. coqui* has high population densities in albizia (*Falcataria moluccana*) dominated forests. Because albizia is a nitrogen-fixer, we hypothesized that albizia dominated forests promotes higher population densities of coquis than in native ohi'a (*Metrosideros polymorpha*) dominated forests. We compared populations of frogs at two study sites, Lava Trees State Monument (LTSM) and Nanawale Forest Reserve (NWFR). Each site contained both ohi'a and albizia dominated forest and at each site and forest type, three replicate 20x20m plots were established for mark-recapture analysis of frogs. All frogs were measured for mass, snout-vent length and position within the plot. Frogs larger than 17mm were individually marked with subcutaneous tags. The two densest frog populations were found in the albizia forest within the LTSM study site, and in the ohi'a study site within NWFR. Contrary to our hypothesis, there is no clear effect of forest type on coqui population densities. It is not yet determined what main factors drives Hawaii's coqui population density to be higher than that found in Puerto Rico, however, it is clear that the dominant forest type does not have a primary effect on coqui population density. Furthermore, and unfortunately, it is possible for native ohi'a dominant forests to support coqui densities larger than those found in Puerto Rico.

Color pattern polymorphism in *Eleutherodactylus coqui*: evidence of selection in Puerto Rico and founder effects in Hawaii

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The frog *Eleutherodactylus coqui* was introduced from Puerto Rico to Hawaii over 20 years ago. To examine the evolutionary consequences of this recent introduction, and in an effort to understand the evolutionary processes acting on color polymorphism across the entire range of *E. coqui,* we studied coloration in populations from Puerto Rico and Hawaii. A recent study found significant correlations between habitat and color patterns in Puerto Rico, and suggested that these were the result of selection. We collected data on color pattern frequencies in multiple populations (PR n=13; HI n=16) and tested the mode of inheritance for color patters through controlled laboratory crosses. As a test of selection we used the locus comparison approach on estimates of genetic structure from the color pattern locus and from published mitochondrial DNA sequences. Color patterns on *E. coqui* are located on the dorsal surface of the frogs and are abbreviated as follows: 9-no pattern, 11-thin middorsal stripe, 11w-wide middorsal stripe, 16-dorsolateral stripes, and 6-interoccular bar. We found a greater number of color patterns within Puerto Rican populations ($\bar{x}$ = 4.3 ± 0.2 SE) than within Hawaiian populations ($\bar{x}$ = 2 ± 0.0 SE). We compared heterogeneity for color patterns between populations in Puerto Rico and Hawaii. Heterogeneity between populations in Puerto Rico was marginally significant (P = 0.06), while heterogeneity between populations in Hawaii was highly significant (P < 0.0001). To discover the mode of inheritance for these color patterns, we crossed *E. coqui* of different color patterns in the lab. We determined that a single locus model with five alleles is sufficient to explain the patterns of inheritance, and that the allele for no pattern (9) is recessive with all other alleles codominant. We found that reduced number of color patterns in Hawaiian populations can be explained by the loss of three alleles (either 11w, 16, 6 or 11, 11w, 16). The alleles missing in Hawaii were the most rare alleles in all Puerto Rican populations, consistent with a loss of diversity due to founder effects in Hawaii. This result is consistent with a recent phylogeographic study using mitochondrial DNA that found substantial variation in Puerto Rico, but little genetic variability in Hawaii. For the locus comparison approach, we estimated F_{ST}, a measure of population differentiation, across Puerto Rico using the allele frequencies of the color pattern locus and published mtDNA sequences. We compared these estimates by calculating expected differences based on different modes of inheritance for nuclear and mitochondrial DNA. Differentiation in the color pattern locus (F_{ST} = 0.16) is well below the 99% confidence limits for F_{ST} (0.56–0.83) based on mtDNA, suggesting that color pattern allele frequencies are being maintained by selection in Puerto Rico.

The Effect of Environmental Variables on Sound Pressure Levels of Chorusing Male *Eleutherodactylus coqui*

