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Improving resources and citizen science for controlling invasive coquí frogs in Pacific Island parks

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WPI

Wildlife Services
NWRC
National Wildlife Research Center

Improving resources and citizen science for controlling invasive coquí frogs in Pacific Island parks

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Submitted:

6 March 2020

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Acknowledgments

We would like to thank the following individuals, organizations, and businesses for their involvement and help throughout our project.

- The National Wildlife Research Center (NWRC) for sponsoring our project.
- Our liaison Dr. Steve Hess, and Professor Lauren Mathews, for providing support and guidance over the entire course of our project as well as additional support prior to our arrival.
- Professor Sarah Stanlick for providing support and guidance prior to our arrival.
- Franny Brewer, Communications Director from the Big Island Invasive Species Committee for speaking with us about invasive species management.
- Pest Report Facilitator Elizabeth Speith, Coquí Control Project Coordinator Abe Vandenburg, and Public Relations and Education Coordinator Lissa Strohecker from the Maui Invasive Species Committee for speaking with us about coquí management and educational outreach.
- Sam Aruch, an app developer from Natural Resource Data Solutions Inc. for discussing app development with us.
- Tim Tunison from the Coquístadores for teaching us about current coquí control methods.
- Professor Mautz, a Biology Professor from the University of Hawai'i at Hilo for discussing current coquí control methods and opinions on coquí management.
- Tom Piergrossi from Vintage Green Farms and Kevin Walmsley from Elite Pacific Properties for discussing with us how coqui frogs have affected their businesses
- Students at the University of Hawai'i at Hilo for taking our survey.
- All Volcano and Facebook survey respondents for taking our survey.
- All Hilo C’20 WPI students for supporting us over the past few months in our project.

Authorship

The contents of this report are a result of the collaboration by all of the authors. It would be incorrect to say that one person took authorship over any section. We completed all writing and editing together.

Executive Summary

Invasive species are a common problem throughout the Hawaiian Islands and have detrimental environmental and economic effects. The National Wildlife Research Center (NWRC) is tasked with monitoring and managing invasive species, such as the coquí frog. Originally from Puerto Rico, the coquí frog hitchhiked on nursery plants and became an established invasive species in Hawai'i in 1988. They are most commonly found on the Big Island, where the frogs cause noise pollution, eat native invertebrates, decrease the property value, and have recently been found to be a host for rat lungworm. Invasive species organizations on the Big Island of Hawai'i are working to manage the spread of the coquí frog. Our goal is to provide the NWRC with resources, materials, and knowledge for expanding its citizen science outreach in invasive species management.

Citizen science is defined as scientific research completed by the general public in collaboration with scientists to collect, categorize, and analyze large-scale patterns. Citizen science engages community members to help advance scientific knowledge. Engaging citizens in research can be successful in collecting a large amount of data. However, some projects have not been successful due to a lack of data verification. Learning from the benefits and errors of previous citizen science projects, we assisted the NWRC in the production of their own citizen science project. The NWRC would like to engage citizens in the control efforts to gather data on the spread of the coquí frog across the Big Island of Hawai'i.

To accomplish the project goal, we designed a mobile application to track the occurrences of coquí frogs. In order to acquire all of the information the NWRC wanted, the app needed to have audio and image file uploading, location pinning, and offline data caching. To gather information to assist in creating the app, we conducted surveys of local residents and interviewed experts. The surveys collected general demographic information about surveys of local residents and interviews with coquí management and invasive species experts. Through the surveys, we gathered information about what individuals know about coquí frogs in Hawai'i and if they would use an app to track occurrences of coquí frogs. We used this data to evaluate any additional aspects that would be included in the app. We found that people have a lack of understanding about the coquí frog in Hawai'i. This encouraged us to consider including an educational component in the app.

We then created three separate storyboards, one with essential functions, another with educational aspects, and a third with interactive components. Our first storyboard focused on the essential requirements for the app. This storyboard would make the development process comparatively quick and low-cost since it is the lowest in complexity, while still containing all the necessary functions for the app to collect the desired data from users. Our second storyboard expanded on the essential requirements to include an educational component. This contained panels with basic facts about the coquí frogs, differences between the coquí and greenhouse frogs, a description of the effects from the coquí on the Big Island, and what the user can do to help. Our third and final storyboard focused on making the app more interactive. This storyboard added the ability to view a map of the user's own sightings. It also included a feature where the more sightings a user reports, the higher their character advances. Their character starts as a baby frog, then continues to advance further to a froglet, frog, knight frog, and finally a royal frog. After we completed these storyboards, we identified options to partner with other organizations.

To develop the app, the most cost-effective and viable approach for the NWRC is to partner with another organization with an established outreach program, such as the Hawai'i Invasive Species Council (HISC). The app could either be an extension of an existing invasive species management app, such as HISC's 643-PEST reporting app or could be a new app created using our storyboards as guidance. The app's development, maintenance, and data handling would be shared between the two or more organizations. The benefits of working with HISC are that the NWRC would be provided with assistance in making the app, and the current outreach strategies of HISC would facilitate marketing of the app.

Another option is for the NWRC to create their own app through the storyboards we designed. We identified one app development platform, Alpha Anywhere, that would allow the full development of our storyboarded app, even by individuals with no coding experience. This option would allow the NWRC to meet all of the needs required, however, they would need to upkeep and maintain the app themselves. The ongoing cost of this option are significant, such as the cost of Alpha Anywhere, and publishing in the Apple App Store and Google Play Stores. The benefits of this method include that the app would meet all of the NWRC's requirements and the NWRC could easily access the data and maintain full control over the app. Since the NWRC currently does not have an outreach program, they would need to market the new app to potential users through social media or flyers.

We hope that the research we have done provides the NWRC with the right tools and background information to continue developing an app that will bridge the gap between users and scientists. This will hopefully allow the NWRC to develop a better understanding of coqui ecology in Hawai'i and provide them with more informed management strategies.

Introduction & background

Invasive species are a common problem throughout the Hawaiian Islands and have detrimental economic and environmental effects. The National Wildlife Research Center (NWRC), within the Animal and Plant Health Inspection Service (APHIS), is one organization working to assist the state of Hawai'i in managing invasive species, one being the coquí frog. For our project, we helped develop strategies, including app designs, to increase citizen-science-based efforts to help the NWRC achieve its task of managing the frogs.

Invasive species are organisms that are introduced to an environment where they are not native and can have many negative impacts (Congressional Research Service, 2013). The introduction of a species to an environment it is not familiar with can have unknown or detrimental effects, such as loss of biodiversity, changes to the ecosystem, and impacts on the economy (Lovell, 2006). When a foreign species is added to an environment, it competes for resources in the new habitat (Didham, 2005). Invasive species disrupt the natural interaction of predator and prey or introduce novel parasites into the ecosystem. This introduction may cause a loss in biodiversity if the invasive species interfere with the native species. They can also cause industries, like fisheries and agriculture, to decrease in profit, as well as force some businesses to shut down. Other impacts include infrastructure being damaged, tourism decreasing, and endangering citizen health (Reaser, 2007).

Natural introductions of species to islands are limited because of the water that separates them and other landmasses (Reaser, 2007). The introduction of different species to an island can happen either by humans bringing a species intentionally, or through the species attaching itself to a ship, car, plane, or other item being transported. New species coming into the environment can affect the ecosystem that is established, especially on islands. Island ecosystems are classified as one of the most vulnerable to introduced species and have not been able to adapt to changes caused by invasive species (Reaser, 2007). Most of the native species on Hawai'i's Big Island are endemic to the island, meaning that they are found only in that area and nowhere else. Since these endemic species can only live in a specific set of conditions, they do not adapt well to change. Overall, invasive species can have tremendous negative impacts and can affect organisms in the introduced area.

Invasive coquí in Hawai'i

In Hawai'i, many invasive species have threatened the natural ecosystem, including the coquí frog. Coquí frogs, or *Eleutherodactylus coquí,* are commonly found in plant nurseries, gardens, and greenhouses. Originally endemic to Puerto Rico, this species began spreading to Florida and various islands. Although the frogs are non-native to many locations, they are most notable for their negative impacts on Guam and Hawai'i, where they are categorized as a "pest species" (National Wildlife Federation, n.d).

The invasion of Hawai'i began in 1988 when stray frogs hitchhiked on nursery plants being transported to the Big Island (Kraus, 1999). Their hitchhiking behavior allowed the coquí frog to spread all around the island. Evaluation of frog populations on the Big Island indicates that the coquí adapted rapidly after introduction to the new environment, presumably because Puerto Rican and Hawaiian climates are similar (Velo-Anton, 2007). The small size of the species allows it to evade human capture and permits hiding in plants, so it is unknowingly transported.

Even though Hawai'i is lush with diverse flora, the state is no longer able to make the horticulture market one of their main sources of income. The coquí hitchhike on plants for export, causing any shipments from Hawai'i to be inspected. Any plants found to be infested are destroyed or sent back. Nurseries can treat their plants to control the frogs, but this is expensive and can increase shipping costs (Kraus, 1999).

Coquí frogs are able to reproduce at high rates because their natural predators, snakes, are not found in Hawai'i. Other species introduced to the island, such as mongoose, rats, and chickens, have started eating the coquí frogs (Pitt, 2012). The frogs do not make up a majority of these animal's diets and this consumption does not reduce the coquí population (Pitt, 2012). Another contributor to their high rate of reproduction is the parental care of the frogs. The male frog guards the eggs until hatching and, unlike many other species of frogs, only humidity is needed to reproduce since it does not have a tadpole stage. This mode of reproduction permits the species to reproduce in more areas and have more offspring (College of Tropical Agriculture and Human Resources, n.d.). Since the coquí frog is not preyed upon by snakes in Hawai'i, like it is in Puerto Rico, the frogs survive for a longer period of time. The current distribution of the

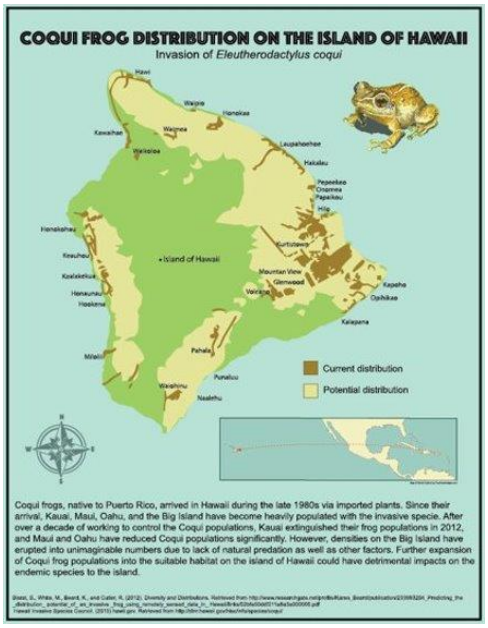

Figure 1: The current and potential distribution of the coquí frog on the Big Island.

coquí frog, as well as the potential distribution, is shown in Figure 1. These adaptations allow the coquí to thrive in Hawai'i, harming the rest of the islands' ecology.

Since the frog is spreading rapidly, this raises concern for native species. Coquí in Hawai'i primarily feed on leaf-litter invertebrates, which are found in the decomposing leaves on the ground. Their feeding patterns have the potential to decrease endemic invertebrates and increase the nutrient cycling rates of plants. The increased rate of nutrient cycling can harm native species that have evolved in nutrient-poor conditions (Silvertown, 2009).

More recently, a study showed that some coquí carry the rat lungworm parasite. The parasite is known to cause rat lungworm in humans, however, the effects of coquí being a host have not yet been discovered (Niebuhr, 2020).

Now an established invasive species on the Big Island, there are negative effects from the coquí frog on the ecosystem, economy, and the people who live there. The frog's mating call registers at 90 decibels, which causes locals and tourists to complain about the calls near their homes and on vacations. Close proximity to a high density of frogs can reduce property value. Reaser (2007) reported that the noise caused by coquí is to blame for substantial decreases in real estate value. Buyers have also been known to back out of contracts because of the loud noise (McAvoy, 2005). Although they are loud, some people have found their mating call pleasant or are simply not bothered by the frogs' presence on the island. One individual that filled out our survey stated in the extra comments section that "they help put me to sleep". While there are negative ecological and economic impacts from the coquí, individuals have varying opinions on the frogs.

In an attempt to involve the community in the reduction of the frogs, small groups work to manage the spread in areas that are not completely infested yet, such as the town of Volcano, Hawai'i. One of these groups, known as the Coquístadores, works to manage the species in this area. This volunteer group is dedicated to providing knowledge and giving advice on how to

capture and eradicate frogs. There are assigned neighborhood coordinators that certify citizens to become “block captains” and dispose of the coquí in their immediate area (T. Tunison, personal communication, January 30, 2020). There are also larger organizations such as the Big Island Invasive Species Committee (BIISC) that monitor various action species. An action species is any species that requires an immediate response, through chemical control methods or capturing by organizations that manage invasive species (F. Brewer, personal communication, February 5, 2020). Any invasive species that is not yet completely established is designated as an action species.

Two major methods of management are used to control the spread of the coquí - capturing and freezing the frog in a plastic bag, or spraying with citric acid (Tuttle, 2008). The latter of these two methods is not completely reliable, which is why scientists are searching for new methods. The Hawai'i Department of Land and Natural Resources approved the spraying of citric acid to control the frogs and scientists analyzed its effectiveness in a study using 11% and 16% citric acid. Results show that one 16% citric acid treatment reduces adult coquí density 3-fold if the plot is completely treated, but the frogs could live up to 5 months after spraying. However, repeated treatment of 11% acid reduces adult density by 440-fold (Tuttle, 2008). This is the safest method and currently, the only chemical control method that is legal in the state of Hawai'i. Although it is a safe method, it is expensive and some plants are sensitive to the spray and get leaf burns (Pitt, 2012). New methods of invasive species management, in general, are branching into technology. This includes mobile citizen science applications that can be used to upload data about various species.

Citizen science

Citizen science is defined as scientific research completed by the public in collaboration with scientists to collect, categorize, and analyze large-scale patterns (Bonney, 2014). The citizens act as public observers, sharing and contributing data that will benefit researchers. Depending on the resources available, citizen science programs can be successful in advancing scientific knowledge by accumulating large databases of research. However, with this large abundance of data comes a certain sense of unreliability. The datasets need to be of extremely high quality to be considered accurate. In order to have a successful project, methods need to be

in place to boost data accuracy and regulate bias, involving volunteer training and testing and systematic statistical modeling (Kosmala, 2016).

An early example of citizen science began in 1915, with Cornell University professor Arthur Allen. He developed the American Museum of Natural History Ornithological Expedition with the goal of learning more about bird migration patterns (Cornell Lab of Ornithology, 2020). Their purpose evolved over time, and the Cornell Lab of Ornithology is now heavily involved in bird conservation. Initially, a large network of volunteers would gather information about bird migration patterns and record this data on written cards. To modernize this process, Cornell developed an application called eBird in 2002. This program engages amateur bird watchers to become citizen scientists. eBird is used in a scientific perspective to monitor birds at Important Bird Areas (IBAs), providing data on bird distribution based on season and abundance. eBird grew increasingly in popularity, with a reported 330,000 users in 2016 from 250 countries, tracking 10,300 species. There are recorded 100 million bird observations each year solely through eBird. Most recently, the data helped scientists determine the connection between bird migrations and climate change (Cornell Lab of Ornithology, 2020).

Information and Communication Technology (ICT), which is the use and study of computers, networks, computer languages, and databases, surged over the past few years (BYU Idaho, n.d.). This new interest in technology-based citizen science most often presents itself in the form of mobile applications. Programs like eBird rely increasingly on the use of smartphone apps that participants use to submit data. A common example of how citizen scientists can assist in research usually involves a smartphone app that includes GPS location and digital media sharing (Sturm, 2017). There are a number of widely used apps for species management, such as iNaturalist and eBird. The goal of these apps is to share and discuss ecological findings among local communities, as well as researchers.

These applications upload the data collected to a large database that researchers can access. The most common use for these applications by scientists is to gather information and understand the spatial distribution of invasive species (Mahr, 2019). With this data, scientists are able to complete large quantities of research that otherwise would take many years to complete without citizen assistance.

While citizen science projects have the potential to be successful, a lack of resources can cause a program to be biased. The CoralWatch citizen science project, which collects coral data,

started at the University of Queensland. Over six years participants recorded 18,560 records, but not all accurately. A large number of errors occurred, 64% of records had an inaccurate GPS location and 50% of records had false written data comments. Seventy percent of these errors could be prevented if the app developers from the University had implemented a more in-depth data validation service (Hunter, 2012). In order to combat these errors, the University of Queensland set new methods in place to verify data, such as photographic evidence. A study analyzing invasive species apps showed that 73% of apps required photographic proof of the logged species to support any claims (Johnson, 2020). Having this secondary data submission in addition to personal comments simplifies the data validation process since there is photographic evidence.

Interest in citizen science increased rapidly over the last decade due to new techniques that ensured efficient collaboration of professional scientists and community members (Lee, 2017). In 2016, Dr. Roland Kays of North Carolina State University began an annual citizen science challenge. Originally, Dr. Kays challenged students to explore how mammals use green space on the NC State campus (NC State University Libraries, n.d.). Dr. Kays hosted an event to motivate student involvement which included a DJ and a 270° projection of images in the Visualization Lab. Dr. Kays attempted to engage with a college demographic, offering free t-shirts and food. The first students to volunteer received a free shirt entrance into a raffle for a camera trap, a remotely activated camera with a motion sensor trigger. He created a hashtag to spread over social media and offered smaller prizes to the best photo posted with the hashtag (Harrington, 2019). After the initial challenge, 87% of students said they had never heard of citizen science before, and 97% said they would participate again (Harrington, 2019). The research not only benefited the students and inspired them, but also assisted the scientific community and motivated other colleges to follow a similar path.

An important aspect of citizen science is its impact on communities. It can raise the public's level of knowledge about ecological issues and engage the population to become more involved in their local communities. A study in Bangladesh completed from 2014-2017 evaluated climate adaptation with the assistance of citizen scientists (Bremer, 2019). The study described four major takeaways about the value of citizen scientists in ecological research. First, citizen science produces information that travels beyond the boundaries of current science. Second, citizen science encourages openness to science in the community. Third, citizen science

raises awareness and understanding of natural changes, giving community members a broader view of where they live. Finally, citizen science can encourage a participatory government that includes citizens on local issues (Bremer, 2019). Ecology and citizen science have become very common in the scientific community. The 2008 meeting of the Ecological Society of America in Wisconsin showed 60 studies that involved citizen science (Silvertown, 2009). It is clear from the resounding amount of citizen science use in the ecological community that participation benefits the research in question, community understanding, and quality of life as a whole.

