

# SUMMARY: COQUI BIOLOGY AND CONTROL IN VOLCANO



One of many color phases of coqui frogs

**Coqui identification:** Coqui vary greatly in color from brown, tan, to yellow (and even red or black), with or without a stripe down the back, and occasionally with stripes on the sides of body or head. Females are much larger than males. Males call loudly; females have a softer rasping call to defend territory. Calls usually start with a “warm up” repetition of the first note, “ko,” a territorial call to other males, and then the characteristic “kee” call to attract females. See the HEAR website on page 5 to hear the range of calls coqui make. Coqui are reported to live 4-6 years and continue to increase in size as they age. It is not surprising then that island coqui seem to be getting bigger, now that they have been on the island for over 10 years. Coqui are similar in appearance to the greenhouse frogs, only much larger. The call of the greenhouse frog is much quieter and has been characterized as a “cricket-like chirping.” Check the CTAHR website for a detailed comparison between the two closely related frogs, both accidentally introduced to Hawai‘i.

Female



Male, brooding eggs

**Life cycle:** Coqui eggs are fertilized internally. This implies that “pregnant” females can be transported to Volcano and produce young. Coqui do not have a swimming tadpole stage and thus do not require standing water to reproduce. Reproduction can take place in a forested environment without streams or ponds. A clutch of 15-40 eggs is typically laid in a rolled over leaf, or in moss, leaf litter, and other protected sites (e.g. old cars). Eggs are brooded by the males to keep them moist. Under laboratory conditions in Hawai‘i, mating pairs can produce a new clutch of eggs every 2 ½ weeks or 1,400 eggs per year. It takes about 14-17 days for eggs to hatch out into tiny froglets. Froglets reach maturity and reproduce in about eight months. In the cooler temperatures of Volcano, maturation of eggs and froglets is undoubtedly slower. Eggs and froglets have been observed in Royal Hawaiian Estates and inferred from size of populations in some sites in Hawaiian Orchid Isle Estates. Eggs, but no froglets, have been seen to date in Mauna Loa Estates and Volcano Village. So far, no eggs or froglets have been found in Volcano Golf Course. This absence could reflect a combination of effective control efforts incomplete searching, or temperature-delayed reproduction.



Clutch of coqui eggs



Recently hatched froglet

**Populations densities:** Coqui frogs reach their highest populations densities in wet, heavily vegetated lowland areas. In forested areas of lower Puna there are found as many as 23,000 frogs/acre, with 2,000 adults/acre. This is approximately twice the density of coqui, on average, in its native range in Puerto Rico. A recent study of potential coqui predators in Hawai‘i, including black rats, Polynesian rats, cane toads, and mongoose, indicated that only mongoose predated coqui. Kalij pheasants, chickens, scratching and overturning leaf litter, may incidentally grab a protein-rich coqui meal. Cats are also reported to prey on coqui. However, none of these predators take enough frogs to control a population. Coqui populations in Puerto Rico are thought to be more affected by predators that include scorpions and snakes. In Puerto Rico, populations of coqui are much smaller at higher locations (2,500 feet). However, it would be imprudent to extrapolate this trend to Hawai‘i with different vegetation, competing organisms, and predators. The availability of nest and retreat sites in the understorey in Puerto Rico was found to limit coqui populations there. The ginger, tree fern, and uluhe understorey in much of Volcano seem to provide excellent nesting sites and harborage.



Native rain forest in Volcano with rich understorey potentially available for coqui harborage and ample leaf litter suitable for invertebrate prey.

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Amakihi is an insectivorous native forest bird found in Volcano.



An unusual, carnivorous caterpillar of an endemic Hawaiian moth in Volcano rain forest it is not known if coqui catch flies when they perch. Pupae stages on the ground would be vulnerable.

