Final Report
Southeast Climate Adaptation Science Center

1. ADMINISTRATIVE

Project title: Climate Change Implications for the Conservation of Amphibians in Tropical Environments

Project Number: 025

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2. PUBLIC SUMMARY

The U.S. Fish and Wildlife Service and the Puerto Rico Department of Natural and Environmental Resources want to develop a plan of actions to protect 12 species of coqui frogs (*Eleutherodactylus* spp.) that are currently considered at risk of being considered threatened or endangered, requiring additional protections under the Endangered Species Act. Actions center on two possible adaptation strategies: a) translocations to suitable, unoccupied habitat, and b) identifying climate-resilient habitats to ensure the persistence of species. Knowledge required to implement these strategies includes understanding how microhabitat and microclimatic factors – the local environmental conditions around individual frogs influence their occupancy (distribution), abundance, and reproduction; these were estimated by focusing on four

representative species (*E. wightmanae*, *E. brittoni*, *E. antillensis,* and *E. coqui*). The abundance of all species but *E. antillensis* was positively and strongly influenced by moisture levels. As expected, *E. antillensis* exhibited an opposite relationship. Similarly, the reproductive activity of *E. coqui* was influenced by higher relative humidity and the presence of a chorus of other individuals. We found that our four focal species were not affected (e.g., abundance, reproduction) by the passing of hurricane Maria in September 2017, possibly because fallen debris creates conditions of increased food and shelter. Our findings help to assess habitat suitability, potential climate refuges, and inform timing for managed translocations.

3. TECHNICAL SUMMARY

The U.S. Fish and Wildlife Service and the P.R. Department of Natural and Environmental Resources are seeking information to help prevent the listing of species "at risk" from becoming threatened or endangered. Conducting managed species translocations and establishing climate change *refugia* are two adaptation strategies that will help meet the aforementioned conservation objective. Successful implementation of strategies require on-the-ground validation of demographic responses to transient climate conditions. Accordingly, we estimated the effect of local abiotic and biotic factors on occupancy and abundance of four representative amphibian species (*E. wightmanae*, *E. brittoni*, *E. antillensis*, and *E. coqui*), and also assessed how the same factors influenced reproductive activity of *E. coqui.* Occupancy and abundance of *E. wightmanae*, *E. brittoni* and *E. coqui* were positively and strongly influenced by moisture levels, a sharp contrast to *E. antillensis,* whose highest occupancy probabilities (≥0.6) recorded at ≤300 m and with average relative humidity values <75%. High probability (≥0.6) of encountering *E. coqui* active nests (≥1 nest with eggs) was influenced by the presence of a chorus, average relative humidity (≥80%) and temperatures ≤26° C. Hurricanes can inflict marked reductions in population numbers, but impacts vary by location and species. We found that the abundance (chorus) of *E. antillensis* and *E. brittoni* increased after the hurricane, but the abundance of the other two species did not differ between years. Lack of impacts was probably mediated by low structural damage to forest tracts (e.g., 9% canopy loss) and accumulation of debris that creates suitable microhabitats. Our findings help assess habitat suitability in terms of parameters that foster local population growth, and provide a basis to test spatio-temporal predictions about demographic rates in potential climate *refugia* and or as a result of managed translocations.

4. PURPOSE AND OBJECTIVES

Provide information to the U.S. Fish and Wildlife Service and the P.R. Department of Natural and Environmental Resources to implement two adaptation strategies, managed translocations and identifying climate refuges, to help prevent the listing of species “at risk” from becoming threatened or endangered. We quantified local abiotic (physical) and biotic (habitat) conditions and modeled their effect on two population state variables, occupancy probability and the probability of detecting a few or many frogs our index of abundance of four representative species, namely, *E. wightmanae*, *E. brittoni*, *E. antillensis*, and *E. coqui*. In the case of *E. coqui*, we investigated the effects of the same covariates on the probability of detecting reproductive activity (i.e., ≥1 nest with eggs) in a location. Finally, Hurricane Maria made landfall in Puerto Rico on September 20, 2017 with sustained winds of 249 km/hr, allowing us to also assess post-hurricane impacts on demographic parameters (e.g., abundance, reproduction) of our focal species.