Methodology

We wanted to provide the National Wildlife Research Center (NWRC) with resources, materials, and knowledge for expanding its citizen science outreach in invasive species management. Our liaison, Dr. Steven Hess, expressed interest in a mobile application. He stated that the desired audience for the application is younger residents of the Big Island. He also requested that it record sound, upload images, and have offline GPS and data caching capabilities to accommodate areas that do not have service such as national parks. In addition to these requirements, we looked into adding an educational component to the app to raise awareness of the economic and environmental effects of the frogs. We analyzed currently available citizen science apps, but none completely met Dr. Hess's requirements. We conducted further research on how to create an application by:

1. Gathering basic information about people's understanding and opinions of the coquí frog in Hawai'i.
2. Evaluating alternative approaches to strengthen citizen science programs with respect to coquí management.

We used this information to design a storyboard for a citizen science app for coquí management. The following chapter includes the methodology for completing these objectives.

Objective 1. Gathering basic information about people's understanding and opinions of the coquí frog in Hawai'i.

In order to ensure we design an effective app, we first had to understand the gap in knowledge regarding coquí frogs and their effects. This data is a valuable reference for future coquí management. We surveyed and interviewed various professors, visitors, experts, residents, and students. We used the information we learned to customize the app.

Surveys

We surveyed students at the University of Hawai'i at Hilo, members of local Hawai'i Facebook groups, and visitors in the free speech area of the Hawai'i Volcanoes National Park. We conducted these surveys to gather information about the individual's understanding of coquí effects, opinions on coquí frogs, and to assess their interest in using an app to track the frogs. At

the University of Hawai'i at Hilo, we offered a free cookie as an incentive to motivate students to take the survey. We used the same survey for the in-person surveys at the University and posting on Facebook, located in Appendix A. The surveys given in Hawai'i Volcanoes National Park contained information about rat lungworm, due to new information about the rat lungworm parasite in coquí frogs (Appendix B).

Semi-structured interviews with experts

We conducted all interviews in a semi-structured format, which allows for an in-depth conversation while maintaining defined questions to gain the information that is required (Ritchie, 2015). This style allowed us to explain our background and project-related work, and develop a deeper connection with the interviewees. We interviewed each expert with a different set of questions. Although we had a similar initial set of questions, follow-up questions varied depending on the interviewee's expertise.

Professor Mautz is a biology professor at the University of Hawai'i at Hilo whose work focuses on coquí frogs. Professor Mautz is a coquí expert and asking him a series of questions helped us gauge the lapse in coquí management. The interview questions are located in Appendix D.

To gain insight on the coquí status in Volcano, we interviewed Tim Tunison, a retired Hawai'i Volcanoes National Park biologist and a member of the Coquístadores. Mr. Tunison provided insight into the resources currently available for coquí control. The interview questions are located in Appendix E.

We interviewed Franny Brewer, the Communications Director of the Big Island Invasive Species Committee (BIISC) to learn about their outreach and gain any insight into how to make our app successful with users. BIISC is an organization that works to control and prevent the establishment of invasive species on the Big Island, as a part of the state government. The interview questions are located in Appendix F.

We interviewed Pest Report Facilitator Elizabeth Speith, Coquí Control Project Coordinator Abe Vandenberg, and Public Relations and Education Coordinator Lissa Strohecker from the Maui Invasive Species Committee (MISC). We conducted these interviews to gain insight into the pest reporting process, learn about mobile applications they are working on, determine if they are willing to collaborate with the NWRC on coquí management, and attempt

to find potential funders for our application. These interview questions with Ms. Speith are located in Appendix G and the interview questions with Mr. Vandenburg and Ms. Strohecker are found in Appendix H.

MISC directed us to the app developer they use, Sam Aruch from Natural Resource Data Solution Inc. We talked to him to understand more about the app development process, how currently available apps function, and to see the feasibility of our concepts for a potential app. The interview questions are located in Appendix I.

Informal inquiries with business owners

We emailed various plant nurseries and realtors from the Hilo and Kona areas to gather insight into how the coquí affects their businesses. This informal inquiry helped us understand the economic and environmental effects that the coquí have on the island. We chose these businesses to see if there is a contrast between an area that is infested with coquís, such as Hilo, and an area with limited coquís, such as Kona. The emails sent to nurseries and realtors can be found in Appendix J.

Objective 2. Evaluating alternative approaches to strengthen citizen science programs with respect to coquí management.

We researched how to develop a custom app that would be ideal for the NWRC's needs. However, recognizing that a custom app might not be feasible for the NWRC, we also evaluated alternatives that would require less effort and expenses.

Initial development and planning for a custom app

For our first step in planning the creation of a custom app, we designed a storyboard and an online mockup. We then analyzed app development software and contractors to find the best method to create the app. Lastly, we created a government funding proposal to attempt to receive federal funding to complete the app development process.

Creating a storyboard and online mockup

A storyboard is a design process that describes the content and structure of an app, and details how the user will accomplish specific tasks in the design. It allows app developers to have

a clear vision throughout the process and ensures that developers do not overlook any steps critical to the project (Holtzblatt, 2004).

Starting out with a paper draft of the storyboard allowed us to make edits and be creative with design ideas before beginning online mockups. We developed three different storyboard options, such as an essential functions storyboard, an educational storyboard to educate the public on invasive species, and an interactive storyboard to engage users. To create the most accurate representation of what the app should look like, we chose to use the online software Figma, which is a collaborative graphic design tool. We chose Figma because it is free and allows developers to view the user interface of the app, which displays the graphical layout of the application. It also allows users to test the application as it would appear on their phones.

Evaluation of app development software and the use of contractors

Once we finished the online storyboard, we completed an analysis of app development software. We contacted app development software websites using the inquiry in Appendix K. We did this to evaluate current software options based on price and capability. We first required that the software company be based in the U.S. Second, if the NWRC opts to develop our storyboard into a functioning app themselves, we needed to make sure that the software required no coding to create the app. As a final requirement, we considered whether or not each software option meets the needs of the NWRC's requirements for the app**.**

We also evaluated the use of contractors to create and upkeep an app in a government setting. Contractors are developers that are hired and are held in a contract that would allow them to continuously upkeep the app, depending on the terms of the contract. This method of development would allow the NWRC to own their app, without having to manage or create it themselves.

Government funding proposals

We compiled all the information gathered into two short proposals for the NWRC to use to apply for federal grants. The first proposal is intended to be used in the situation that the NWRC decides to develop its own app using an app development software. The second proposal would be used in the situation that the NWRC decides to hire a contractor to create the app for them. Any option moving forward would require a cost, so a proposal is beneficial for Dr. Hess to use as an attempt to receive outside funding. This proposal can be found in Appendix S.

Evaluation of existing applications

After analyzing currently available citizen science apps, the two apps that most closely resembled the functionalities that our sponsor required are iNaturalist and 643-PEST. We created a table of benefits and disadvantages, where we classified whether each app met Dr. Hess's requirements.

Results and Analysis

The most relevant data we collected, the information we gathered from our interviews, and the alternative approaches we identified from our research are displayed and explained in the following section.

Objective 1. Gathering basic information about people's understanding and opinions of the coquí frog in Hawai'i.

We gathered information from the community, experts, and business owners to evaluate the general knowledge and opinions of the coquí frog in Hawai'i. All figures and diagrams are created from 222 responses gathered through surveys on Facebook, the University of Hawai'i at Hilo, and Hawai'i Volcanoes National Park. Not all respondents answered all questions, so sample sizes do not total for 222 for all questions. Any additional data can be found in Appendix T.

Surveys

We distributed a short survey in person at three locations, as well as on six Facebook groups around the Big Island. We did this to understand the scope and depth of knowledge about coquí frogs among community members. Our survey locations are listed in Appendix C.

Figure 2 relates age to the free-response question "please list all of the environmental effects the coquí have on Hawai'i that you are aware of:". We hand-scored these responses to identify correct and incorrect responses. In Figure 2, the younger age groups could identify fewer environmental effects. Only 23.2% of the respondents knew more than one environmental effect of the coquí frog. When comparing the question "please list all of the economic effects the coquí have on Hawai'i that you are aware of:" to age, the trends are similar to the environmental effects. However,

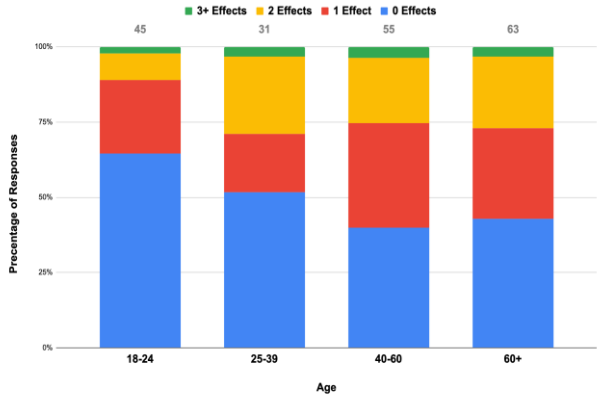

Figure 2: The amount of environmental effects the coquí have on the Big Island that respondents are aware of compared to age. There are a total of 194 responses. The numbers above the bars indicate the total number of responses in each category.

much less economic effects are known - only 6.7% of respondents knew more than one economic effect.

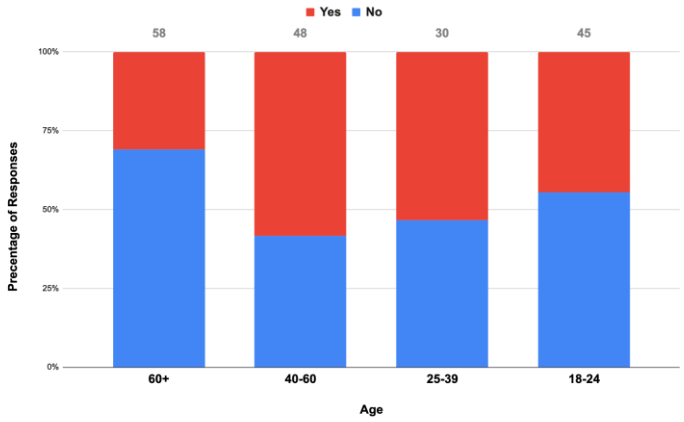

Figure 3: The percentage of respondents who said they would or would not use an app to track coquí frogs compared to age. A total of 181 respondents answered both questions. The numbers above the bars indicate the total number of responses in each age category.

Figure 3 relates age to the free-response question, "would you be interested in using a smartphone app to assist scientists in tracking the spread of coquís?". The 18-24 and 60+-year-olds are the least likely age groups to use the app. The 40-60-year-old age group indicates that a slight majority would use the app. However, the 25-39 age group is at an approximately 50% split of whether they would use the app.

Figure 4 relates two different questions, "would you be interested in using a smartphone app to assist scientists in tracking the spread of coquís?", and "please list all of the environmental and economic effects the coquí have on Hawai'i that you are aware of:". This is a combination of all economic and environmental effects added together, which is why there are 361 responses.

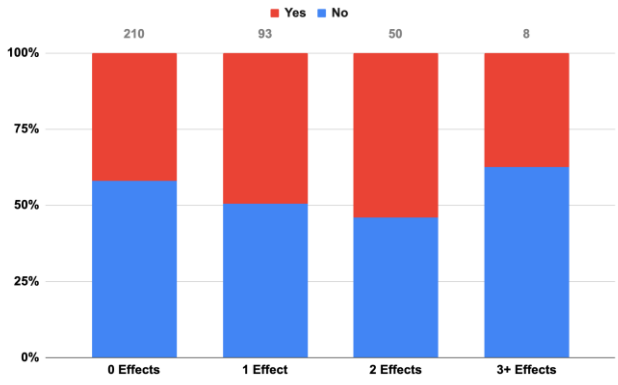

Figure 4: The amount of environmental and economic effects respondents are aware of compared to whether they would use a smartphone app to track coquí frogs. A total of 361 respondents answered the question. The number above the bars indicate the total number of responses in each category

We did not consider the 3+ effects responses in the data analysis since the sample size is too small for the data to be viable. From this, we learned that the respondents that know the least effects are least likely to use the app. Respondents who know 1 effect have an even split of whether or not they would use the app. Those who know 2 effects have a slight majority that would use the app.

The surveys indicated that there may be a gap in people's knowledge about the economic and environmental effects from the coquí on the Big Island. The data trend shows that the individuals who responded that they would use an app are also the ones who knew more effects of the coquí frogs on Hawai'i. However, from this information, the data may reflect a correlation related to a third characteristic that we didn't directly measure. This informed us on how we would focus our educational app design in our storyboard in the following chapter. Regardless of app usage, coquí frog education is an important aspect of invasive species management.

Semi-structured interviews with experts

To gain a better understanding of opinions on the coquí frogs, as well as on our potential app, we conducted several interviews with experts. Tim Tunison is a member of the Coquístadores based in Volcano, HI; we interviewed him on Jan 30, 2020. Mr. Tunison explained the demographics of Volcano skew older (the average age of Volcano residents is 52.7 years old: Hawai'i Demographics, 2017). Residents are most likely out of touch with technology, and a smartphone app would not be widely adopted within the town.

In our interview with Professor William Mautz from the University of Hawai'i at Hilo on Jan 24, 2020, he explained that in his personal opinion the coquí population is so large and well-established that it is now not worth trying to control. Although Professor Mautz believed a potential app would be beneficial for scientists, he thought that there would be a lack of enthusiasm from the public.

In our interview with the Big Island Invasive Species Committee (BIISC) on Feb 5, 2020, Franny Brewer informed us that they have an app called 643-PEST which is a reporting app for all invasive species, run by the Hawai'i Invasive Species Council (HISC) and maintained by the Hawaiian Biodiversity Information Network (HBIN). However, the app is not usually used for coquí frogs since they are no longer considered an action species; they are completely established on the Big Island. BIISC also focuses on informing the public on invasive species as a whole through many outreach programs in schools and public facilities. Since BIISC focuses heavily on public outreach and education, we created an infographic for the NWRC to use to increase their own educational outreach of coquí frogs. Ms. Brewer put us in contact with individuals from the Maui Invasive Species Committee (MISC) who are in charge of the 643-PEST app.

In our first discussion with MISC on Feb 5, 2020, we spoke to Elizabeth Speith about the data collected from the 643-PEST app. She informed us that they own the app and a website. Only 2% of all their reports of invasive species sightings come from the app, while the remainder comes from the website. She explained that the app is used for the purpose of controlling invasive species, not gathering ecological data. Due to the app malfunctioning on the Android platform, she disclosed that they began developing a new version of the 643-PEST app. MISC is equipped with teams who are ready to capture and eradicate invasive species to prevent any further spread.

Ms. Speith put us in contact with Sam Aruch, one of the developers who created the 643-PEST app. We discussed our potential app ideas, including Dr. Hess's requirements for app functions. He explained that they are all feasible and can be completed, though it would be more expensive to create a new app with these than the redevelopment of the 643-PEST app. While 643-PEST does currently lack some of the main requirements, like audio upload and offline GPS usage, Mr. Aruch explained that these features could potentially be added to the redeveloped version of the 643-PEST app. To add Dr. Hess's requirements to the new 643-PEST app, Mr. Aruch estimated that it would cost approximately $15,000, as a one-time fee, and an additional $2,500/year for upkeep.

In our second and final conversation with MISC on Feb 12, 2020, we talked to Abe Vandenburg and Lissa Strohecker about our potential app. They seemed extremely interested in our ideas and the final product. They expressed that they do not use 643-PEST often but would benefit from an app that could be used for both citizens and scientists. They both showed a passionate interest in incorporating education in the potential app, to encourage both citizens and scientists to use the application.

Informal inquiries with business owners

We collected opinions on the coquí frogs by sending out informal inquiries to realtors and nursery plant farms. After emailing three realtors and three nursery plant farms, only two sources responded, one from each category.

The realtor that responded, Kevin Walmsley, gave insight into the effects of invasive coquí on the real estate market. He confirmed that it is mandatory for the sellers of a house to disclose if they have a property with frogs. Since the coquí frogs' call is considered noise

pollution, it “affects the owners right to quiet enjoyment of a property” (K. Walmsley, personal communication, Jan 28, 2020). The Kona side of the Big Island does not have as many coquí frogs, therefore, even though they need to be disclosed when selling a house, it is not as much of an annoyance. In higher frog density areas, however, “that is when people really seem to get annoyed by them,” and when citizens work to de-frog their property (K. Walmsley, personal communication, Jan 28, 2020). Mr. Walmsley informed us about other coquí removal services that exist on the island to de-frog, besides government organizations.

We also communicated with Tom Piergrossi, the operator of a small plant nursery. He informed us that all of the import and export orders are hand-inspected to ensure the frogs are not spreading. These efforts are being made now even though coquí is well established, but the grower pointed out that “these and LFA [little fire ants] could have been stopped early on if an attempt had been made, it was not,” (T. Piergrossi, personal communication, Jan 30, 2020). Overall, the grower indicated that small businesses check for the frogs, however, individual shipments from “eBay and online plant purchases”, as well as an uneducated public are the problems that raise concern (T. Piergrossi, personal communication, Jan 30, 2020).

Objective 2. Evaluating alternative approaches to strengthen citizen science programs with respect to coquí management.

Through researching different ways to create a mobile app, we have come up with several different options for how we think the NWRC should proceed with their project. These options include the NWRC developing a custom app themselves, the NWRC hiring a contractor to make them an app, or the NWRC using/modifying existing apps.

Initial development and planning for a custom app

From the data gathered in Objective 1, we created three paper storyboards and three online mockups. We evaluated the government’s contractor rules and analyzed 105 app development software.

Creating a storyboard and online mockup

We developed three paper storyboards in order to create a draft design of what the potential app would look like. These storyboards showed three different versions of the app, but

could also be compiled into a single app if resources allow. The first includes the essential app functions that Dr. Hess listed as required components, including sound recording and uploading of GPS coordinates. The paper storyboard for the essential functions can be found in Appendix L and the online mockup in Appendix O. If cost is a limiting factor in the development of the app, this is projected to be the least expensive option because it contains the least amount of features by only including the bare minimum of Dr. Hess's requirements.

The second storyboard presents educational materials to provide information to users on the economic and environmental effects of the coquí frog. The paper storyboard can be found in Appendix M, and the online mockup in Appendix P. The third storyboard depicts an interactive app that includes a personal profile and ranking system to engage users by challenging them to report more frog sightings. The more sightings a user reports, the higher their character advances. Their character starts as a baby frog, then continues further to a froglet, frog, knight frog, and finally becomes a royal frog. Once we designed and finalized the paper storyboards, we developed them into online mockups. The paper storyboard can be found in Appendix N, and the online mockup in Appendix Q.