## Diet and impacts on invertebrates and native birds:

Coqui area generalist insectivores which consume a broad range of invertebrates. Inventories of the stomach contents of coqui were made on Hawai'i Island and Maui in lowland sites with non-native vegetation and non-native invertebrates. No systematic study of coqui diets has been conducted in Volcano. Studies from lowland areas with the highest densities of coqui indicate that frog populations are consuming 285,000 invertebrates/acre/night. Most were leaf litter arthropods with some herbivorous and flying invertebrates. Sixty percent of the prey were non-native ants, amphipods, and isopods. No mosquitoes and a very small percentage of termites were found in the somatach. The preference for litter arthropods suggests that Volcano's lush, wet forests will provide ample food resources for coqui. The lowland diet studies found too that some native beetles and flies were preyed upon, suggesting the potential for impacts on native invertebrates in higher elevation native forest. Diet studies do not directly address potential effects on native forest birds, which largely are found at higher elevations. These birds at least partly depend partly on caterpillars and moths with life stages on the ground and available to coqui. It is also not known if coqui predate arthropods on their nocturnal perches. It is suspected that coqui could provide an ample prey base for unwanted potential predators such as Brown Tree Snake.



The common native forest bird, Apapane, eats mostly nectar but also depends on invertebrates, including feeding them to its young.



A recovering native rain forest scene in Volcano Village recently cleared of invasive kahili ginger. Coqui could facilitate the spread of invasive alien plants by speeding up the rate of nutrient cycling.

**Impact on Ecosystems:** The high densities of coqui and their consumption of huge amounts of leaf litter invertebrates suggests that coqui could affect litter decomposition and nutrient cycling. Changes in these ecosystem processes could affect species composition of Volcano forests. Intuitively, one might expect that leaf litter would accumulate because coqui consume invertebrates that fragment and decompose litter. However, a recent study in Hawai'i found that plant growth and leaf litter decomposition rates were actually higher in high density coqui areas than comparable areas without coqui. Coqui increased leaf litter decomposition rates by producing excrement which provided nutrients to microbes carrying out decomposition. They increased plant growth by providing nutrients to these plants. These findings suggest that coqui have the potential to increase nutrient cycling rates. This could give invasive plants a competitive advantage over native plants which evolved in a nutrient-poor environment.



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**Prevention:** Coqui are arriving in Volcano as hitchhikers on vehicles, plants, and packaging, probably in that order. Dispersal to Volcano is increasing as populations densities build up on the island. Coqui seem to be dispersed to Volcano primarily on vehicles that are parked in infested areas of the island. Coqui climb on to vehicles in infested areas to seek harborage or at night to call. When these vehicles slow down or park in Volcano the frogs jump off. Vehicles delivering goods or services, contractors, family members, or guests are the usual dispersal agents. There may be more coqui on vehicles that depart infested areas early in the morning while frogs are still perched. Eliminating all dispersal from vehicles is challenging, especially if you have family and friends driving up to visit you. There are probably fewer frogs on vehicles that park well away vegetation. It may help to depart infested area during daylight hours when frogs typically descend from perches to feed on the ground. A visual inspection of the vehicle may help to some degree too, but frogs may be tucked away inside wheel wells, bumpers, and other hard to see or access places. A thorough washing of vehicles is the most effective means of prevention. There are very few frogs hitchhiking on rental cars to Volcano's many vacation rentals and B&Bs (except by employees). Rental cars are washed and inspected. One Volcano Village resident had eight frogs in 2009. She attributed the coqui arrivals to parking her car at the Hilo airport while working off-island. She now takes her car to the car wash after leaving the Hilo airport and before driving to Volcano. No frogs were delivered to her residence in 2010. The car wash at the Chevron station near Walmart also washes the undercarriage for a more thorough cleansing.

Frogs also frequently arrive on plant material. They may be located on the plants or hiding in the pots or potting mix. Recently some Volcano Golf Course residents brought potted plants to Volcano. They inspected the foliage before transport and found no frogs or eggs. When they got home, six male frogs, probably hiding in the drain holes at the bottom of the pots, hopped away but were caught. They uprooted the plants and found many froglets in cavities within the potting mix. If you have to bring up plants from infested areas, first inspect them, and then quarantine them in a clear plastic bag or in a closed space for several days. To sanitize plants, you can soak pots and wash foliage in 113° water (the temperature of a hot shower) for a few minutes. Check the CTAHR website for details about the hot shower method of sanitation. Coqui also hide in packaging and boxes. You may open up the box for your new water heater from Home Depot and surprise some hiding coqui. Inspect the outside of the package and open it in a confined space where you can capture frogs if found.