5. ORGANIZATION AND APPROACH:

We established forty-eight (48) secondary forest survey sites between the townships of Adjuntas (18°10'58.27"N; 66°40'29.91"W) and Maricao (18° 8'37.56"N; 66°58'47.87"W; datum = NAD83). We structured our sampling scheme after Pollock’s Robust Design. In this scheme, there were two (2017) and three (2018) primary sampling periods within year, each having three secondary sampling occasions. Primary periods in 2017 were April-May and July-August. Primary sampling periods in 2018 were February-March, April-May, and July-August. The three secondary periods within primary periods were 7 days apart, encompassing a period of 21 days. We collected acoustic data (presence/non-presence) across 83 sites surveyed in 2017 (48) and 2018 (35) using ARBIMON (Automated Remote Biodiversity Monitoring Network) portable recorders. We also collected abiotic (e.g., humidity, temperature, soil moisture,) and biotic (e.g., canopy and ground cover) at each sampling site. We used artificial nest structures to assess reproductive activity. Thirty-six (36) structures were placed amongst leaf litter at each survey site.

6. PROJECT RESULTS

Occupancy and abundance of *E. wightmanae*, *E. brittoni* and *E. coqui* were positively and strongly influenced by moisture levels. *E. antillensis* exhibited the opposite pattern, with highest occupancy probabilities (≥0.6) recorded at ≤300 m and with average relative humidity values <75%. High probability (≥0.6) of encountering *E. coqui* active nests (≥1 nest with eggs) was influenced by: 1) the presence of a chorus, 2) average relative humidity (≥80%), and 3) average temperatures ≤26° C. The probability of detecting a chorus of *E. antillensis* and *E. brittoni* increased a year after Hurricane Maria struck Puerto Rico (20 September 2017), but did not differ statistically for the other two species.

7. ANALYSIS AND FINDINGS

We used a multi-season, multi-state occupancy modeling framework to obtain estimates of occupancy (Psi), our index of abundance (R), detection (*p*), and delta (dlta) using program PRESENCE. Occupancy (Psi0) is defined as the probability that a site is occupied, given that the site was unoccupied in the previous season. Detection (*p*) is defined as the probability of detecting an *Eleutherodactylus* frog in a survey station given that the station is occupied. Parameter R0 is the probability of occupancy with a chorus of a species of *Eleutherodactylus* (i.e., state 2), given that the survey station is occupied and was unoccupied in the previous season. This is our index of abundance, henceforth referred to as abundance. Delta is defined as the probability that state 2 (chorus) was true, given that the survey station was occupied. We used logistic regression to assess the probability of encountering active nests (i.e., nest with eggs) on any of the 83 sites surveyed during this study. We ran the model using reproductive activity data in a binary fashion: 0 (no nest) or 1 (≥1 nest with eggs). Model terms were the response variable and the three principal components described above.

Occupancy and abundance increased with elevation and average relative humidity for three of the four species of *Eleutherodactylus* frogs as predicted. *E. brittoni* also responded to relative humidity but required average relative humidity for occupancy and abundance to increase markedly (~>80%), and up to ~90% for it to exceed 60% probability. *E. coqui* occupancy responded much like *E. wightmanae* and *E. brittoni*. Unlike the three previous species, *E. antillensis* exhibited higher probability of occupying sites over time and of detecting a chorus at lower values of relative humidity (<75%).

The index of abundance for *E. brittoni* and *E. antillensis* was higher in 2018 (post-Maria) than in 2017, and there was no evidence for statistically significant differences for the other two species between years. Moreover, the average probability of finding an active nest of *E. coqui* was higher in 2018 than in 2017. Positive or invariant population responses were recorded despite an average reduction of 9% in canopy cover and an increase of 5% in ground cover. The total number of *E. coqui* active nests found in 2017 was 51 and 82 in 2018. Active nests/survey site was 1.04 (2017) and 2.41 (2018). Hatching success (i.e., at least 1 egg hatched) was 0.23 (2017) and 0.10 (2018).

8. CONCLUSIONS AND RECOMMENDATIONS

The rapid pace of global warming has elevated the urgency of conducting research to better predict demographic responses of amphibians at multiple scales and geographic contexts. Bottom-up approaches, as the one employed in this study, are valuable because they establish the link between local environmental conditions and demographic processes; facilitating new insights that can inform adaptation decisions related to the identification of climate *refugia* and the timing and implementation of managed translocations. The intensity of hurricanes will likely increase with projected global warming; however, as in previous studies. Hurricanes have been shown to have negative impacts on *Eleutherodactylus* populations, but it varies by location as shown in this study. A plausible explanation for positive or non-changing population responses is that hurricane damage (e.g., fallen trees, debris) creates more suitable microhabitat conditions.