Evaluation of app development software and contractors

Out of the 105 software websites that we researched and contacted, only one included the requirements needed to develop the app, called Alpha Anywhere. The software that did not meet all of the requirements can be found in Appendix R.

Alpha Anywhere meets all of Dr. Hess's requirements, which include recording sound and image uploading, offline GPS, and data caching capabilities. Alpha Anywhere costs $5,000/year to create and publish an application, but there is a 30-day free trial available to design and view an app from their website. If using Alpha Anywhere, someone from the NWRC would be in charge of creating the app themselves.

After a discussion with Dr. Hess, we realized that hiring contractors is a difficult process because the NWRC is a federal agency, which is why contracting is done through a contracting officer. To obtain a rough estimate of how much our essential functions storyboard would cost, we discussed pricing with app developer Sam Aruch from NRDS. He explained that the app would cost approximately $15,000 - $20,000 to create, and $10,000 to set up an API and backend on NRDS's existing platform. This includes the cost to publish in both the Apple App

Store and the Google Play Store. In total, the app would cost approximately $30,000 with an additional $2,500/year for maintenance.

Government proposals

The proposals we prepared to help the NWRC develop collaborative relationships and seek funding to support app development are in the Appendix S. The NWRC can add on any pertinent information depending on what type of grants they decide to apply for.

Evaluation of existing applications

Since the development of a new app can be costly and time-consuming, we also evaluated two existing apps that seemed most likely to meet the NWRC's needs. In the situation that the NWRC decides to use an existing application, Table 1 shows the advantages and disadvantages table of these apps.

Table 1: Analysis of Currently Available Applications

App Name	Advantages	Disadvantages
iNaturalist	- GPS location capability. - Image upload capability. - Audio file upload capability. - The app is widely known, and many people use it. - Includes educational features about many species. - Available on iOS and Android.	- No verification protocol for uploaded data. - No direct communication with the owners (National Geographic). - Location uploading only works with service. - Data is not easily obtainable. - The interface is not user-friendly.
643-PEST	- GPS location capability. - Image upload capability. - Data verified by HISC. - Links to a website that provides more information on invasive species in Hawai'i (http:/dlnr.hawaii.gov/hisc/info/invasive-species-profiles). - Available on iOS and Android.	- No audio file upload capability. - Location uploading only works with service. - It only contains a free-response submission that allows for a high error rate in data.

From our analysis, we gathered that 643-PEST would work as a better option for Dr. Hess's needs. While both applications have GPS location capabilities and image uploading, neither of these functions works unless a user's phone is in an area with service at the time the user makes the attempt to upload. A disadvantage of iNaturalist is the suggestive image technology. The app allows a user to take a photo of a species and based on the photo it will give the user recommendations on what that species is. However, suggestions are only 60-80% accurate (Ueda, 2019). 643-PEST would be easy to collaborate with and access data since it is part of HISC, while iNaturalist's data is not easily attainable.

Synthesis and Future Directions

In summary, we have given the NWRC a number of resources that leave them well-positioned to improve their understanding of coquí ecology in Hawai'i and develop data-driven management practices for this species. These resources include the data from our surveys, interviews, and storyboards for app design. From our results, we inferred that the public does not have as much knowledge about the coquí frog as we previously assumed. We originally assumed that many citizens around the island knew that the coquí frog is invasive. From our surveys, we found that 45% of respondents dislike coquí frogs. After learning they are invasive, 61% of respondents stated that they dislike coquí frogs.

Education and outreach are one way to inform the public about the coquí and possibly increase the willingness for people to use the app. We created three storyboards, one including essential functions, another including educational aspects, and a final one including interactive components. Through this information, we have developed a set of strategies for the NWRC on how they can leverage these resources to produce a functioning app.

In order to utilize any of our suggestions, the NWRC would need to develop a marketing strategy to promote the app and educate the public on coquí frogs. A source for outreach would be through social media, such as Facebook, Instagram, Twitter, and LinkedIn. To interact with the public, we created an educational infographic about coquí frogs on the Big Island, which can be found in Appendix U. Educational outreach is not an inherent component of the work of the NWRC, but the incorporation of citizen science outreach could assist the NWRC in achieving its research mission. Collaborating with another organization whose mission does include educational outreach is the best option to allow the NWRC to achieve its citizen-science goals with respect to the coquí app. This would allow the NWRC to reach out to a younger age demographic through social media and hopefully increase their awareness of coquí frogs and willingness to use the app. Using an infographic can also aid in helping currently established outreach programs if the NWRC decides to partner with another organization to create their app.

Based on our research, we have proposed several alternative approaches for the NWRC to continue with the project. We have listed them in order of what is the most cost and time-efficient method, as well as most feasible for the NWRC.

1. Working with HISC on their redevelopment of 643-PEST

The NWRC could capitalize on the Hawai'i Invasive Species Council's (HISC) redevelopment of the 643-PEST app by forming a collaboration with them to ensure that the new app meets the NWRC's required features. We consider this to be the best and most viable option because it would allow for quick development of the app, as well as offer a currently available outreach program. In addition, the Invasive Species Councils have extensive public outreach activity, with the purpose of educating citizens and encouraging them to report invasive pests. Collaborating with HISC would give the NWRC the benefit of HISC outreach data collected by the citizens, without detracting from their main purpose, which is research. HISC's outreach program is used to educate the public about the management of coquí and other invasive species. The app would also be used to track other invasive species, giving the NWRC access to data on other species as well as on the coquí frog. Since HISC already began its development process, the storyboards we created would be used as a reference to some aspects or concepts that may be incorporated. Specifically, modifications to the new app would be needed to include offline GPS tracking and data caching abilities, as well as audio file upload. According to our interview with Mr. Aruch, even these modifications would be costly, so this isn't a perfect solution.

2. Creating a brand-new app in partnership with another organization

If HISC is no longer a viable option, the NWRC could contact other similar organizations, like the Hawai'i Department of Agriculture, Hawai'i Department of Land and Natural Resources, and Hawai'i Department of Health, to collaborate. We put this option second because more research needs to be done on the organizations to see their interest, while we have already been in communication with HISC, who is very interested in the project. Working with another organization would allow the NWRC to split to development costs and market the app more effectively. The NWRC and partnering organization could submit one of the government proposals we created to gain funding (Appendix S). While such a collaboration could provide the NWRC with a usable, marketable app, there could be difficulties coordinating with multiple parties to design and publish the app. This option would allow the NWRC to create an app that would fulfill all of their requirements by using the storyboards we created (Appendices L-P). This option could also potentially lower the cost to the NWRC, and possibly provide them with an existing outreach program to promote the app.

3. The NWRC hires a contractor to make and upkeep an app

The NWRC could opt to hire a contractor to create a brand-new app specifically for the purpose of tracking the occurrences of coquí frogs. It would also mean that the NWRC would not need to maintain the app themselves. This option is ranked below partnerships because while it would ensure that Dr. Hess's requirements are met, it would be more expensive. Since the NWRC does not already have an established citizen science program, they would also need to conduct their own outreach to recruit citizen scientists to use the app. The infographic in Appendix U would be useful in the initial marketing and outreach for the NWRC.

The hiring process for government contractors would be done through beta.sam.gov. However, hiring a contractor can be an expensive option and the process involves time and negotiation. The NWRC does have the option to submit one of the government proposals we created to gain additional funding for the contractor (Appendix S).

4. The NWRC makes the app through development software

Our final recommendation would be for the NWRC to develop their own app using the software Alpha Anywhere. While this option would provide the NWRC with a functioning app, it is the least viable option because this would likely involve the most time and effort to deploy an app**.** Alpha Anywhere is a user-friendly site that does not require coding, so someone with little to no experience can use them to create an app. However, it would still require some skill and motivation to convert our storyboards into an app. Once published, the app would be fully functional and be modeled after the design of the storyboards we created (Appendices L-P). Alpha Anywhere allows for the app to be published on both iOS and Android platforms.

Along with the yearly free to create an app with Alpha Anywhere, there is also a fee to publish the application into the app store. The Apple App Store publication fee is $99 per year, and the Google Play Store is a one-time $25 fee. Similar to hiring a contractor, the app would be specifically designed to fit their needs, but the NWRC would need to conduct their own outreach**.** Similar to the marketing strategy discussed in the previous approach, the NWRC could use the infographic in Appendix U for education and outreach. Since they would be the owners of the app, it would be up to the NWRC to update and maintain the app.

Conclusion

All of the suggested approaches would ultimately result in the NWRC receiving data from an app that fulfills all of their needs. The major differences among the four approaches we have described are the app developer, how the app is marketed, and the time necessary to complete development. The comparison in Table 2 summarizes the important features of the four strategies we have outlined in this section. The cost of the project would also vary with each approach, but price estimates are unknown for collaborating with an organization. Prices for all four approaches could also vary if government funding is received. For these reasons, we did not compare the cost in Table 2.

Table 2: Summary of alternative approaches

	Professional developer makes the app	Good existing public outreach	A quick app development process
Working with HISC on their redevelopment of 643-PEST	✓	✓	✓
Creating a brand-new app in partnership with another organization	✓	✓	✗
The NWRC hires a contractor to make and upkeep the app for them	✓	✗	✗
The NWRC makes the app themselves through development software	✗	✗	✗

Invasive coquí frogs on the Big Island of Hawai'i are an environmental, economic, and public health concern. There is great potential for citizen science involvement in coquí tracking. We think there is a strong potential for effective collaboration between HISC or a similar organization and the NWRC. We hope that this research provides the NWRC with the right tools and background information to continue developing an app that will bridge the gap between users and scientists.

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Appendices

Appendix A: Facebook and University survey

Script:

Aloha!

We are a team of students from Worcester Polytechnic Institute in Massachusetts. We would like you to take a few minutes to fill out this survey to see your knowledge about the coquí frog. This is a collaborative project with the National Wildlife Research Center. Your participation in this 3-minute survey is voluntary, anonymous, and greatly appreciated. Mahalo!

1. What is your age?
    - ➢ Less than 18
    - ➢ 18-24
    - ➢ 25-39
    - ➢ 40-60
    - ➢ 60+
    - ➢ Prefer not to answer
2. What is your gender?
    - ➢ Male
    - ➢ Female
    - ➢ Other
    - ➢ Prefer not to answer
3. Do you have young children (18 or younger)?
    - ➢ Yes
    - ➢ No
    - ➢ Prefer not to answer
4. What is the highest level of education received?
    - ➢ Less than high school

- ➢ High school/ GED
- ➢ Some college
- ➢ 2-year degree
- ➢ 4-year degree
- ➢ Master's degree
- ➢ Doctorate degree
- ➢ Professional degree
- ➢ Prefer not to answer

5. What is your zip code?
6. What type of phone do you have?
   - ➢ iPhone
   - ➢ Android
   - ➢ Other
7. Do you live on the Big Island?
   - ➢ Yes
   - ➢ No (just visiting)
   - ➢ I am a student here

   Condition: **Yes is selected.** Skip to: Question 9.

   Condition: **No (just visiting) is selected.** Skip to: Question 9.

   Condition: **I am a student here.** Continue to: Question 8.
8. Do you intend to stay here after college?
   - ➢ Yes
   - ➢ Maybe
   - ➢ No
9. How long have you lived here?
   - ➢ Not applicable
   - ➢ Less than a year
   - ➢ 1-5 years
   - ➢ 5+ years

- ➢ Born and raised here

10. What is your opinion on the coquí frog?
    - ➢ I like them
    - ➢ I do not have an opinion
    - ➢ I do not like them
    - ➢ I do not know what they are
11. Please list all of the environmental effects the coquí have on Hawai'i that you are aware of: _____
12. Please list all of the economic effects the coquí have on Hawai'i that you are aware of: _____
13. Coquí frogs are invasive to Hawai'i. Based on this information, does your opinion of them change?
    - ➢ My opinion has not changed
    - ➢ I do not like them now
    - ➢ I like them now
14. What measures have you taken to prevent the spread of coquís?
    - ➢ I donate to local organizations
    - ➢ I capture frogs
    - ➢ I donate to local organizations and capture frogs
    - ➢ Other
    - ➢ None
15. Would you be interested in using a smartphone app to assist scientists in tracking the spread of coquís?
    - ➢ Yes
    - ➢ No
16. Please list any other invasive species (besides coquí) that are on the Big Island of Hawai'i that you are aware of: _____
17. Is there anything else you would like to tell us in regard to your experience with the coquí frog? _____

Appendix B: Volcano survey

Script:

Aloha!

We are a team of students from Worcester Polytechnic Institute in Massachusetts. We would like you to take a few minutes to fill out this survey to see your knowledge about the coquí frog. This is a collaborative project with the National Wildlife Research Center. Your participation in this 3-minute survey is voluntary, anonymous, and greatly appreciated. Mahalo!

1. What is your age?
    - ➢ Less than 18
    - ➢ 18-24
    - ➢ 25-39
    - ➢ 40-60
    - ➢ 60+
    - ➢ Prefer not to answer
2. What is your gender?
    - ➢ Male
    - ➢ Female
    - ➢ Other
    - ➢ Prefer not to answer
3. Do you have young children (18 or younger)?
    - ➢ Yes
    - ➢ No
    - ➢ Prefer not to answer
4. What is the highest level of education received?
    - ➢ Less than high school
    - ➢ High school/ GED
    - ➢ Some college

- ➢ 2-year degree
- ➢ 4-year degree
- ➢ Master's degree
- ➢ Doctorate degree
- ➢ Professional degree
- ➢ Prefer not to answer

5. What is your zip code?
6. What type of phone do you have?
   - ➢ iPhone
   - ➢ Android
   - ➢ Other
7. Do you live on the Big Island?
   - ➢ Yes
   - ➢ No (just visiting)
   - ➢ I am a student here
8. Do you intend to stay here after college?
   - ➢ Yes
   - ➢ Maybe
   - ➢ No

     Condition: **Yes is selected.** Skip to: Question 9.

     Condition: **No (just visiting) is selected.** Skip to: Question 9.

     Condition: **I am a student here.** Continue to: Question 8.
9. How long have you lived here?
   - ➢ Not applicable
   - ➢ Less than a year
   - ➢ 1-5 years
   - ➢ 5+ years
   - ➢ Born and raised here
10. What is your opinion on the coquí frog?

- ➢ I like them
- ➢ I do not have an opinion
- ➢ I do not like them
- ➢ I do not know what they are

11. Please list all of the environmental effects the coquí have on Hawai'i that you are aware of: _____
12. Please list all of the economic effects the coquí have on Hawai'i that you are aware of: _____
13. Coquí frogs are invasive to Hawai'i. Based on this information, does your opinion of them change?
    - ➢ My opinion has not changed
    - ➢ I do not like them now
    - ➢ I like them now
14. Have you heard of rat lungworm disease?
    - ➢ Yes
    - ➢ No
15. Coquí frogs are a carrier of rat lungworm disease. Based on this information, does your opinion of them change?
    - ➢ My opinion has not changed
    - ➢ I do not like them now
    - ➢ I like them now
16. What measures have you taken to prevent the spread of coquís?
    - ➢ I donate to local organizations
    - ➢ I capture frogs
    - ➢ I donate to local organizations and capture frogs
    - ➢ Other
    - ➢ None
17. Would you be interested in using a smartphone app to assist scientists in tracking the spread of coquís?
    - ➢ Yes

➢ No

18. Please list any other invasive species (besides coquí) that are on the Big Island of Hawai'i that you are aware of: _____
19. Is there anything else you would like to tell us in regard to your experience with the coquí frog? _____

Appendix C: Survey locations

Table 3 shows where the location for where we gave out each survey, either on Facebook or in person.

Table 3: Location of Surveys

	Facebook survey	In-person survey
Location	● Hilo Happenings ● Hawai'i Tracker ● Big Island Hawai'i ● All things big island ● Kona-HI.com: buy sell and trade ● Kona happenings	● The University of Hawai'i at Hilo 01/24/2020 ● Hawai'i Volcanoes National Park 01/29/2020 ● Volcano Farmers Market 02/23/2020

Appendix D: Interview with Professor Mautz

Script:

We are a team of students from Worcester Polytechnic Institute in Massachusetts. This is a collaborative project with the National Wildlife Research Center. Your participation is greatly appreciated, and you may opt-out at any time. If you would like, we would be happy to include your comments as anonymous. Would it be ok if we recorded this conversation?

1. What is your involvement in coquí management?
2. Where do you see coquí management has fallen short?
3. Do you see an app being able to bridge this gap?
4. What demographic do you see using an application?
5. Have you in your field of research come across any tools that can aid us in our research?
6. Do you think there are other areas, other than National Parks, that this app could be used in?

Appendix E: Interview with Tim Tunison

Script:

We are a team of students from Worcester Polytechnic Institute in Massachusetts. This is a collaborative project with the National Wildlife Research Center. Your participation is greatly appreciated, and you may opt-out at any time. If you would like, we would be happy to include your comments as anonymous. Would it be ok if we recorded this conversation?

1. What is your involvement in coquí management?
2. Where do you see coquí management has fallen short?
3. Do you see an app being able to bridge this gap?
4. What demographic do you see using an application?
5. What kind of resources would you need?
6. How many people are involved?
7. What will it take to be successful (people, out in the rain catching frogs)?
8. We heard you had a table at the farmers market, would we be able to set up one weekend and ask some questions to people in the market?
9. Since the government has strict regulations, we're looking for someone to take ownership of the app, do you know of any non-govt organizations that would possibly be interested?
10. Are there any other people on the island, outside of Volcano, that you know of who is working in invasive species monitoring and control, and who might be willing to speak with us?
11. Do you have any other insight?

Appendix F: Interview with Franny Brewer

Script:

We are a team of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews with various organizations to see how much information they know about coquís. This is a collaborative project with the National Wildlife Research Center. Your participation in this interview is voluntary and you may opt-out at any time. If you would like, we would be happy to include your comments as anonymous. Would you mind if we recorded this interview?

1. What is your role in BIISC?
2. How long has BIISC been around?
3. What type of outreach does the program perform?
4. How does your reporting system work?
5. Has it been successful? Which have you seen to work better, the website or the app?
6. What do you do with the information once a species is called in?
7. Do you partner with other organizations? Do the organizations you partner with have access to the 643-pest data?
8. How do you go through the data and check the validity of responses?
9. Would you be interested in partnering with the NWRC for sharing coquí data?
10. Would you be willing to edit the 643-PEST app to include sound recording uploading? (Example of a coquí frog call)

Appendix G: Interview with Elizabeth Speith

Script:

We are a team of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews with various organizations to see how much information they know about coquís. This is a collaborative project with the National Wildlife Research Center. Your participation in this interview is voluntary and you may opt-out at any time. If you would like, we would be happy to include your comments as anonymous. Would you mind if we recorded this interview? Since this is for a paper would you be ok with us using your name?