**Rapid Response:** The optimal time to control coqui is when they first arrive in Volcano. They will be calling more consistently then (even at temperatures below 58 degrees, the temperature below which calling typically ceases) and so are easier to locate and capture or spray. In addition, a rapid response reduces the chances of successful breeding. The biggest challenge in controlling coqui in the cooler, more mauka neighborhoods of Volcano is that the frogs will only intermittently after the first few days. Once an introduction of coqui frogs develops into a breeding population, the challenge becomes many times greater and more expensive. Killing hidden egg masses and numerous froglets requires much many repeat applications of citric acid.



Vehicles are probably the main vector for coqui frogs to Volcano, especially those that park near infested vegetation at night.



Potted plants brought from lowland nurseries may harbor coqui frogs and eggs. These may be hiding in holes at bottom of pots or in cavities in the potting mix.



**Try not to capture coqui with your fingers. Use your cupped hand but be alert to the frog squeezing out between your fingers or around your palm.**

**Hand-Capture:** Use a headlamp to keep both hands free. To locate a calling frog, walk 360 degrees around the suspected site. Some frogs will stop calling if they hear voices or see lights. In this case, it is best to go silent, step back, and turn off your lights. Imitating the coqui call or playing a recording may elicit a response. Almost all frogs will go silent if you disturb the vegetation upon which they are perched. If you have to move leaves to locate a frog, do so very slowly and carefully to keep your frog calling or prevent it from jumping down. Frogs high up or on the ground present a special challenge to locate. If you walk toward a calling frog and you reach that spot but now the calling seems to be behind you. Then you walk back to that site and it seems behind you again. This pattern indicates that the frog is probably high in a tree or tree fern between the two sites or, more rarely, on the ground.

Hand capture is probably more effective when two hands are used, one under the leaf or perch and the other coming down on the frog in a cup-like fashion. In some cases, frogs may be located on the side of a tree fern or tree so that one hand cannot be placed behind them. Capturing these frogs, even with a cupped hand, is challenging. You typically have 10-30 seconds at least after spotting a frog to get prepared for capture. Capture effectiveness is enhanced by working deliberately and with good visibility and access to the prey. However, one should not wait too long because coqui can jump to lower leaves or to the ground where they are especially difficult to see.

Coqui frogs are not slimy and far from fragile. They recover quickly after capture and can jump from your hand unless firmly held. They should be placed in quart sized plastic bags very carefully because they can easily jump out of the bag in the process. Flexible bags secured with ties may be safer to use. With zip lock bags, the frog can be confined to the bottom of the bag with one hand on the outside of the bag, while the top is zipped shut with the free hand. The most humane way thought to kill captured coqui is to put them in the freezer where they will die, probably painlessly, within minutes.

**Citric acid spray:** Citric acid is ideal for situations in which hand capture is not possible such as when frogs are located high in tree ferns or trees or deep in uluhe. It is also the best tool when there are multiple calling frogs and the presence of eggs and females is suspected. Citric acid is the only EPA approved chemical for use in controlling coqui. Frogs breathe through their skin so they are highly sensitive to chemicals contacting their skin. Other products have been reported to be effective such as baking soda, concentrated Simple Green Soap, and hydrated lime. Caffeine, at about 10 times the concentration found in coffee, was studied for use but not approved. Citric acid comes in a granular form and is available from BEI on Kekuaaoa Street and CPS on Leilani Street in 50 pound bags, at a cost of approximately \$100 per bag. Smaller amounts may be available at Garden Exchange. It is mixed at one pound of acid per one gallon of water and can be applied with a hand sprayer, back pack sprayer, or larger truck mounted sprayers. Citric acid is effective when it directly contacts the frog so you need to locate the frog at night on its perch, ideally when it is calling, so that you can confirm its precise location. Never spray when it is raining. Some applicators spray the ground and understory first, before the perch site, because frogs may jump from the perches before the spray contacts them. Be thorough when spraying to ensure contact. With small sprayers, you may need to actually see the frog to make sure the small volume of spray used actually contacts the frog. A full 50 gallon drum sprayer used by the Volcano Coquistadores can usually control three separate frogs. Citric acid can irritate the eyes and openings in the skin. It is prudent to wear eye protection and gloves.