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As the invasive frog, *Eleutherodactylus coqui*, continues to expand in Hawai'i, attempts to control its population are in progress, and there is a need to measure frog abundance quickly, inexpensively and with reasonable accuracy. Current methods for assessing coqui frog populations include mark-recapture analysis of population density and census counts of active frogs. Mark-recapture analyses are more accurate, but they are labor-intensive and expensive. Male coqui frogs call at night and their loud continuous chorusing commonly reaches levels of 70 decibels in dense populations. Sound pressure level (SPL) is relatively simple and inexpensive to measure, but its accuracy as a measure of frog abundance or activity is not known. We used parameters of an overnight chorus SPL model described elsewhere in the conference (Benevides et al.) to examine variation in SPL in separate populations of frogs. We repeatedly recorded coqui choruses in lowland wet forest of southeast Hawai'i Island in 2006-2007 using a data logging SPL meter with band pass filtering (1-3.15 kHz) to exclude sound energy outside the range of the coqui call. Results showed that the chorus model parameters are subject to large variability, and dense populations of frogs ranging from 1,900 – 5,600 adult frogs per hectare (mark-recapture analysis) were not readily distinguished by the peak magnitude of night time SPL. However, higher densities of frog populations resulted in peak SPL activity starting significantly sooner after sunset. Lower temperatures significantly reduced SPL of population vocalization. Lower temperatures also significantly delayed the start and end times of peak SPL activity. Leaf wetness significantly affected SPL rise characteristics. Relative humidity, over the narrow range (89 - 100%) found in East Hawai'i forests, had no significant effect on SPL of frog vocalization. Peak SPL is not sensitive to differences in frog population size for populations greater than 1,900 adult frogs/ hectare. Use of other SPL model parameters for estimating population size requires knowledge of effects of temperature and moisture on frog activity.

Effect of Habitat Structure on Population Density of *Eleutherodactylus coqui*

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The hypothesis that Puerto Rican coquí populations are limited by the availability of retreat and nest sites was first tested by Margaret Stewart and colleagues (1983. Science 221:570) by adding artificial retreat sites to small plots. Working in Puerto Rico's Luquillo Experimental Forest throughout the 1980's and 1990's, I had the opportunity to measure the impact on coquí populations of a variety of natural and artificial habitat impacts including treefalls, artificial gaps, brush piles, landslides, and Hurricane Hugo. Results of these studies confirmed that coquíes will actively move from areas of lesser structure into nearby areas of greater structural complexity. In addition, the results from Hurricane Hugo demonstrate that population increases can occur on the landscape level. I suggest that evaluations of habitat complexity and nest site availability may be helpful in understanding and combating the coquí's invasion of Hawai'i. Habitat manipulations may help to reduce exotic coquí populations and artificial nest sites may be useful as frog traps.

POSTER PRESENTATION ABSTRACTS

(*denotes presenter among multiple authors)

Effects of pesticide exposure on native and invasive amphibians: a synthesis through meta-analysis

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Agricultural landscapes provide unique challenges to amphibian populations worldwide. In addition to the chemical impacts that many amphibian species experience in agriculturally dominated landscapes invasive species may also be impacting their survival and persistence. As such pesticide exposure and invasive species have potentially far reaching ecological impacts on native amphibian populations. In the first quantitative analysis of pesticides on invasive amphibian species, we used meta-analytic techniques to explore the effects of pesticides on survival and growth of invasive species and native species. A large body of literature exists on the impacts of pesticides on growth and survival of both invasive species and native species. We explored the potential of pesticides to provide a route of invasion for non-native species into new ranges. By comparing the growth and survival of native and invasive species we looked at a connection between tolerances to chemical stressors and the ability to invade disturbed landscapes. Variation in tolerances between invasive and native species may have important implications for the spread of invasive species into new territories and their persistence in those territories.

Acidic Calcium Sulfate (ACS-P) as a Non-toxic Agent for use in Controlling Coqui Frogs: A Product Introduction Field Study

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In view of the need to find new products and alternatives for controlling the spread of coqui frogs (as well as a replacement for the soon to expire emergency EPA approval for the use of hydrated lime), a commercially available food sanitation product was evaluated for inclusion in the current inventory of chemicals applied as sprays. This product is made from ingredients that are generally regarded as safe (GRAS), and is approved for use in food by the FDA and USDA. The efficacy of this product stems from its very unique characteristic of having a very high concentration of hydrogen ions (low pH) while at the same time having very low corrosive effects on human skin. A five normal concentration with a pH of approximately zero may be held in one's hand without harm. Contrarily, when very small amounts are applied to the skin of coqui frogs it is quickly absorbed and respiration is immediately impaired with lethal results. Results of a field study using one hundred coqui frogs showed 95% of all frogs were killed within fifteen minutes when sprayed with only 1.0 ml of this product. Phytotoxicity varied from none to moderate according to the plant variety and could be minimized using a

mist versus heavy spray or totally eliminated by rinsing the plant within thirty minutes of application. There are many benefits to this product and further laboratory study is needed to balance lethality versus phytotoxicity; however due to its FDA/USDA approval for use in food it may be possible to gain emergency approval by the EPA as a minimal risk pesticide for use against coqui frogs