1. What is your role in MIISC?
2. Do you market the app in any way?
3. Who runs the app and maintains it?
4. Can you queue data or if you don't have service does the data get lost (ex: Volcanoes National Park)?
5. How does your reporting system work?
6. Has it been successful? Which have you seen to work better, the website or the app?
7. What do you do with the information once a species is called in?
8. Do you partner with other organizations? Do the organizations you partner with have access to the 643-PEST data?
9. Would you be interested in partnering with the USDA for sharing coquí data?
10. Would you be willing to edit the 643-pest app to include sound recording uploading? (Example of a coquí frog call)

Appendix H: Interview with Abe Vandenburg and Lissa Strohecker

Script:

We are a team of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews with various organizations to see how much information they know about coquís. This is a collaborative project with the National Wildlife Research Center. Your participation in this interview is voluntary and you may opt-out at any time. If you would like, we would be happy to include your comments as anonymous. Would you mind if we recorded this interview? Since this is for a paper would you be ok with us using your name?

1. What is your role in MIISC?
2. Do you market the app in any way?
3. Who runs the app and maintains it?
4. Has it been successful? Which have you seen to work better, the website or the app?
5. What do you do with the information once a species is called in?
6. Do you partner with other organizations? Do the organizations you partner with have access to the 643-PEST data? Do other people use locus?
7. Would you be interested in partnering with the USDA for sharing coquí data?
8. What is he looking for in an app?
9. Would he use an app?

Appendix I: Interview with Sam Aruch

Script:

We are a team of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews with various organizations to see how much information they know about coquís. This is a collaborative project with the National Wildlife Research Center. Your participation in this interview is voluntary and you may opt-out at any time. If you would like, we would be happy to include your comments as anonymous. Would you mind if we recorded this interview? Since this is for a paper would you be ok with us using your name if we need to quote you?

1. How long have you been working in the field?
2. How long have you been working with government agencies?
3. Are there any regulations for government projects?
4. What features are you planning on putting in the new app?
5. How long does the development process take?
6. How expensive is the developmental process? / How do your contracts work?
7. What is your preferred choice of storyboard? (paper, online, Figma, Swiftic?)
8. How often do you update the 643-PEST App?
9. Can you explain the process of obtaining data for partners?
10. Can you queue data or if you don't have service does the data get lost (ex: Volcanoes National Park)?
11. What would be a long-term upkeep plan?
12. Would you be willing to edit to include audio uploading? (Example of a coquí frog call)

Appendix J: Informal inquiries to nursery plant owners and realtors

Email:

Aloha,

We are a group of students working with the NWRC to create a mobile app to track the spread of coquí frogs around the Big Island of Hawai'i. We were wondering if the coquí invasion has had an impact on your business at all and how you have adapted to them on the island? If you have any other information or opinions on the coquí we would love to hear them.

Mahalo!

Brittany, Amelia, Marina, and Adam

Appendix K: Informal inquiries to app development websites

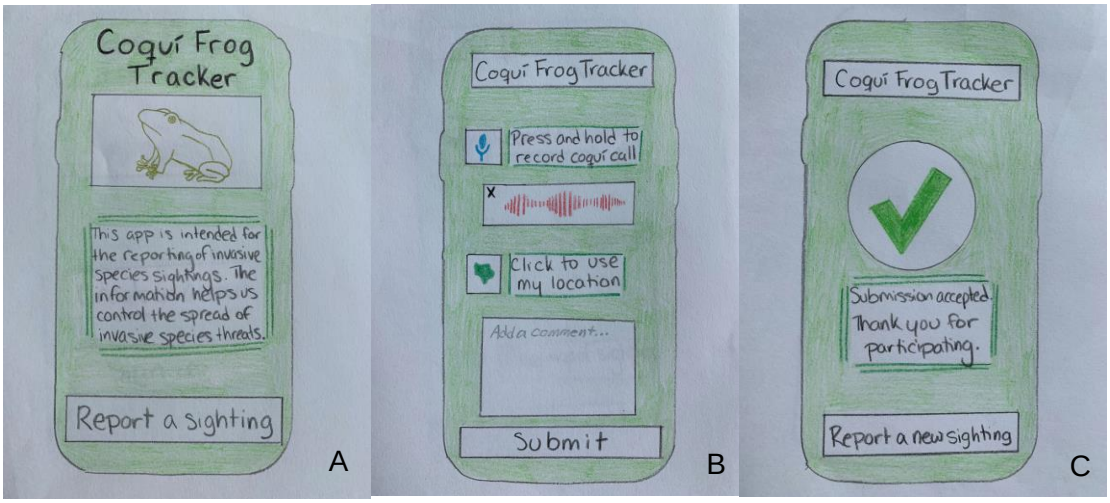
Email:

Hello,

I'm looking into various app developing websites for my boss and am looking for some quick information. We're trying to create a mobile app for the lowest price possible while still maintaining the required functions we need. Do your apps allow for location tracking and pinning (including while in an area with no service), audio recording, and submission of information to a database? Let me know, thank you!

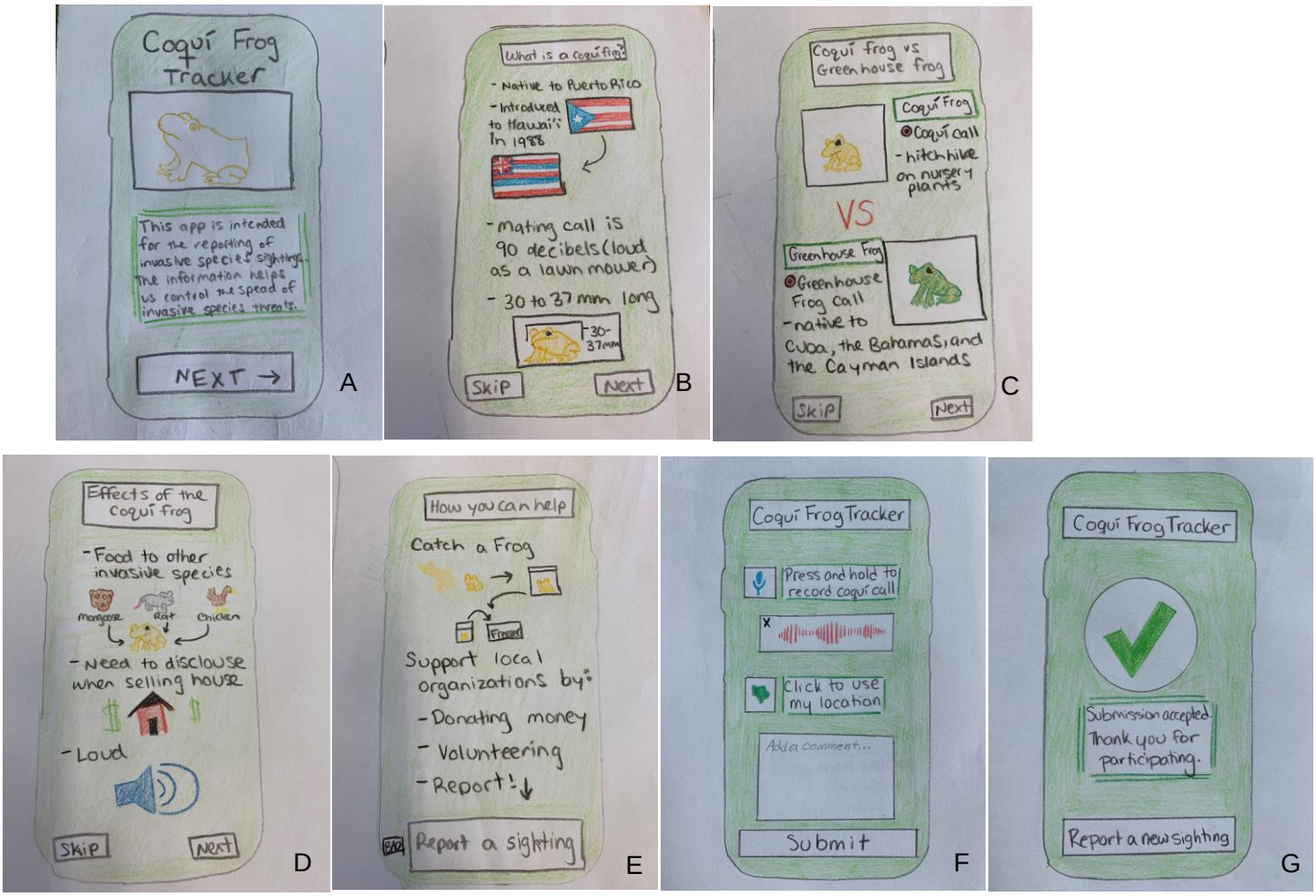
Brittany, Amelia, Marina, and Adam

Appendix L: Essential functions paper storyboard



This storyboard lets the user click on the “Report a sighting” button in Image A, which brings them to Image B where a coquí call can be recorded. If the user presses the “Click to use my location” button in Image B, it will upload the user’s current location. If the user presses the “Add a comment…” box in Image B, it will allow them to type a free-response comment. The “Submit” button in Image B would send the data to a backend database for analysis. When the data is successfully submitted, Image C will show the user so they can exit the app or “Report a new sighting”, which would bring them back to Image B.

Appendix M: Educational paper storyboard



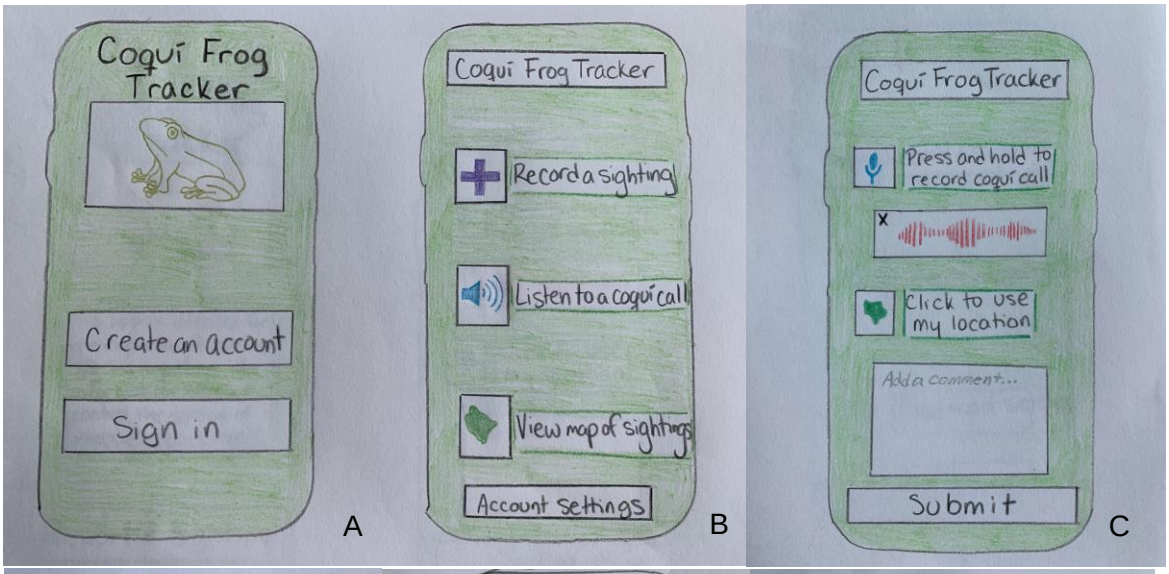
In this educational storyboard, Image A allows the user to click the arrow button on the bottom of the screen which will bring them to Image B. Image B describes what a coquí frog is and gives basic facts about them. The user can click “Skip” in the bottom left corner, which will bring the user to Image E. If the user clicks “Next” in the bottom right corner, it will bring them to Image C.

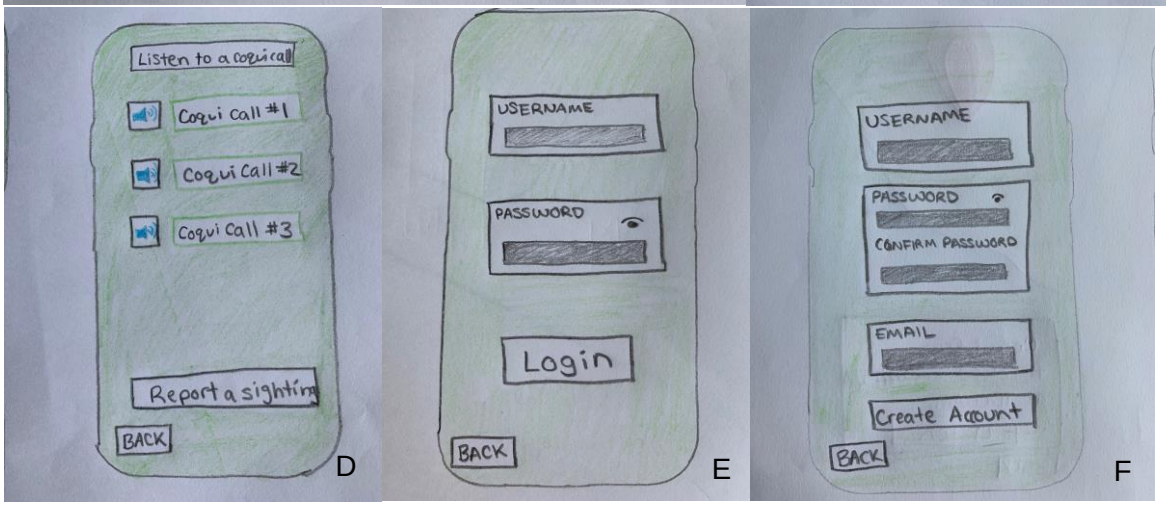
Image C describes basic differences between the coquí frog and the greenhouse frog. The user can click on the audio symbols to listen to the different calls a coquí and greenhouse frog make. The user can click “Skip” in the bottom left corner, which will bring them to Image E. If the user clicks “Next” in the bottom right corner, it will bring them to Image D. Image D

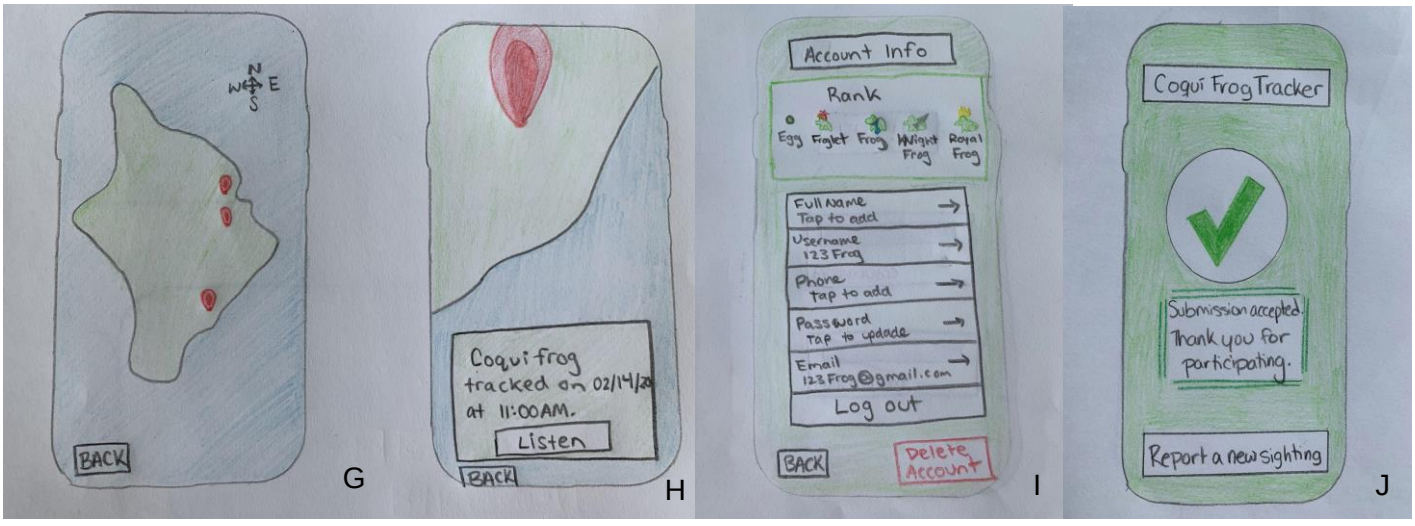
describes some major economic and environmental effects of the coquí frogs on Hawai'i. The user can click “next” in the bottom right corner, it will bring them to Image E. Image E describes how users can help control the spread of coquí frogs. The user can click “report a sighting” on the bottom of the screen which will bring them to Image F.

If the user presses the “Record a coquí call button” in Image F, it will allow them to take a recording. If the user presses the “Click to use my location” button in Image F, it will upload the user’s current location. If the user presses the “Add a comment…” box in Image F, it will allow them to type a free-response comment. The “Submit” button would allow for the data to be sent to a backend database for analysis. When the data is successfully submitted, Image G will show the user they can “Report a new sighting”, which would bring them back to Image E.

Appendix N: Interactive paper storyboard







In this interactive storyboard, Image A would allow for the user to click on the button “Create an account”, or “Sign in”. Choosing “Create an account” will bring the user to Image F where basic information can be added to create an account. The “Back” button in Image F will bring users to Image A. The “Sign in” button on Image A will bring users to Image E where they can input the login information. The “Back” button will go to Image A, and the “Login” button will bring users to Image B. Image B depicts four buttons, “Record a sighting”, “Listen to a coquí call”, “View map of sightings”, and “Account Settings”.