**50 gallon drum sprayer with 50 lb bag of citric acid**



**Knapsack and hand held sprayer**

**Traps:** Coqui seek harborage in dark, damp places and you can provide that kind of habitat with ¾ inch PVC pipes glued together to form a short tee at one end with all three ends left open. Traps are effective about one-third of the time and are most useful if used in an array in high density coqui areas. Traps should be tied to the tree or vegetation the frogs are calling from. Consult the CTAHR website below for design and placement suggestions.



**Control strategy for coqui in Volcano:** Frogs are controlled in Volcano because of the noise they make and because of potential impacts to native forest and birds. The optimal strategy for invasive species control is early detection and rapid response to eradicate newly established populations on the island or state. Unfortunately, coqui are well established and increasing in density on Hawai'i Island and not eradicable. The strategy in this case is to prevent their establishment in high value areas such as Volcano community. Frogs are controlled in higher elevation neighborhoods, even though breeding populations have not been observed there to date. Coqui live for four to six years and hundreds of frogs would accumulate. With greater numbers the chances of completing the breeding cycle are enhanced, especially with a warm, wet summer or a warming climate. Other communities on the island in Kohala, Hāmākua, South Kona, and Ka'ū are also following this strategy. Prevention and rapid response are the essential components of a strategy of exclusion. Each neighborhood has a coordinator who receives reports of frogs, keeps a data base, and trains and organizes other volunteers. Ideally, each neighborhood will develop a cadre of "block captains" who take primary responsibilities for sections of the neighborhood to share the workload and prevent volunteer burn-out. Control efforts in Volcano focus on "androcide," killing the calling males, to prevent reproduction. Also, the maturation of egg clutches may be reduced since males brood the eggs. Females are sometimes captured while searching for males and they are controlled during spraying operations. The use of imported biological control agents on coqui is not promising. Coqui are only minimally susceptible to the chytrid fungus, which is decimating frog populations world-wide. The chytrid fungus is already present in the wild in Hawai'i and Puerto Rico and affects only a very small percentage of the frogs in both locations.

**What you can do to help:** The greatest contribution you can make is to contact your neighborhood coordinator, receive on-the-"job" training, and become a "block captain" for residences near your home area. For example, a block captain in Volcano Village is the primary person responsible for coqui control on upper Kīlauea Ave, Rohner Lane, and Hāpū'u Lane. See the latest Volcano Community News for a listing of coordinators and their phone number or call the Volcano Coqui Hotline (443-4023) for the same information on the recorded message. Another support role is to report all frogs you hear to your neighborhood coordinator. They are too busy catching frogs to have time to monitor frogs, and they may not hear all frogs from the roads and streets in Volcano. A major concern of the Coquistadores is unreported frogs that may develop into breeding populations. For example, a concerned employee at Kīlauea Lodge reported a frog deep in the property, beyond hearing range from the roads and driveways. A silent female may eventually find this calling male and started a population that would finally be heard when it became large enough but control by then would have been very difficult. Another way to help is to donate money for citric acid or other supplies. Citric acid is expensive and no longer available through state and county grants. Donations can be made at the coqui frog table at the farmers' market on Sundays, through your neighborhood coordinator, and by check made out to Cooper Center Council, coqui control, P.O. Box 1000, Volcano, HI 96785.

**A few references:** <http://www.ctahr.hawaii.edu/coqui> (University of Hawai'i website on biology and control of coqui); <http://www.hear.org/AlienSpeciesInHawaii/species/frags/> (The range of coqui calls); [http://www.aphis.usda.gov/wildlife\\_damage/nwrc/publications/09pubs/pitt091.pdf](http://www.aphis.usda.gov/wildlife_damage/nwrc/publications/09pubs/pitt091.pdf) (Pacific Science article from 2009 summarizing state of knowledge about biology and impacts); [http://www.hear.org/species/eleutherodactylus\\_coqui/](http://www.hear.org/species/eleutherodactylus_coqui/) (HEAR website information on coqui); [http://volcano-coqui.org/Volcano\\_coqui\\_website/](http://volcano-coqui.org/Volcano_coqui_website/); [http://www.hear.org/species/eleutherodactylus\\_coqui/](http://www.hear.org/species/eleutherodactylus_coqui/) (HEAR website information on coqui); <http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1047&context=nwrcinvasive&seid=1#search=%22Coqui+frog+research+and+management+efforts+in+hawaii%22> (publication on coqui frog research and management efforts in Hawai'i, 2007)