Predicting Niche Conservatism or Niche Divergence in *Eleutherodactylus coqui* using Ecological Niche Modeling

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The establishment of *Eleutherodactylus coqui* on the Hawaiian Islands is a growing concern due to the potential for ecological, economic, and anthropogenic impacts. Although we know the present distribution of *E. coqui* in the Hawaiian Islands, the potential future extent of their spread is still unknown. We used Ecological Niche Modeling (ENM), a tool used to predict the geographic range of a species from presence data, as well as abiotic environmental data layers, to determine the predicted niche of the *E. coqui* in native Puerto Rico and the Hawaiian Islands. ENM allowed us to determine if the niche of *E. coqui* is conserved, meaning that it occupies a similar habitat in Hawaii and Puerto Rico, or whether its niche has diverged, meaning that the niche has changed since its introduction into Hawaii. Locality data for *E. coqui* populations were obtained from Invasive Species Committees and Global Biodiversity Information Facility. Maxent v. 3.1.0 was used to run all models, and images were depicted using DIVA-GIS. Our results will show predicted vulnerable habitats and provide management agencies with information to help stop the spread of *E. coqui*.

Distribution of Native and Invasive Crayfishes in Oregon's Willamette Valley: Exploring Synergy Between Invasive Crayfish and Bullfrogs

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Oregon's Willamette Valley is an agriculturally dominated region inhabited by native Signal crayfish (*Pacifastacus leniusculus*) and invasive Red Swamp crayfish (*Procambarus clarkii)*. This agricultural landscape is inhabited by several other predatory invasive species, such as the American Bullfrog (*Rana catesbeiana*), that may be facilitating crayfish invasion through artificial trophic structures. Due to similarities in behavior and physiological plasticity, and dissimilarity in size, Red Swamp crayfish should not be capable of competitively excluding native Signal crayfish unless another factor is present. Invasive Red Swamp crayfish and native Signal crayfish share similar behavioral traits (e.g., aggression, dispersal, plasticity – typical of invasives) and life histories (keystone species, wide abiotic tolerances, refuge requirements) and both occur as invasive species outside of their native ranges. Signal crayfish are native to the Pacific Northwest and occur as invasive species throughout Northern Europe, while Red Swamp crayfish are native to the

lower Mississippi River and have worldwide distribution as an invasive species. Bullfrogs are sympatric with Red Swamp crayfish, and also share worldwide distribution as invasive species. Bullfrogs are voracious predators, and are known to prey upon crayfish. We surveyed lentic and lotic water bodies to determine the success of Red Swamp crayfish invasion within the Willamette Valley. We then compared species assemblages of sample sites to determine whether invasive Bullfrog presence influences crayfish occupancy.

Control of the Coqui Frog, *Eleutherodactylus coqui*, (Anura: Leptodactylidae) in Plant Nurseries

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The coqui frog, *Eleutherodactylus coqui*, is considered an interisland, interstate and international quarantine pest on potted plants. Potted plants infested with coqui frogs from Puerto Rico were the suspected pathway for coqui frogs in Hawaii. Chemical and non-chemical disinfestation treatments were developed against the coqui frogs. Citric acid was effective against all stages of the coqui frog but phytotoxic to potted plants, including orchids, ferns and chrysanthemums. To prevent phytotoxicity, citric acid treated plants must be rinsed with water one hour after treatment, but rinsing was found to reduce the effectiveness against eggs. Natural pyrethrins plus the synergist, piperonyl butoxide (pbo), were found to be effective against juveniles and adults, but most formulated pyrethrin/pbo products (at maximum labeled rate) required two applications up to 12 hours apart to prevent recovery from paralysis. Heat treatments in the form of hot water dip, drench and shower were highly effective against all stages of the coqui frog at 113 ^{o}F for 5 min. Other quarantine pests, including ants, caterpillars, mealybugs, scale insects, snails and slugs are also effectively controlled by heat treatments. Extensive tests have demonstrated that most tropical flowers and foliage can tolerate heat treatments as high as 120 ^{o}F. Plants that are sensitive to heat treatments may be conditioned at lower temperatures to increase heat tolerance. A physical insect screen barrier surrounding a greenhouse was found effective in excluding coqui frogs, providing coqui-free production of potted plants.