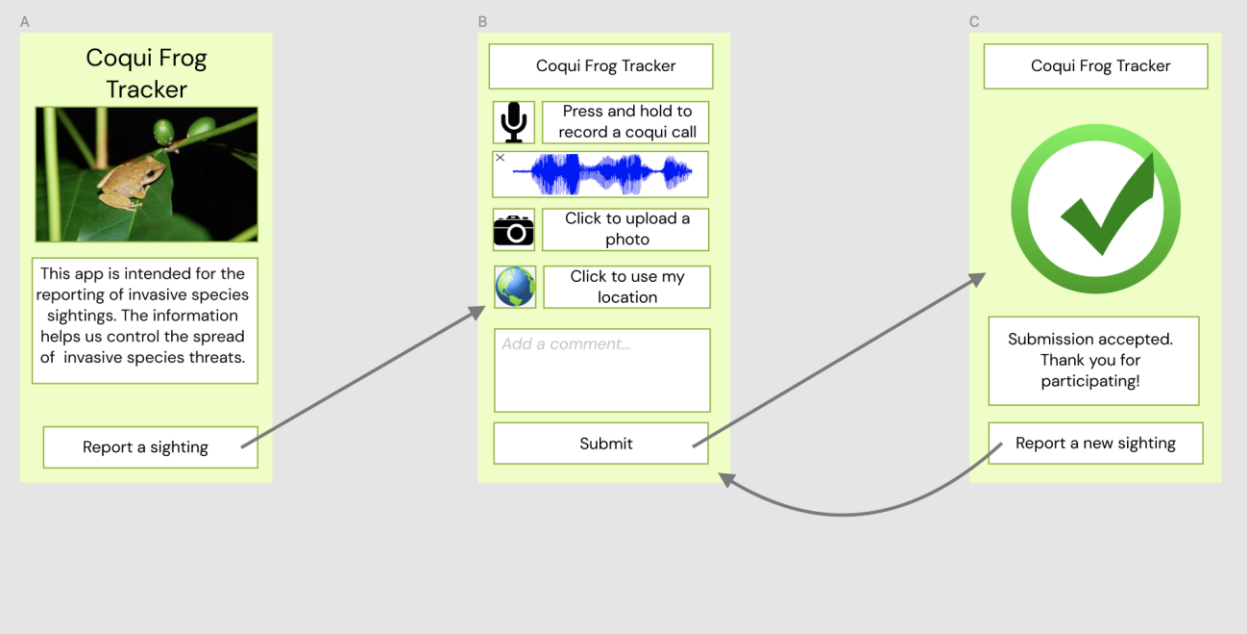
If the user presses the “Record a coquí call button” in Image C, it will allow them to take a recording. If the user presses the “Click to use my location” button in Image C, it will upload the user’s current location. If the user presses the “Add a comment…” box in Image C, it will allow them to type a free-response comment. The “Submit” button would allow for the data to be sent to a backend database for analysis. When the data is successfully submitted, Image J will show the user that they can exit the app or “Report a new sighting”, which would bring them back to Image C.

If the user presses “Listen to a coquí call” in Image C, it will bring users to Image D where different noises that coquís make can be clicked on to play. The “Report a sighting” button on Image D will bring users to Image C where the sighting can be recorded as stated above.

If the user clicks the “View map of sightings” in Image B, a map of all the user’s sightings will be shown in Image G. The user can go back to Image B by using the “Back” button, or can click on a red pin to see the data for that sighting shown in Image H. Image H shows the data collected from that entry and lets the user listen to the recording. The “Back” button brings the user to Image G.

In Image B, the “Account Settings” button brings the user to Image I. This page shows all general information, such as name, username, phone (not required), password, and email. It also shows the rank of the user, Baby frog (0-5 sightings), Froglet (5-10 sightings), Frog (10-25 sightings), Knight Frog (25-50 sightings), and Royal Frog (+50 sightings). There is also the option in Image J to log out or delete the account.

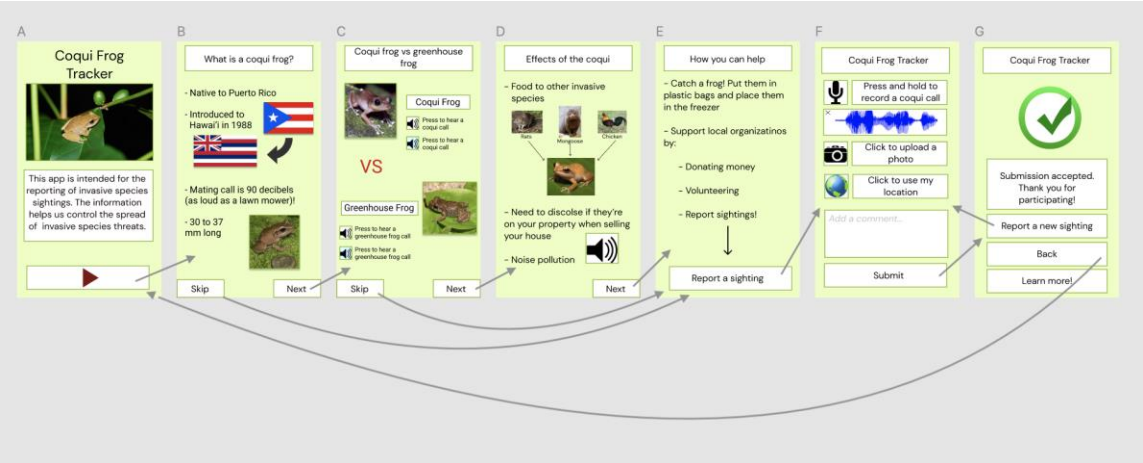
Appendix O: Essential functions online mockup



To view to the online storyboard: https://www.figma.com/proto/mBJyMgrtGm2AO2tkQLK3RM/Coqui-frog-app-storyboards?node-id=49%3A1&scaling=scale-down

This storyboard lets the user click on the “Report a sighting” button in Image A, which brings them to Image B where a coquí call can be recorded. If the user presses the “Click to use my location” button in Image B, it will upload the user’s current location. If the user presses the “Click to upload a photo” button in Image B, it will allow the user to take a photo. If the user presses the “Add a comment…” box in Image B, it will allow them to type a free-response comment. The “Submit” button in Image B would send the data to a backend database for analysis. When the data is successfully submitted, Image C will show the user so they can exit the app or “Report a new sighting”, which would bring them back to Image B.

Appendix P: Educational online mockup



To link to the online storyboard: https://www.figma.com/proto/mBJyMgrtGm2AO2tkQLK3RM/Coqui-frog-app-storyboards?node-id=72%3A3&scaling=scale-down

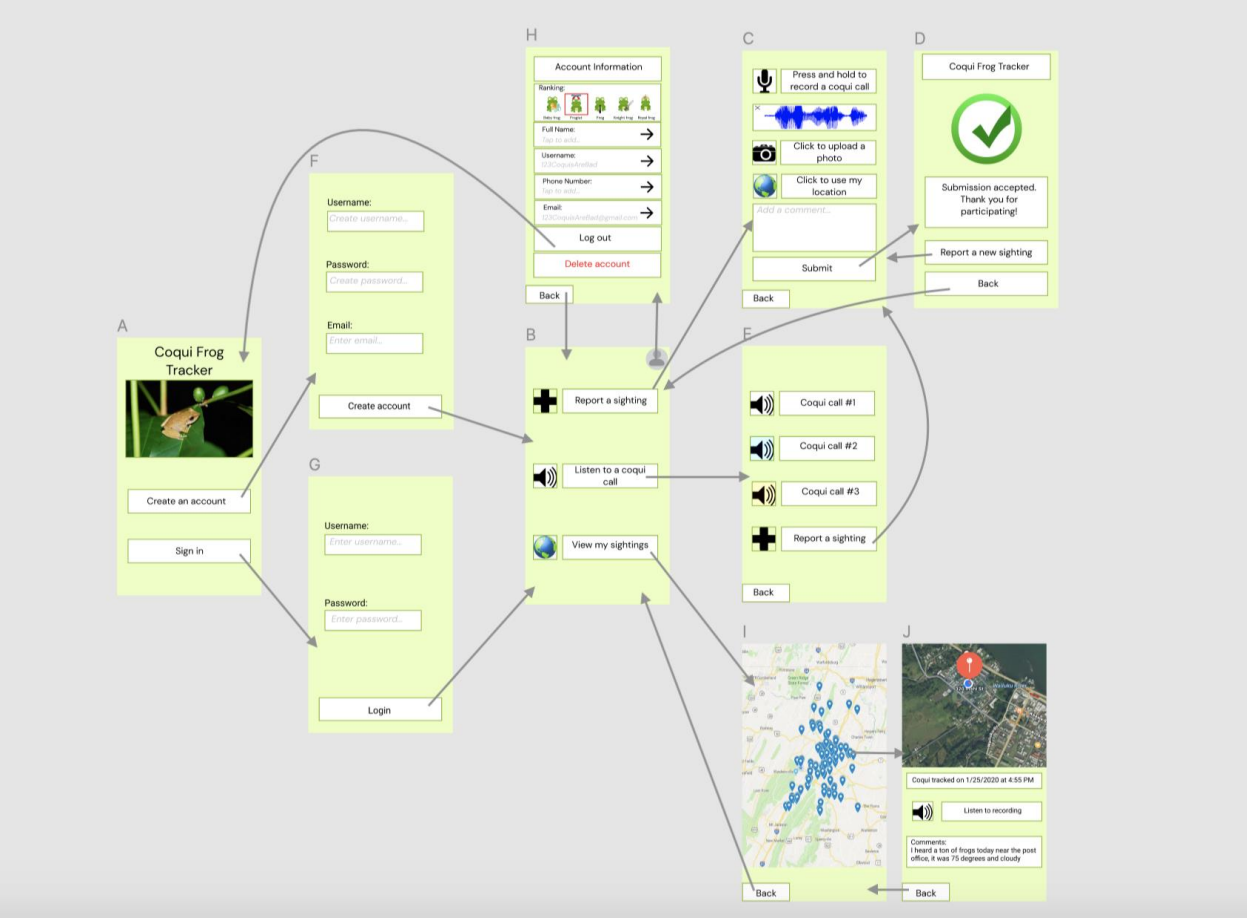
In this educational storyboard, Image A allows the user to click the arrow button on the bottom of the screen which will bring them to Image B. Image B describes what a coquí frog is and gives basic facts about them. The user can click “Skip” in the bottom left corner, which will bring the user to Image E. If the user clicks “Next” in the bottom right corner, it will bring them to Image C.

Image C describes basic differences between the coquí frog and the greenhouse frog. The user can click on the audio symbols to listen to the different calls a coquí and greenhouse frog make. The user can click “Skip” in the bottom left corner, which will bring them to Image E. If the user clicks “Next” in the bottom right corner, it will bring them to Image D. Image D describes some major economic and environmental effects of the coquí frogs on Hawai'i. The user can click “next” in the bottom right corner, it will bring them to Image E. Image E describes how users can help control the spread of coquí frogs. The user can click “report a sighting” on the bottom of the screen which will bring them to Image F.

If the user presses the “Record a coquí call button” in Image F, it will allow them to take a recording. If the user presses the “Click to upload a photo” button in Image F, it will allow the user to take a photo. If the user presses the “Click to use my location” button in Image F, it will

upload the user's current location. If the user presses the "Add a comment…" box in Image F, it will allow them to type a free-response comment. The "Submit" button would allow for the data to be sent to a backend database for analysis. When the data is successfully submitted, Image G will show the user they can "Report a new sighting", which would bring them back to Image E.

Appendix Q: Interactive online mockup



To link to the online storyboard: https://www.figma.com/proto/mBJyMgrtGm2AO2tkQLK3RM/Coqui-frog-app-storyboards?node-id=73%3A62&scaling=min-zoom

In this interactive storyboard, Image A would allow for the user to click on the button “Create an account”, or “Sign in”. Choosing “Create an account” will bring the user to Image F where basic information can be added to create an account. The “Back” button in Image F will bring users to Image A. The “Sign in” button on Image A will bring users to Image E where they can input the login information. The “Back” button will go to Image A, and the “Login” button will bring users to Image B. Image B depicts four buttons, “Record a sighting”, “Listen to a coquí call”, “View map of sightings”, and “Account Settings”.

If the user presses the “Record a coquí call button” in Image C, it will allow them to take a recording. If the user presses the “Click to upload a photo” button in Image C, it will allow the user to take a photo. If the user presses the “Click to use my location” button in Image C, it will upload the user’s current location. If the user presses the “Add a comment…” box in Image C, it will allow them to type a free-response comment. The “Submit” button would allow for the data to be sent to a backend database for analysis. When the data is successfully submitted, Image J will show the user that they can exit the app or “Report a new sighting”, which would bring them back to Image C.

If the user presses “Listen to a coquí call” in Image C, it will bring users to Image D where different noises that coquís make can be clicked on to play. The “Report a sighting” button on Image D will bring users to Image C where the sighting can be recorded as stated above.

If the user clicks the “View map of sightings” in Image B, a map of all the user’s sightings will be shown in Image G. The user can go back to Image B by using the “Back” button, or can click on a red pin to see the data for that sighting shown in Image H. Image H shows the data collected from that entry and lets the user listen to the recording. The “Back” button brings the user to Image G.

In Image B, the “Account Settings” button brings the user to Image I. This page shows all general information, such as name, username, phone (not required), password, and email. It also shows the rank of the user, Baby frog (0-5 sightings), Froglet (5-10 sightings), Frog (10-25 sightings), Knight Frog (25-50 sightings), and Royal Frog (+50 sightings). There is also the option in Image J to log out or delete the account.

Appendix R: List of app development websites we investigated that do not meet our requirements

Fluid UI
GoodBarber
Siberian CMS
AppMachine
Appsbuilder
Xcode
TheAppBuilder
Intel XDK
Xamarin
AWS Mobile SDK
Windows 10 SDK
Knack
Quick Base
TrackVia
Nuclide
Chatroll
MoNimbus
Caspio
Fabric
iBuildApp
Salesforce
Applivery
Swiftic
GameSalad
Clinked
AppYourself
JetBrains
Locatify
Myappbuilder
Fliplet
Kony Quantum/Temenos
Zoho Creator
Sysdev Kalipso
Appsmoment
Crunchbase (Mobicart)
Feathery.io
Visual Studio
Outsystems
Appery.io
Gluon
Android studio
Azure SDK
Codename One
ArcGIS
Shoutem
Mobincube
iOS SDK
BuildFire
Bubble 2.0
AppsGeyser
Dropsource
Nylas
Appian
Genwi
Firebase
JetBrains (Intellij IDEA)
Android NDK
Appnotch
Citrix: Mobile SDK for Windows Apps
Corona SDK
Adobe AIR
RubyMotion
Appcelerator
Verivo
Sweb
Snappii
Thunkable
Felgo
Zeroqode
Appsolid (SEworks)
Ionic Creator V2
AppSheet
BiznessApps
Mobile Roadie
Appgyver
MobAppCreator
App Press
Adalo
NeverCode
Apptive
Hatch Apps
Bobile
Create my free app

Beaconstac	Mobiroller	AppFurnace
Formotus	App Builder Online	Mass Mobile Apps
Trackvia	Double dutch	Paperlit
AppsBar	AppInstitute	Appsm
Appsmakersstore	Generato	AppMakr
Storyline (Voiceflow)	Calvium	GoCanvas
Appdrag cloud backend	Magmito	Appy Pie

Appendix S: Federal government funding proposals

In this Appendix we have two separate proposals. The first is intended to be used in the situation that the NWRC decides to develop their own app using Alpha Anywhere. The second proposal would be used in the situation that the NWRC decides to hire a contractor to create the app for them.

NWRC Invasive Species Management Proposal #1

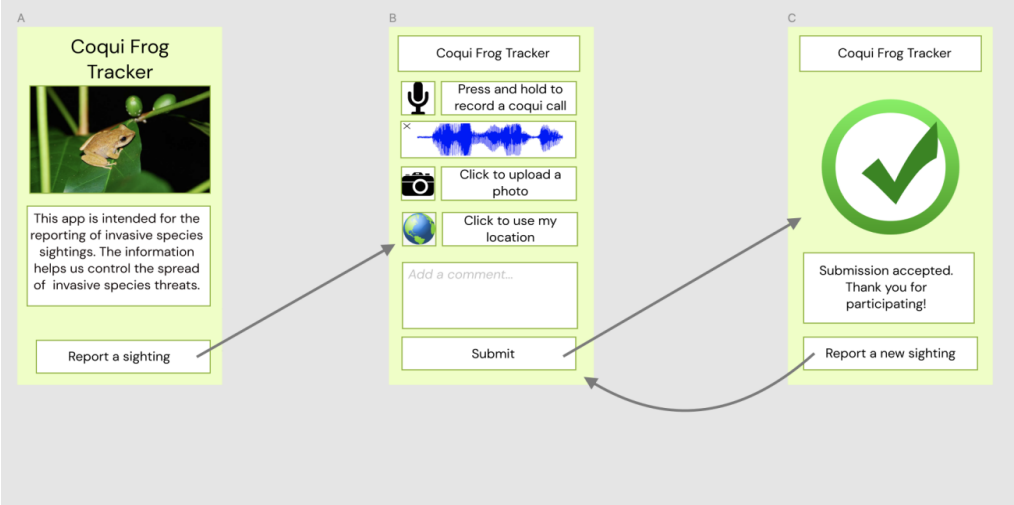
- **Title:** Improving resources for citizen science in the management of frogs in Pacific Island parks
- **Investigator:** Dr. Steven Hess
- **Center:** National Wildlife Research Center
- **DOI stakeholder:** United States Department of Agriculture - Animal and Plant Health Inspection Service
- **Description of the project:** The goal of this project is to develop a cost-effective method of controlling and tracking the spread of invasive species with the help of citizen scientists around the Hawai'i Island and in national parks. This would be done by having the NWRC develop their own app through the no-code app development site, Alpha Anywhere. This app would then be a gateway for citizen scientists to become involved in invasive species management. The NWRC would conduct outreach programs by marketing on Facebook and other media.
- **Budget source:** The creation of an app by inside personnel would fit the needs of the NWRC by including offline GPS and data caching, image uploading, and audio file uploading. Alpha Anywhere would be $5,000 per year. To publish the app on both Apple and Android, the Apple App Store would cost $99 per year to publish the app and the Google Play Store would be a one-time $25 fee to publish on their app store. It would be ideal to post in both the Apple App Store and Google Play Store since 68% of individuals surveyed use iPhones whereas the experts we talked to mostly use Androids for

fieldwork. Having the mobile app in both stores would allow for greater outreach and use of the app by citizens and scientists alike.

- **Timeline:** TBD
- **Key products/output/outcome:** This project would result in a smartphone app and database to engage citizen scientists in the management of invasive species throughout the Islands. This app would be initially focused on coquí frogs but able to be expanded to other invasive species. This app would be used for scientists and citizens to help track the spread of coquí frogs on the Big Island. An audit plan will be developed and implemented a year after the initial development of the app to evaluate the effectiveness of the app and whether more funding will be requested to support the app. The storyboards provided below would guide the development of the new app through Alpha Anywhere. To engage more users, the NWRC would expand their community outreach. Facebook and other social media would be used to market the app. Marketing the app would encourage citizens to participate in citizen science and report coquí frogs. Links to educational sites would be included to encourage participants to learn more about the effects of coquí frogs on Hawai'i.

1. Essential Functions App Storyboard:

This storyboard lets the user click on the “Report a sighting” button in Image A, which brings them to Image B where a coquí call can be recorded. If the user presses the “Click to use my location” button in Image B, it will upload the user’s current location. If the user presses the “Click to upload a photo” button in Image B, it will allow the user to take a photo. If the user presses the “Add a comment…” box in Image B, it will allow them to type a free-response comment. The “Submit” button in Image B would send the data to a backend database for analysis. When the data is successfully submitted, Image C will show the user so they can exit the app or “Report a new sighting”, which would bring them back to Image B.