9. MANAGEMENT APPLICATIONS AND PRODUCTS

Species deal with two competing processes in the face of rapid shifts in environmental conditions: *in-situ* adaptation, or ecological niche tracking. The former is constrained by time (assuming sufficient population levels and genetic diversity), and the latter by the species mobility and availability of suitable habitat, which are often limiting in insular ecosystems. In this work, we focused on building the ecological knowledge required for human-directed facilitation of the latter process because *Eleutherodactylus* are characterized by low mobility and narrow climatic requirements, and occur on highly fragmented landscapes. Decisions on whether to engage in *in-situ* management or managed translocations require explicit links between demographic rates and local environmental conditions. Our best example is *E. coqui*. We not only reaffirmed its distributional affinity for high-elevation habitats, but we identified conditions associated with high probability of detecting a chorus and reproductive activity. Gradual deviations from such conditions are preludes of transitions from suitable to unsuitable habitat that presage shifts in a species' distribution.

We offer two possible lines of research to strengthen the support needed to implement adaptation strategies in Puerto Rico. First, there is a need to determine how widespread are the conditions that foster favorable demographic rates across landscapes, and then validate if demographic rates match predictions. Second, there is a need to replicate our work in areas that will likely be more resistant to the projected trajectories of climatic change. One possibility is to work in the northern karst region. The region harbors the two largest aquifers on the island, and its heterogeneous topography lends itself to harboring suitable microhabitats and retaining remnants of undamaged habitat in the wake of hurricanes. The karst region also offers an opportunity to assess demographic responses of *Eleutherodactylus* frogs under drying conditions that are expected to occur in the wettest areas of the island, such as high-elevation core locations near Maricao in west-central Puerto Rico. Testing demographic responses under these 'out-of-core' conditions will accelerate the learning process, thereby building the foundational biological knowledge needed to evaluate the efficacy of candidate climate change adaptation strategies.

Jan P. Zegarra, Endangered Species Biologist, indicates that “"The findings of this project helps the USFWS-Caribbean Ecological Services Field Office build foundational knowledge regarding the ecology of amphibians of the genus *Eleutherodactylus*, and thus, helps inform conservation decisions to protect our federally listed frog species and others of high conservation priority."

10. OUTREACH AND COMMUNICATION

1) Terando, A. From photons to frog calls: What climate change means for wildlife and what we're doing about it. AAAS Family Science Days, Washington, DC Mar 07, 2016.

2) Terando, A. Climate models, frog calls, and the path towards long-term adaptive species management. American Water Resources Association Specialty Conference – GIS & Water Resources X, Orlando, FL Apr 22-25, 2018.

3) Terando, A. and J. Collazo. Wending our way towards adaptation: Investing in actionable science to promote species conservation in the US Caribbean. SECASC Regional Science Symposium, New Orleans, LA Nov 13-15, 2019.

4) Collazo, J. A. - USGS Cooperative Research Units and SE Climate Adaptation and Climate Center and FWS Working Strategically to Address Species Status Assessments (SSAs) in the Southeast United States. Presentation at the Southeast Regional Office, U.S. Fish and Wildlife Service, Atlanta, GA. February 12, 2020,

5) A. J. Terando and J. A. Collazo – We offered a webinar on November 12, 2020 on our work on amphibians and climate modeling in Puerto Rico to the network of USGS Climate Adaptation Science Centers and other USGS science research centers. The title of the webinar was Climate Change Implications for the Conservation of Amphibians in Tropical Environments.

6) J. A. Collazo, A. J. Terando, José A. Cruz-Burgos, Jan P. Zegarra, Ryan Boyles, Mitchell Eaton, and Jared Bowden. We offered a presentation at the 2020 AGU conference entitled Strategic Habitat Conservation and Adaptive Strategies for Recovery and Pre-listing Conservation of Eleutherodactylus (coqui) Amphibians in Puerto Rico. Abstract ID: 756100. Final Paper Number: GC001-06, December 7, 2020.

7) Rivera-Burgos, A. C., J. A. Collazo, A. J. Terando, and K. Pacifici. In review. Linking demographic rates to local environmental conditions to support Climate Adaptation Strategies for Eleutherodactylus frogs. Global Ecology and Conservation (IP-119108; Approved by BAO).

Metadata link: Approved DataSets - ScienceBase-Catalog