Impacts of “Vegetation Management” and “Trapping” on Coqui Frog Density and Behavior

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Two non-chemical control strategies were evaluated for potential to reduce densities of coqui frogs (*Eleutherodactylus coqui*) over time. One strategy explored the use of "vegetation management," the removal of most thick under-story vegetation to eliminate habitat and refugia which supports high populations of *E. coqui* in Hawaii. Surveys found a reduction in frogs within modified plots, increased usage of remaining refugia, and immigration/emigration of frogs during evenings and mornings within modified areas. Immigration of frogs would likely be reduced as size of modified areas increase. A separate strategy and study employed the use of artificial retreat and nesting sites constructed of polyvinyl chloride (pvc). For a period of 18 months *E. coqui* were collected from within these artificial refuges and removed from the population. Results indicated an impact of trapping on density, found seasonal fluctuations of egg abundance and occupancy within traps, and determined a positive relationship between increased occupancy of traps and vegetation. Both strategies impacted densities and suppressed numbers of frogs but if used alone will not meet expectations of those seeking eradication of *E. coqui* from an area. Potential exists for one or both of these methods to be utilized as part of a "system" of strategies to improve efficacy of current control methods.

What about the people? The importance of understanding human attitudes, knowledge, and behavior in control of *Eleutherodactylus coqui*

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Introduced species do not always become invasive, and the attributes or mechanisms by which a species becomes invasive are still being described. One mechanism that is often overlooked in this transition to becoming invasive is human behavior. In light of increased globalization it is apparent that humans play a role in the establishment and increased movement of species, but less is known about the specific behavioral and attitudinal factors that cause humans to play this role nor about how these factors can be mitigated. Human behavior, understanding, and knowledge of non-native species may result in augmentation of the invasion by inadvertently or purposely providing suitable habitats for exotics. Since the first appearance of the coqui frog (*Eleutherodactylus coqui*) on the Hawaiian Islands, its range has increased due to both intentional and unintentional human behaviors. While many Hawaiians may consider the coqui a nuisance due to its loud call, other Hawaiians have launched campaigns to save the frogs. The latter individuals, as well as those unaware of the consequences of their landscape management practices, may maintain refugia for coqui frogs that allow for their continued spread. For this reason, it is imperative to develop an understanding of the basis for behaviors that sustain coqui populations either purposefully or unintentionally. Questions assessing what Hawaiians know about the coqui frog and invasive species in general should be scientifically addressed. Further, if a change in behavior, attitudes, or knowledge will assist in controlling coqui frogs, then questions exploring the impact of educational programs are a necessity. Social science research can address three research goals: identifying beliefs and attitudes that may inhibit adoption of anti-coqui behaviors, measuring awareness of current outreach and education being used to hinder the coqui invasion, and uncovering gaps in local peoples' informational needs that could be addressed in future educational programs. Fostering a better understanding of the role of human behavior, attitudes, and knowledge about the invasive coqui frog will not only aid in control efforts in Hawaii, but may have the potential to be extended to other systems.