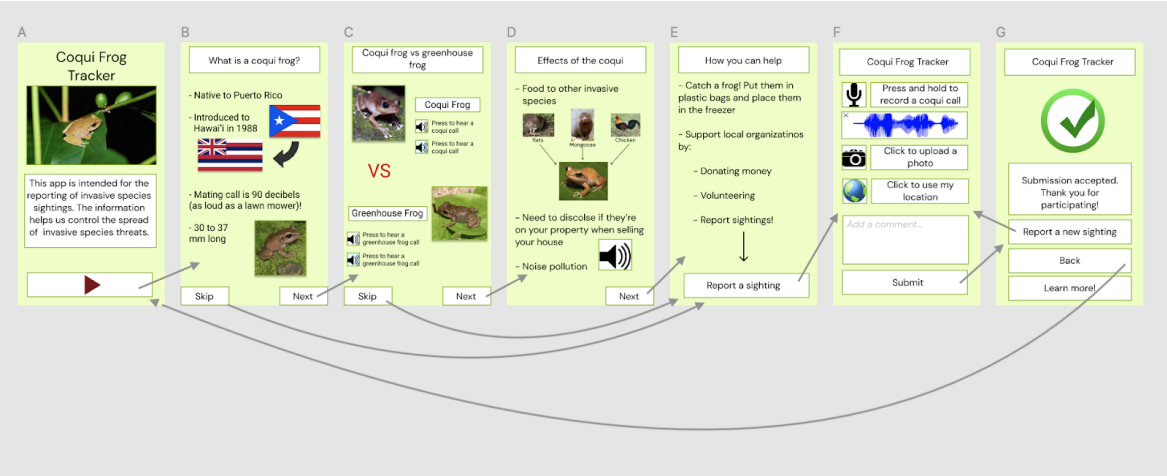
2. Educational Storyboard:

In this educational storyboard, Image A allows the user to click the arrow button on the bottom of the screen which will bring them to Image B. Image B describes what a coquí frog is and gives basic facts about them. The user can click “Skip” in the bottom left corner, which will bring the user to Image E. If the user clicks “Next” in the bottom right corner, it will bring them to Image C.

Image C describes basic differences between the coquí frog and the greenhouse frog. The user can click on the audio symbols to listen to the different calls a coquí and greenhouse frog make. The user can click “Skip” in the bottom left corner, which will bring them to Image E. If the user clicks “Next” in the bottom right corner, it will bring them to Image D. Image D describes some major economic and environmental effects of the coquí frogs on Hawai'i. The user can click “next” in the bottom right corner, it will bring them to Image E. Image E describes how users can help control the spread of coquí frogs. The user can click “report a sighting” on the bottom of the screen which will bring them to Image F.

If the user presses the “Record a coquí call button” in Image F, it will allow them to take a recording. If the user presses the “Click to upload a photo” button in Image F, it will allow the user to take a photo. If the user presses the “Click to use my location” button in Image F, it will upload the user’s current location. If the user presses the “Add a comment…” box in Image F, it will allow them to type a free-response comment. The “Submit” button would allow for the data

to be sent to a backend database for analysis. When the data is successfully submitted, Image G will show the user they can “Report a new sighting”, which would bring them back to Image E.



3. Interactive Storyboard:

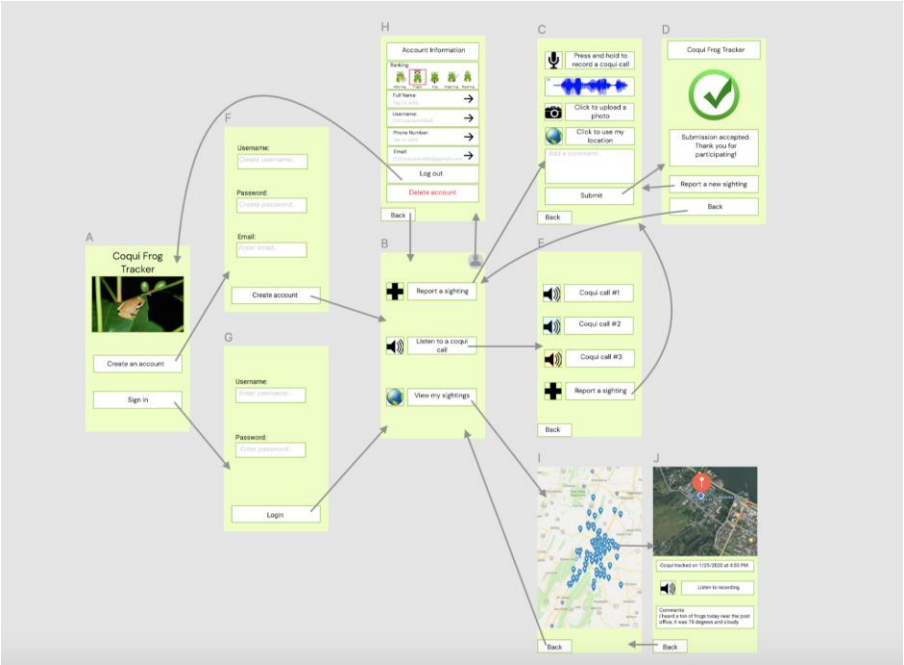
In this interactive storyboard, Image A would allow for the user to click on the button “Create an account”, or “Sign in”. Choosing “Create an account” will bring the user to Image F where basic information can be added to create an account. The “Back” button in Image F will bring users to Image A. The “Sign in” button on Image A will bring users to Image E where they can input the login information. The “Back” button will go to Image A, and the “Login” button will bring users to Image B. Image B depicts four buttons, “Record a sighting”, “Listen to a coquí call”, “View map of sightings”, and “Account Settings”.

If the user presses the “Record a coquí call button” in Image C, it will allow them to take a recording. If the user presses the “Click to upload a photo” button in Image C, it will allow the user to take a photo. If the user presses the “Click to use my location” button in Image C, it will upload the user’s current location. If the user presses the “Add a comment…” box in Image C, it will allow them to type a free-response comment. The “Submit” button would allow for the data to be sent to a backend database for analysis. When the data is successfully submitted, Image J will show the user that they can exit the app or “Report a new sighting”, which would bring them back to Image C.

If the user presses “Listen to a coquí call” in Image C, it will bring users to Image D where different noises that coquís make can be clicked on to play. The “Report a sighting” button on Image D will bring users to Image C where the sighting can be recorded as stated above.

If the user clicks the “View map of sightings” in Image B, a map of all the user’s sightings will be shown in Image G. The user can go back to Image B by using the “Back” button, or can click on a red pin to see the data for that sighting shown in Image H. Image H shows the data collected from that entry and lets the user listen to the recording. The “Back” button brings the user to Image G.

In Image B, the “Account Settings” button brings the user to Image I. This page shows all general information, such as name, username, phone (not required), password, and email. It also shows the rank of the user, Baby frog (0-5 sightings), Froglet (5-10 sightings), Frog (10-25 sightings), Knight Frog (25-50 sightings), and Royal Frog (+50 sightings). There is also the option in Image J to log out or delete the account.



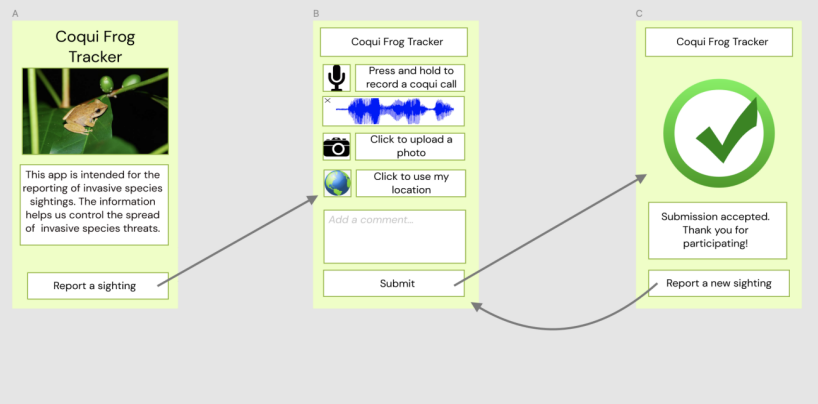
NWRC Invasive Species Management Proposal #2

- **Title:** Improving resources for citizen science in the management of frogs in Pacific Island parks
- **Investigator:** Dr. Steven Hess
- **Center:** National Wildlife Research Center
- **DOI stakeholder:** United States Department of Agriculture - Animal and Plant Health Inspection Service
- **Description of the project:** The goal of this project is to develop a cost-effective method of controlling and tracking the spread of invasive species with the help of citizen scientists around the Hawai'i Island and in national parks. This would be done by either establishing a partnership with the Hawai'i Invasive Species Council or hiring a contractor to create an app with features that would fit the needs of the NWRC.
- **Budget source:** If the NWRC decided to partner with another invasive species management organization, the cost to develop the app is unknown. To determine the price of the app, the partner organization's budget would need to be evaluated, as well as the features and contractors for the app. The contractor would need to be able to code the features listed: offline GPS and data caching, image uploading, and audio file uploading.
- **Timeline:** TBD
- **Key products/output/outcome:** This project would result in a smartphone app and database to engage citizen scientists in the management of invasive species throughout the Islands. This app would be initially geared towards coquí frogs but able to be expanded to other invasive species. This app would be used for scientists and citizens to help track the spread of coquí frogs on the Big Island. An audit plan will be developed and implemented a year after the initial development of the app to evaluate the effectiveness of the app and whether more funding will be requested to support the app. A partnership with another organization could also allow for shared resources across the app leading to potentially lower costs for both organizations. In contract terms, it would

allow for the continued support of the app without much intervention from the sponsored organizations. The storyboards provided below guide the development of the new app that would be created by contractors or in collaboration with partnering organizations. They would also be used as a guide to edit any currently existing applications.

1. Essential Functions App Storyboard:

This storyboard lets the user click on the "Report a sighting" button in Image A, which brings them to Image B where a coquí call can be recorded. If the user presses the "Click to use my location" button in Image B, it will upload the user's current location. If the user presses the "Click to upload a photo" button in Image B, it will allow the user to take a photo. If the user presses the "Add a comment…" box in Image B, it will allow them to type a free-response comment. The "Submit" button in Image B would send the data to a backend database for analysis. When the data is successfully submitted, Image C will show the user so they can exit the app or "Report a new sighting", which would bring them back to Image B.



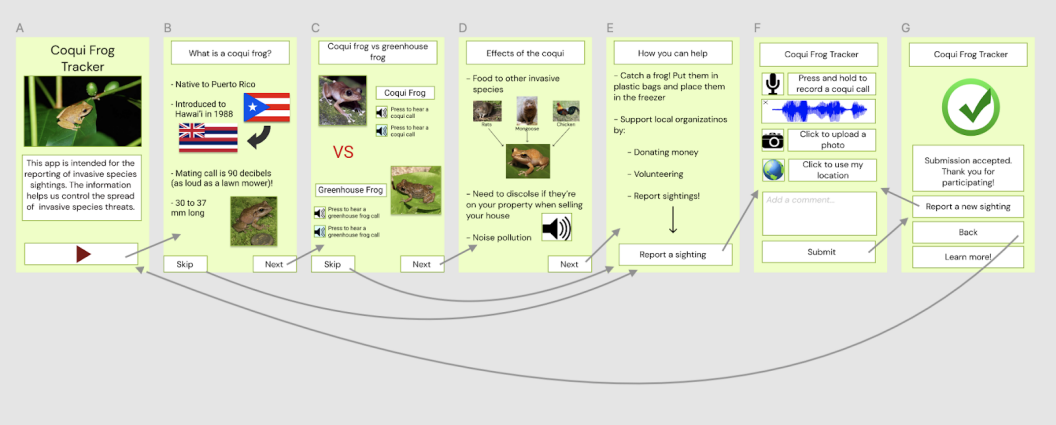
2. Educational Storyboard:

In this educational storyboard, Image A allows the user to click the arrow button on the bottom of the screen which will bring them to Image B. Image B describes what a coquí frog is and gives basic facts about them. The user can click "Skip" in the bottom left corner, which will bring the user to Image E. If the user clicks "Next" in the bottom right corner, it will bring them to Image C.

Image C describes basic differences between the coquí frog and the greenhouse frog. The user can click on the audio symbols to listen to the different calls a coquí and greenhouse frog make. The user can click "Skip" in the bottom left corner, which will bring them to Image E. If

the user clicks “Next” in the bottom right corner, it will bring them to Image D. Image D describes some major economic and environmental effects of the coquí frogs on Hawai'i. The user can click “next” in the bottom right corner, it will bring them to Image E. Image E describes how users can help control the spread of coquí frogs. The user can click “report a sighting” on the bottom of the screen which will bring them to Image F.

If the user presses the “Record a coquí call button” in Image F, it will allow them to take a recording. If the user presses the “Click to upload a photo” button in Image F, it will allow the user to take a photo. If the user presses the “Click to use my location” button in Image F, it will upload the user’s current location. If the user presses the “Add a comment…” box in Image F, it will allow them to type a free-response comment. The “Submit” button would allow for the data to be sent to a backend database for analysis. When the data is successfully submitted, Image G will show the user they can “Report a new sighting”, which would bring them back to Image E.



3. Interactive Storyboard:

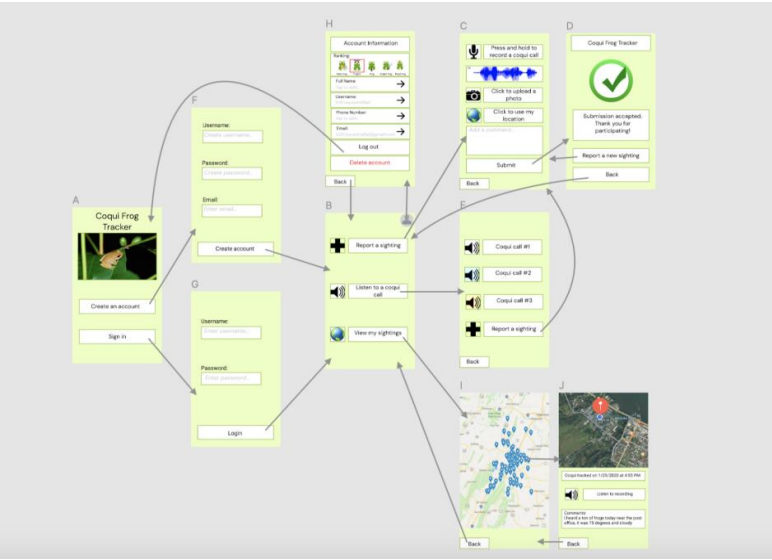
In this interactive storyboard, Image A would allow for the user to click on the button “Create an account”, or “Sign in”. Choosing “Create an account” will bring the user to Image F where basic information can be added to create an account. The “Back” button in Image F will bring users to Image A. The “Sign in” button on Image A will bring users to Image E where they can input the login information. The “Back” button will go to Image A, and the “Login” button will bring users to Image B. Image B depicts four buttons, “Record a sighting”, “Listen to a coquí call”, “View map of sightings”, and “Account Settings”.

If the user presses the “Record a coquí call button” in Image C, it will allow them to take a recording. If the user presses the “Click to upload a photo” button in Image C, it will allow the user to take a photo. If the user presses the “Click to use my location” button in Image C, it will upload the user’s current location. If the user presses the “Add a comment…” box in Image C, it will allow them to type a free-response comment. The “Submit” button would allow for the data to be sent to a backend database for analysis. When the data is successfully submitted, Image J will show the user that they can exit the app or “Report a new sighting”, which would bring them back to Image C.

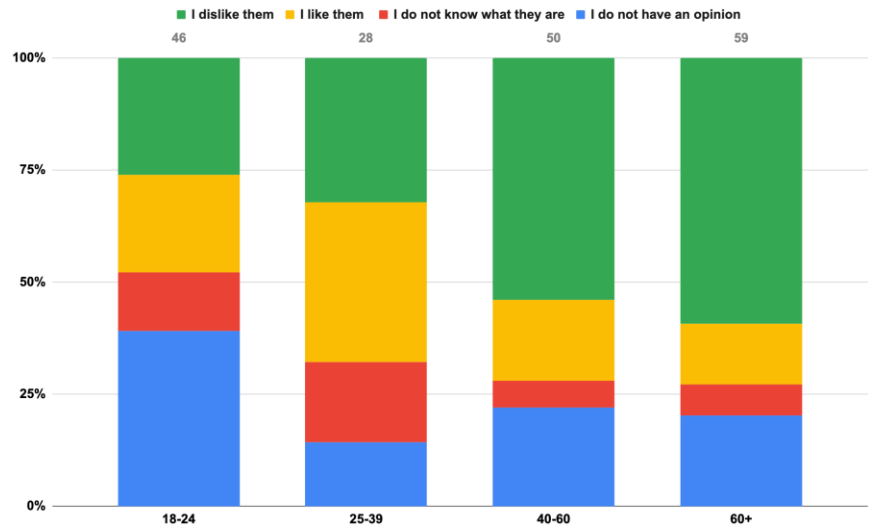
If the user presses “Listen to a coquí call” in Image C, it will bring users to Image D where different noises that coquís make can be clicked on to play. The “Report a sighting” button on Image D will bring users to Image C where the sighting can be recorded as stated above.

If the user clicks the “View map of sightings” in Image B, a map of all the user’s sightings will be shown in Image G. The user can go back to Image B by using the “Back” button, or can click on a red pin to see the data for that sighting shown in Image H. Image H shows the data collected from that entry and lets the user listen to the recording. The “Back” button brings the user to Image G.

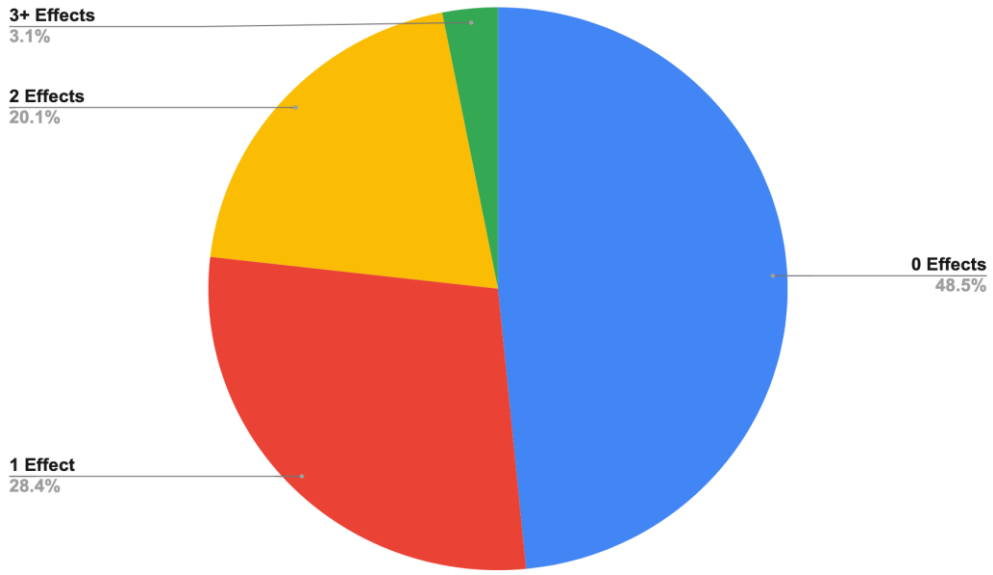
In Image B, the “Account Settings” button brings the user to Image I. This page shows all general information, such as name, username, phone (not required), password, and email. It also shows the rank of the user, Baby frog (0-5 sightings), Froglet (5-10 sightings), Frog (10-25 sightings), Knight Frog (25-50 sightings), and Royal Frog (+50 sightings). There is also the option in Image J to log out or delete the account.



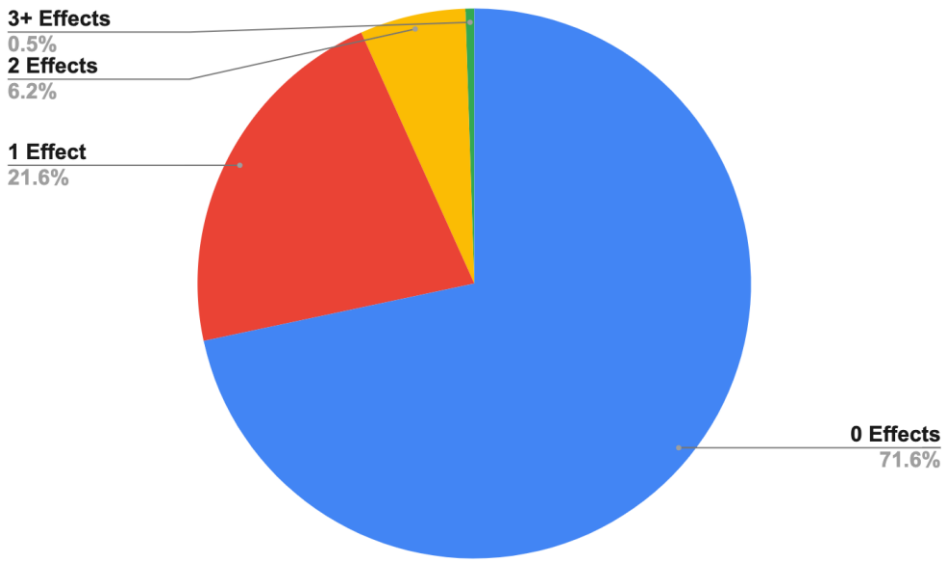
Appendix T: Survey Data



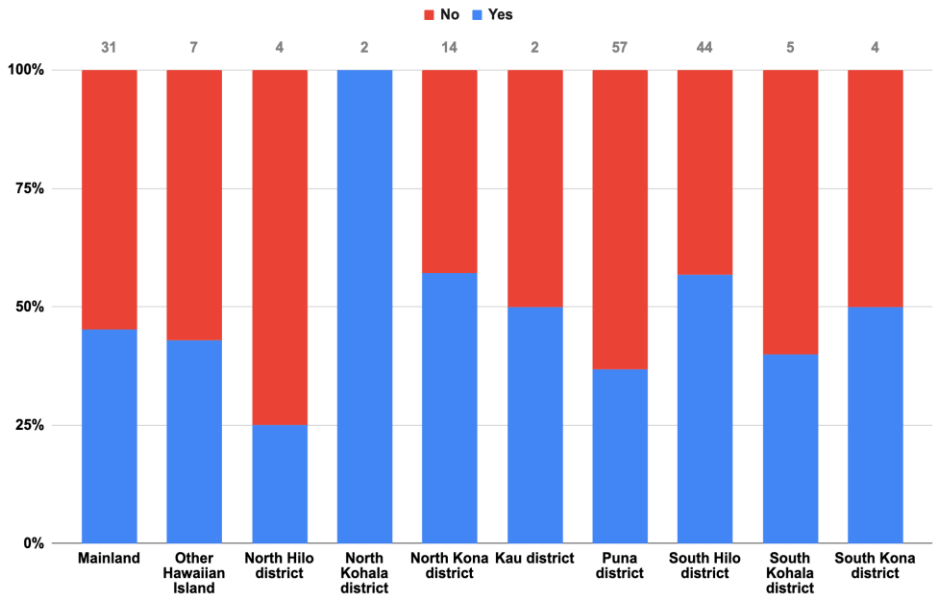
A total of 183 respondents answered the question "What is your opinion on the coquí frog?". This graph shows the age of respondents compared to their opinions on coquí frogs. The numbers above the bars indicate the total number of responses in each category.



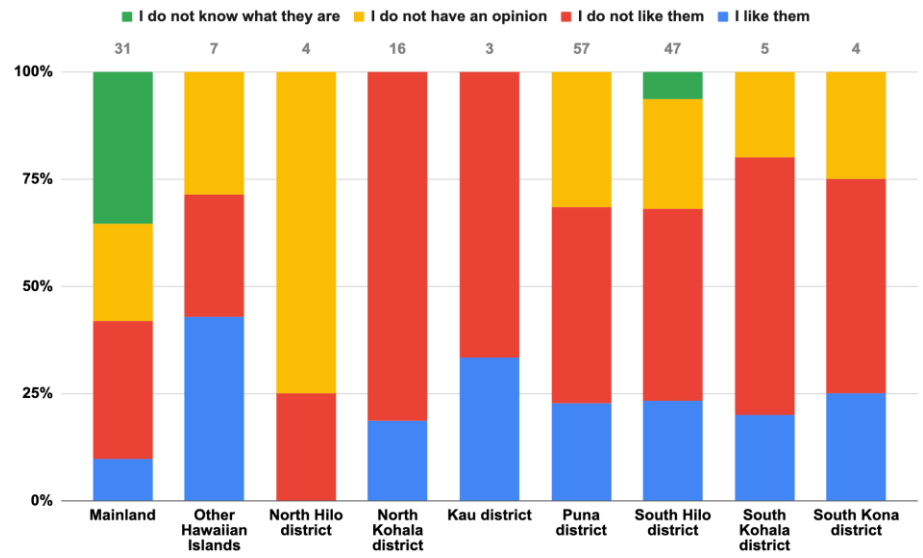
A total of 194 respondents answered the question "Please list all environmental effects the coquí have on Hawai'i that you are aware of:". This graph shows their responses.



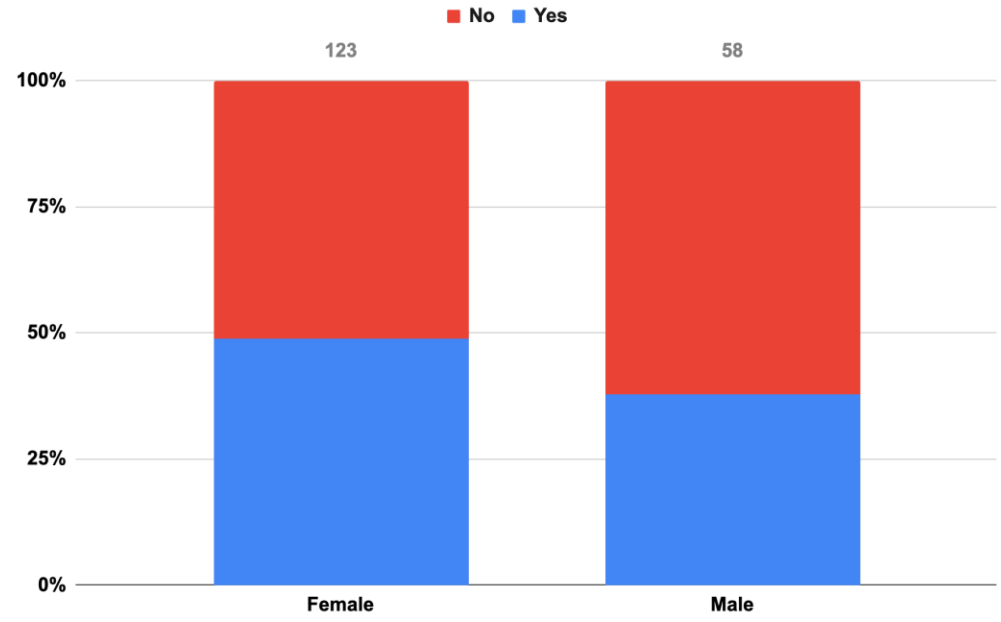
A total of 194 respondents answered the question "Please list all economic effects the coquí have on Hawai'i that you are aware of". This graph shows their responses.



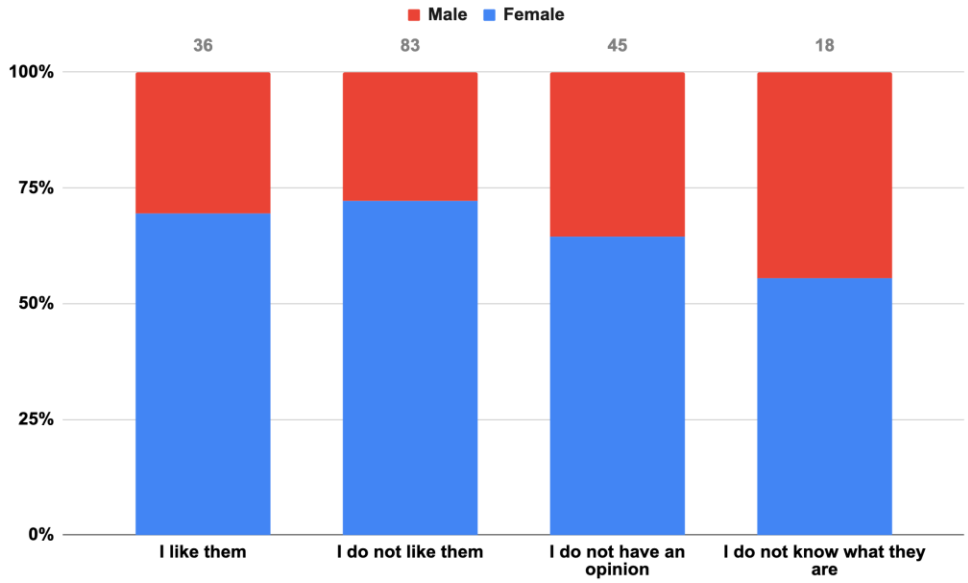
A total of 170 respondents answered the questions "What is your zip code?" and "Would you be interested in using a smartphone app to assist scientists in tracking the spread of coquí frogs?". This graph shows their residency compared to whether they would be interested in using a smartphone app to track the occurrences of coquí frogs. The numbers above the bars indicate the total number of responses in each category.



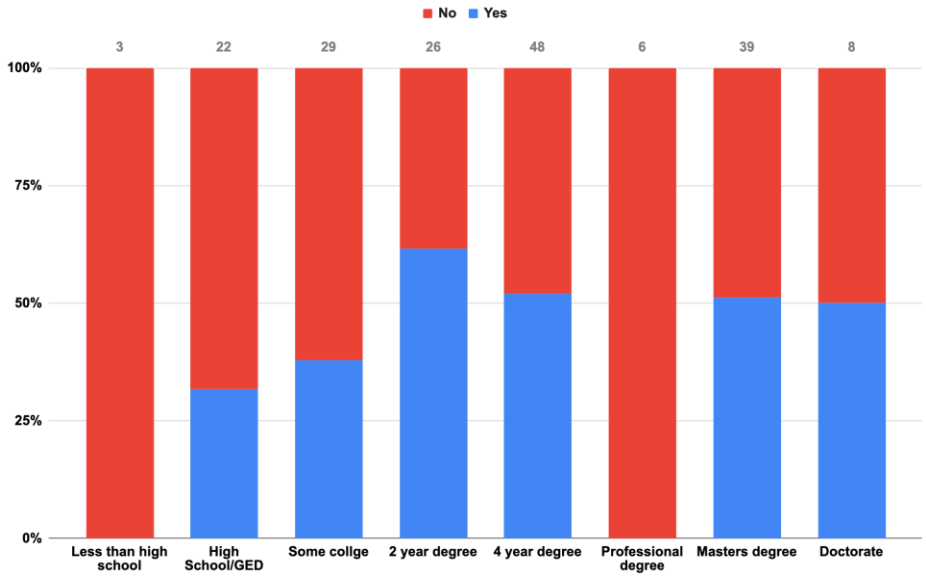
A total of 170 respondents answered the question "What is your zip code?" and "What is your opinion on the coquí frog?". This graph shows their residency compared to their opinions on the coquí frog. The numbers above the bars indicate the total number of responses in each category.



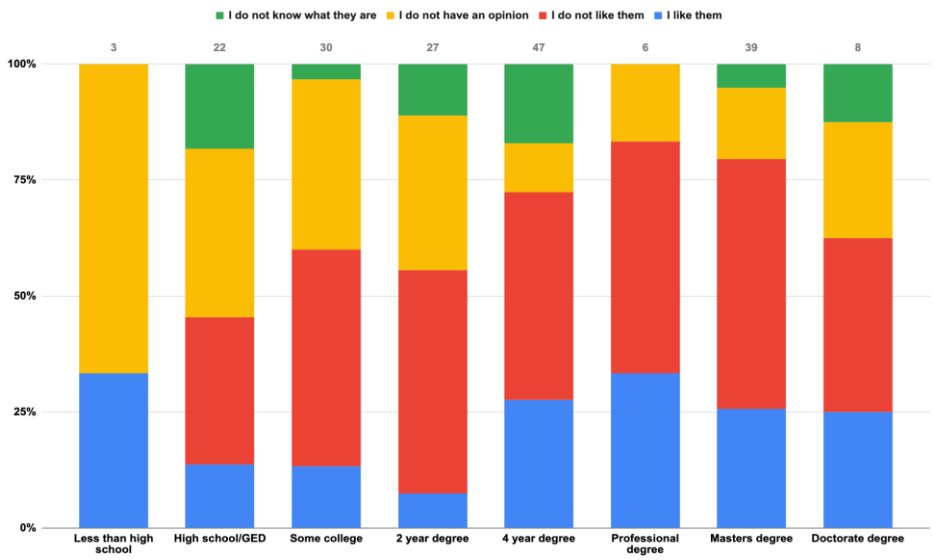
A total of 181 respondents answered the question "Would you be interested in using a smartphone app to assist scientists in tracking the spread of coquís?". This graph shows the gender of respondents compared to whether they would use a smartphone app to track coquí frogs. The numbers above the bars indicate the total number of responses in each category.



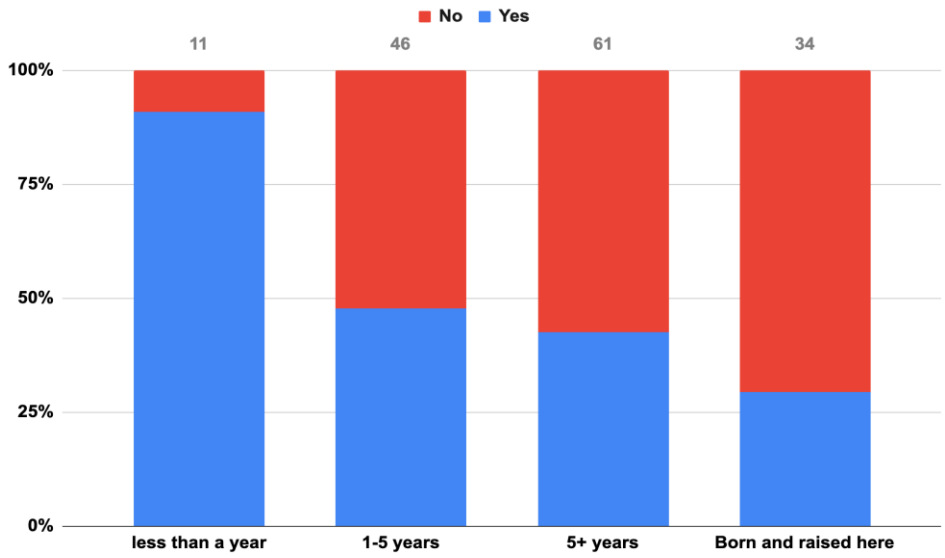
A total of 182 respondents answered the question "What is your opinion on the coquí frog?". This graph shows the gender of respondents compared to their opinion on coquí frogs. The numbers above the bars indicate the total number of responses in each category.



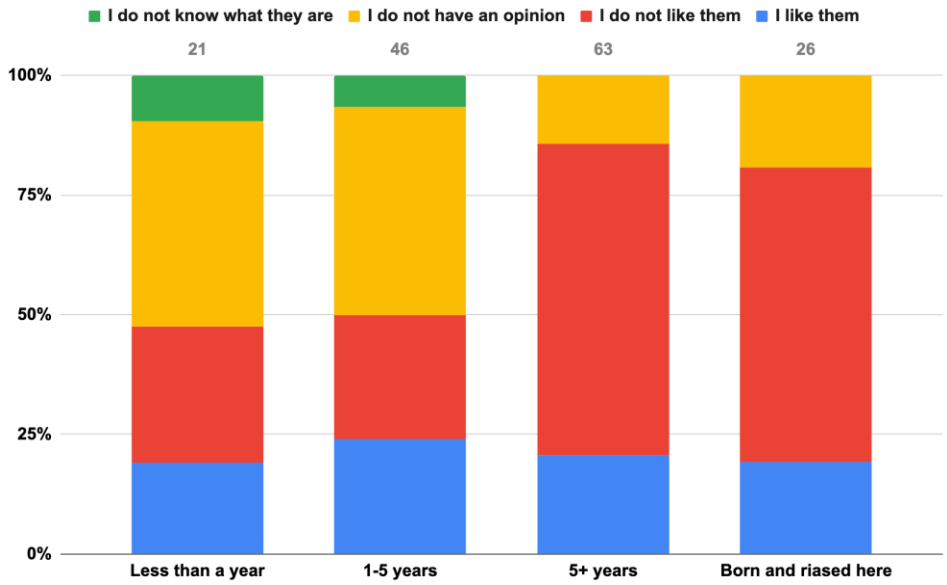
A total of 182 respondents answered the questions "What is the highest level of education received?" and "Would you be interested in using a smartphone app to assist scientists in tracking coquí frogs?". This graph shows the highest level of education received by respondents compared to whether they would use a smartphone app to track coquí frogs. The numbers above the bars indicate the total number of responses in each category.