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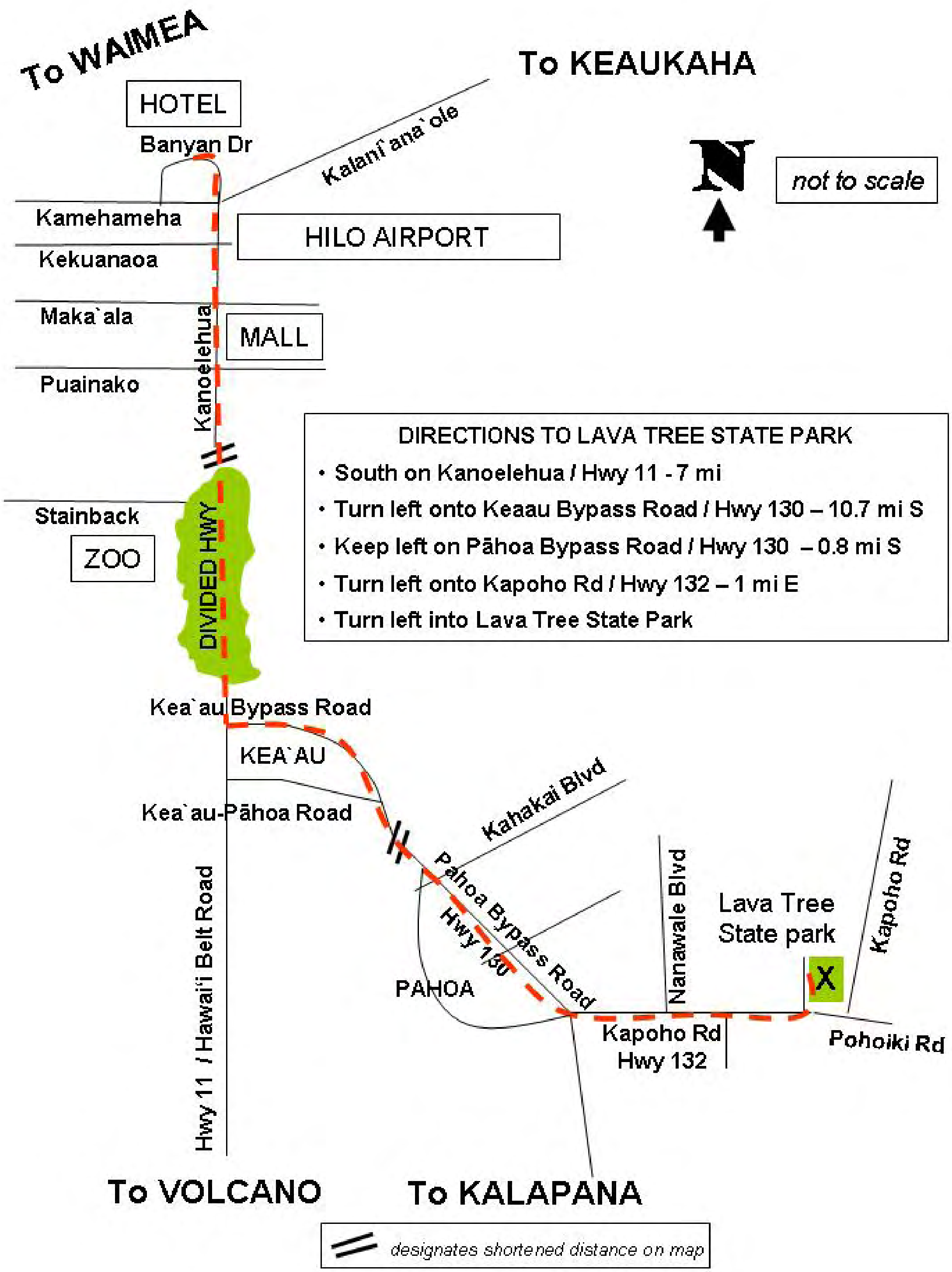
DIRECTIONS TO LAVA TREE STATE MONUMENT PARK

1. From Naniloa Hotel, turn left onto Banyan Drive until you reach Kalaniana'ole Hwy..
2. Go straight at the traffic light – you will be traveling south on Hwy 11 (Kanoelehua Ave / Hawai'i Belt Road / Volcano Hwy) for approximately 7 miles.
3. Turn left at the traffic light onto the Kea'au-Pāhoa Bypass Road (Hwy 130) – you will be traveling approximately 10.7 miles SE. Drive cautiously (no highway divider). *(If you miss this turn, turn left at the next traffic light onto Kea'au-Pāhoa Road, which will merge eventually with Hwy 130.)*
3. When you reach Pāhoa, stay to the left on Pāhoa Bypass Road to skirt old Pāhoa town.
4. Do not turn at the Kahakai Blvd intersection. Continue on Hwy 130 Pāhoa Bypass Road for approximately 0.8 mile.
5. Turn left at the traffic light onto Hwy 132 Kapoho/Pohoiki Road. *(If you drove through old Pāhoa town, you will arrive at this traffic light - go straight onto Hwy 132.)*
6. The entrance to Lava Tree State park will be on the left after approximately 2.5 miles. You will pass Nanawale Blvd on the left – there will be a canopy of trees.
7. As you make your way into the park, the parking lot will open up on the right.
8. If you reach a fork in the road (Pohoiki and Hwy 132), you have gone too far.

Please stay on designated paths while walking in the park - deep fissures are often hidden by vegetation. Restrooms are available - but no potable water. Raingear is recommended. Do not leave valuables in vehicles.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MALL
Puainako
Kanoelehua
DIRECTIONS TO LAVA TREE STATE PARK
• South on Kanoelehua / Hwy 11 - 7 mi
• Turn left onto Keaau Bypass Road / Hwy 130 – 10.7 mi S
• Keep left on Pāhoa Bypass Road / Hwy 130 – 0.8 mi S
• Turn left onto Kapoho Rd / Hwy 132 – 1 mi E
• Turn left into Lava Tree State Park
Stainback
ZOO
DIVIDED HWY
Kea`au Bypass Road
KEA`AU
Kea`au-Pāhoa Road
Kahakai Blvd
Pahoa Bypass Road
Hwy 130
PAHOA
Nanawale Blvd
Lava Tree
State park
X
Kapoho Rd
Kapoho Rd
Hwy 132
Pohoiki Rd
Hwy 11 / Hawai'i Belt Road
To VOLCANO
To KALAPANA
designates shortened distance on map