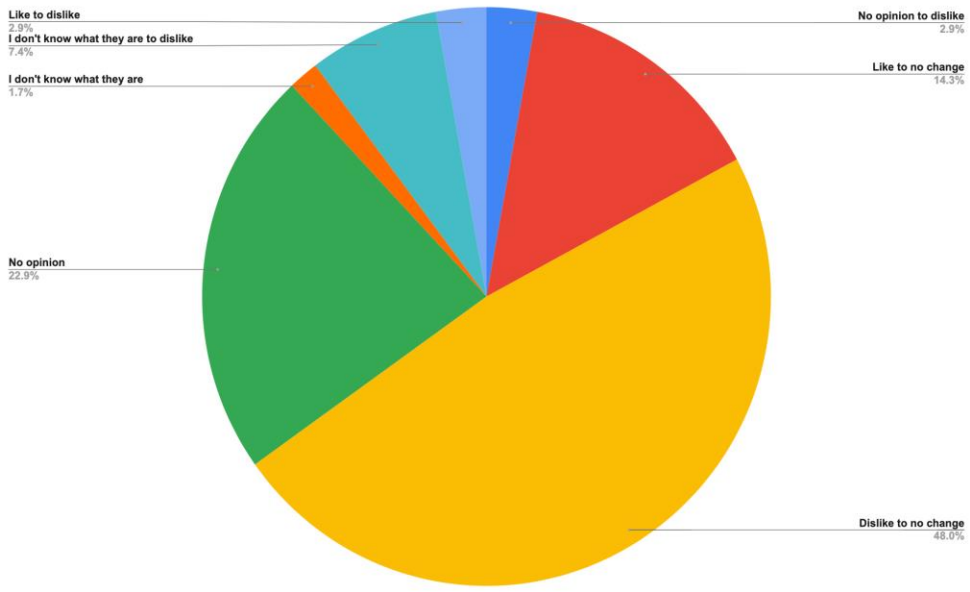
A total of 182 respondents answered the questions "What is the highest level of education received" and "What is your opinion on the coquí frog". The graph shows the highest level of education received of respondents compared to their opinions on coquí frogs. The numbers above the bars indicate the total number of responses in each category.



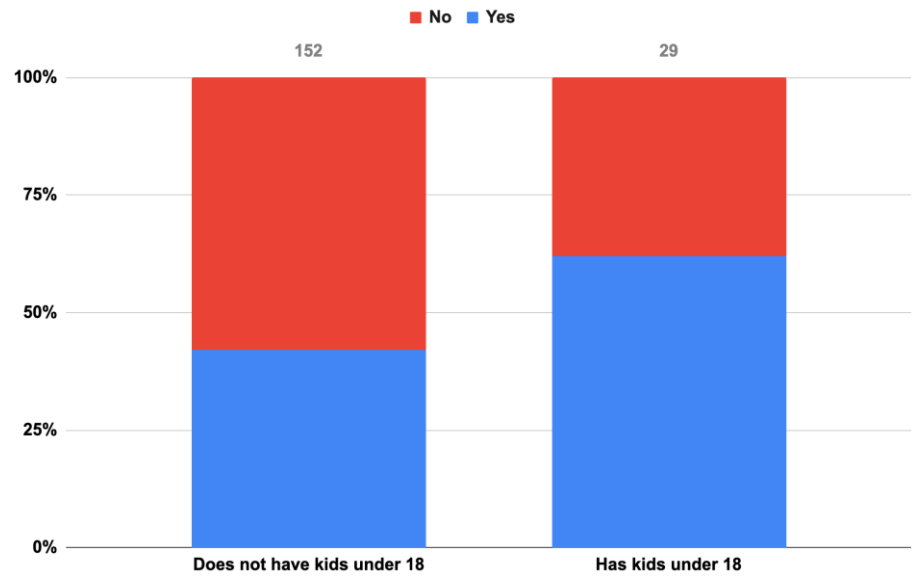
A total of 154 respondents answered the questions "Would you be interested in using a smartphone app to assist scientists in tracking coquí frogs?" and "How long have you lived here?". This graph shows how long respondents have lived on the Big Island compared to whether they would use a smartphone app to track coquí frogs. The numbers above the bars indicate the total number of responses in each category.



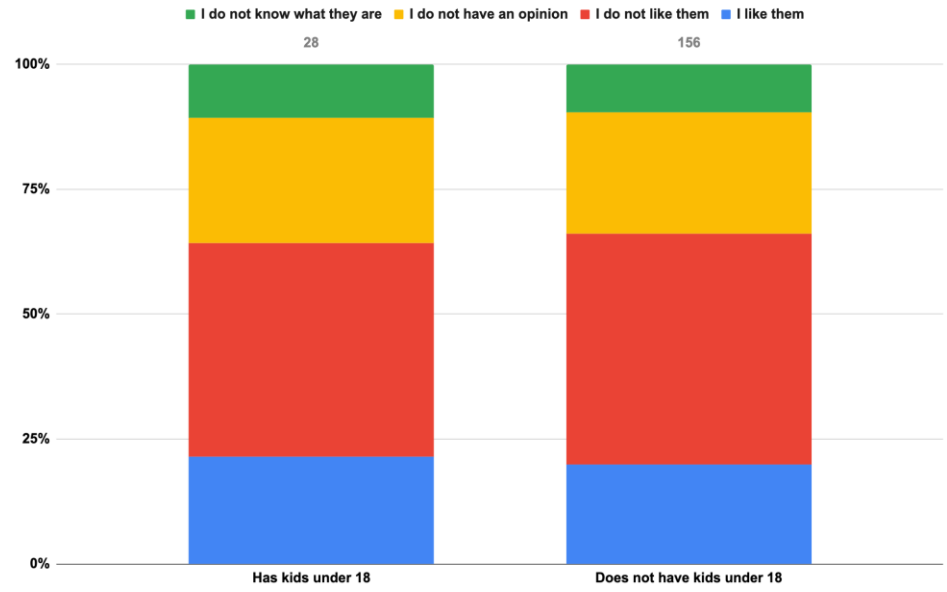
A total of 154 respondents answered the questions "What is your opinion on the coquí frog?" and "How long have you lived here?". This graph shows how long respondents have lived on the Big Island compared to their opinions on coquí frogs. The numbers above the bars indicate the total number of responses in each category.



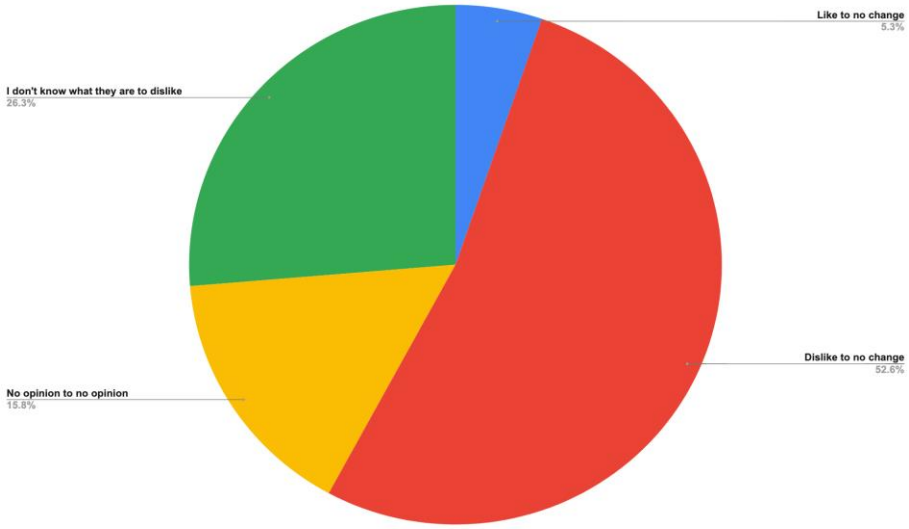
A total of 175 respondents answered the question "Coquí frogs are invasive to Hawai'i. Based on this information, does your opinion of them change?" This graph shows their responses.



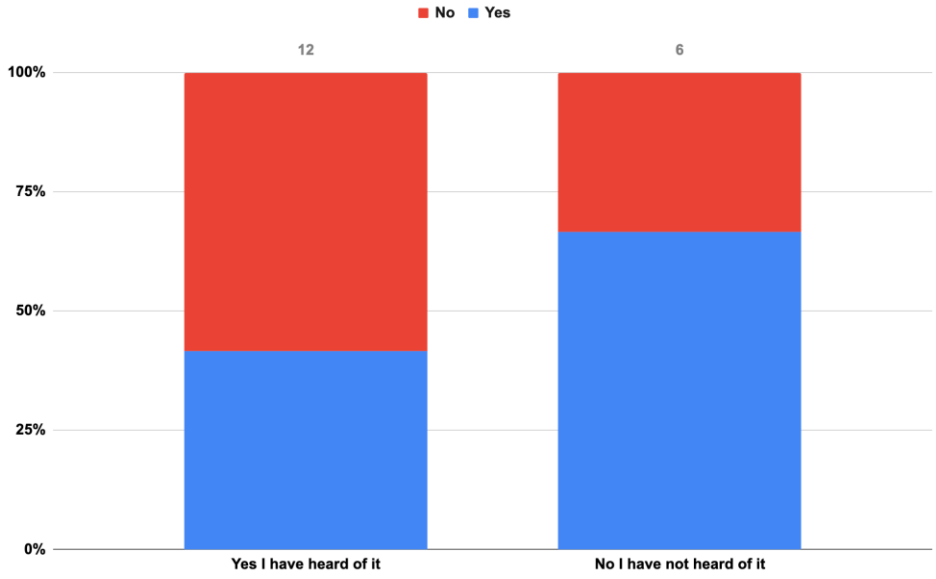
A total of 181 respondents answered the questions "Do you have young children (18 or younger)?" and "Would you be interested in using a smartphone app to assist scientists in tracking coquí frogs?". This graph shows if respondents have kids under 18 compared to whether they would use a smartphone app to track coquí frogs. The numbers above the bars indicate the total number of responses in each category.



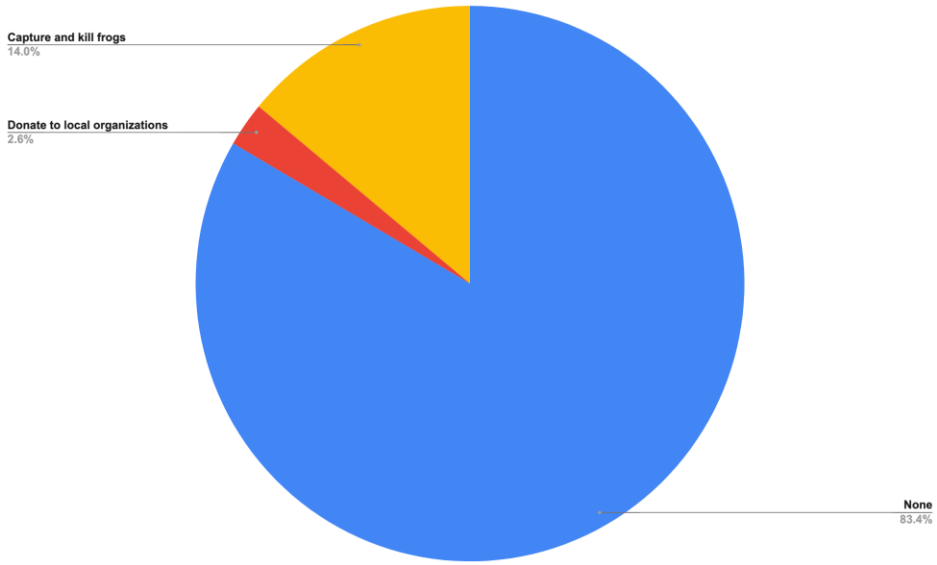
A total of 184 respondents answered the questions "Do you have young children (18 or younger)?" and "What is your opinion of the coquí frog?". This graph shows whether respondents have young children compared to their opinions of coquí frogs. The numbers above the bars indicate the total number of responses in each category.



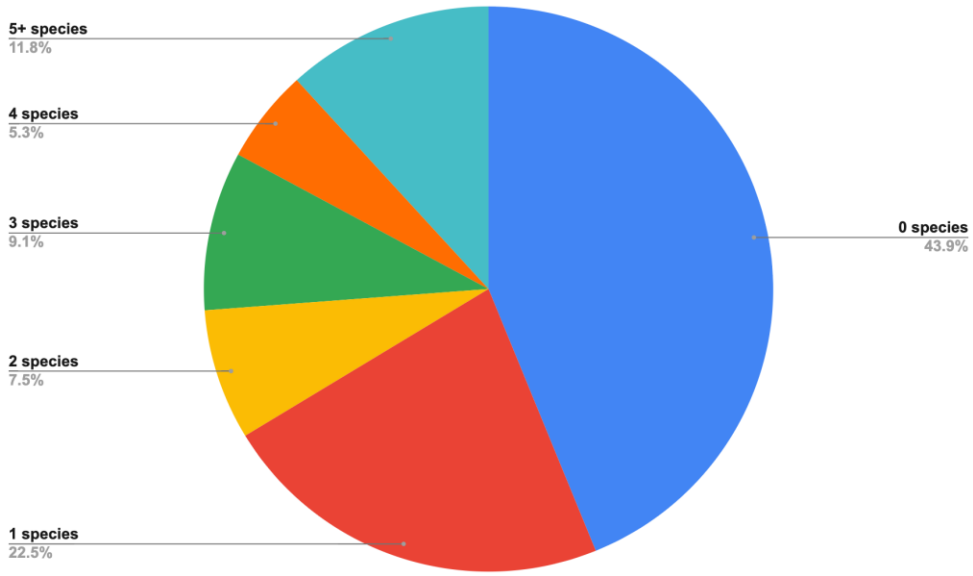
A total of 18 respondents answered the question "Coquí frogs are a carrier of rat lungworm disease. Based on this information, does your opinion of them change?". This graph shows their responses.



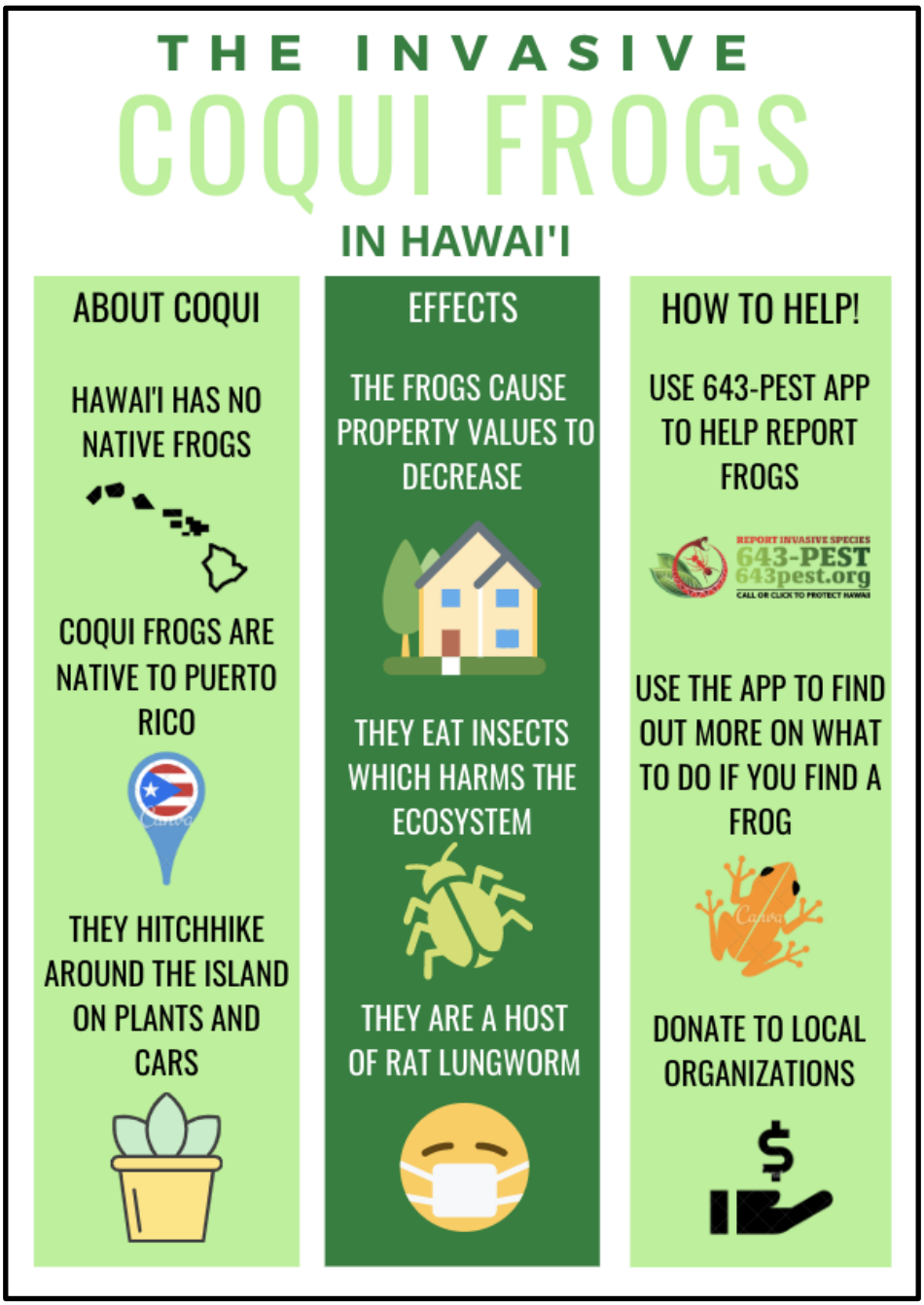
A total of 18 respondents answered the questions "Coquí frogs are a carrier of rat lungworm disease. Based on this information, does your opinion of them change?" and "Would you be interested in using a smartphone app to assist scientists in tracking the spread of coquís?". This graph shows if respondents have heard of rat lungworm compared to whether they would use a smartphone app to track coquí frogs. The numbers above the bars indicate the total number of responses in each category.



A total of 193 respondents answered the question "What measures have you taken to prevent the spread of coquís?". This graph shows their responses.



A total of 187 respondents answered the question "Please list any other invasive species (besides coquí) that are on the Big Island of Hawai'i that you are aware of:". This graph shows their responses.

Appendix U: Educational Infographic

This infographic can be posted on social media sites to inform citizens about the coquí frog and engage them in citizen science.