ASSESSMENT OF *Eleutherodactylus richmondi* POPULATIONS AT THE MARICAO STATE FOREST, PUERTO RICO

by

Jan Paul Zegarra Vila

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Approved by:

______________________________ ______________
Allen R. Lewis, Ph.D. Date
Member, Graduate Committee

______________________________ ______________
Carlos J. Santos, Ph.D. Date
Member, Graduate Committee

______________________________ ______________
Fernando J. Bird-Picó, Ph.D. Date
President, Graduate Committee

______________________________ ______________
Juan G. González-Lagoa, Ph.D. Date
Representative of Graduate Studies

______________________________ ______________
Lucy Bunkley-Williams, Ph.D. Date
Chairperson of the Department

ABSTRACT

Since 1986, several publications have indicated *Eleutherodactylus richmondi* (ER) population declines or disappearances in Puerto Rico. The bulk of these reports come from the Caribbean National Forest (El Yunque) and less time has been spent surveying amphibian communities in other areas of the island. Literature reports of ER populations were used to verify their current distribution and status in the Maricao State Forest. A total of eleven sampling areas was established and surveyed from July 2005 through December 2006. These sites were integrated into a geographical information system (GIS) and associated with a map of potential suitable habitat for ER created by Villanueva (2006). Approximately 60% of the Maricao State Forest contains potential suitable habitat and the areas sampled contain roughly 73%. Calling ER individuals were found in three of the eleven sampling areas; 86 ER counts for the entire assessment. ER counts were significantly different among sampling areas, but not between seasons. This investigation confirms previous reported declines for the Maricao State Forest and there is no evidence of recovery. There is a strong possibility that local ER population extinctions have occurred. These localized populations might be part of a metapopulation dynamic. The probability of recovery is plausible with continuing survey efforts and establishing a captive breeding program.

RESUMEN

Desde el 1986, varias publicaciones han indicado declinaciones o desapariciones de poblaciones de *Eleutherodactylus richmondi* (ER) en Puerto Rico. La mayor parte de estos trabajos vienen del Bosque Nacional del Caribe (El Yunque) y se ha dedicado menos tiempo al estudio de las comunidades de anfibios en otras áreas de la Isla. Se utilizaron reportes de las poblaciones de ER para verificar su distribución y el estado actual en el Bosque Estatal de Maricao. Se estableció un total de 11 áreas de muestreo y éstas se cotejaron desde julio 2005 hasta diciembre 2006. Estas áreas fueron integradas en un sistema de información geográfico y asociado a un mapa de hábitat adecuado potencial creado por Villanueva (2006). Aproximadamente, un 60% del Bosque Estatal de Maricao contiene hábitat adecuado potencial y las áreas de muestreo contienen un 73%. Se encontraron ER cantando en tres de las once áreas de muestreo; 86 ER contados entre todas las búsquedas. Los ER contados fueron significativamente diferentes entre las áreas de muestreo, pero no entre las épocas de sequía y lluvia. Esta investigación confirma las declinaciones reportadas previamente para el Bosque Estatal de Maricao y no muestra evidencia de recuperación. Es probable que hayan ocurrido extinciones locales de poblaciones de ER. Estas poblaciones localizadas pueden ser parte de una dinámica de metapoblaciones. Las posibilidades de recuperación son viables con esfuerzos continuos de muestreos y estableciendo un programa de reproducción en cautiverio.

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INTRODUCTION

Amphibian declines are no longer a speculation. Like many other groups of organisms, amphibians are facing worldwide population declines, range contractions, and even species extinctions (Semlitsch, 2003). Declines have been reported from each of the six continents on which amphibians occur (Houlahan et al., 2000). Out of 5,918 amphibian species, the Global Amphibian Assessment lists 427 species as critically endangered (International Union for the Conservation of Nature, IUCN category of highest threat), including 122 species that are “possibly extinct” (IUCN). The geographic distribution of “rapidly declining species” is non-random and neotropical species are much more affected than others (Stuart et al., 2004). This region is the most species rich region of anurans in the world (Duellman, 1999).

The causes of declines in Latin America are varied, but they have most often been associated with habitat loss, chytridiomycosis (a disease caused by the fungus *Batrachochytrium dendrobatidis*), and climate change (Lips et al., 2005). Mayor components of amphibian fauna are found in the West Indies, where 84% of amphibians belong to the largest genus (*Eleutherodactylus*) of vertebrates described (Hedges, 1999). All of the twenty species encountered in the Puerto Rican Bank are endemic to the bank region. Puerto Rico is no exception to the global trend in amphibian disappearance (Burrowes and Joglar, 1991; Joglar and Burrowes, 1996) and those that have occurred in protected reserves are particularly difficult to explain. Long term surveys at certain sites on the Island have revealed that among the 18 endemic species of anurans in Puerto Rico, three are apparently extinct, eight are declining, one at risk, and six probably are stable (Joglar, 1998).

One of the species that falls under the declining category is *Eleutherodactylus richmondi* (ER) and has been suggested to be included in the federal and state endangered species list (Drewry, 1986; Joglar and Burrowes, 1991; Joglar, 1992; Joglar, 1998). Historically, in the decades of 1960 and 1970, the species was described to be abundant in El Yunque and other localities in the Island. There is a strong disparity between the apparent abundance in the past with that of the present, especially at pristine protected areas such as the Caribbean National Forest (El Yunque). Also, the bulk of the existing data for this species comes from El Yunque and less time has been spent surveying other areas of the Cordillera Central. Moreno (1991) suggested that one of the major obstacles for a definitive assessment of several of the *Eleutherodactylus* species is the need for islandwide quantitative censuses. In addition, Joglar and Burrowes (1996) suggest that ER has a high probability of extinction because of its specialized morphology and ecology.

Although ER has not been included in the federal endangered animals list, it is listed under state and IUCN categories. The Department of Natural and Environmental Resources (DNER) list ER as vulnerable: B1; D2 (Departamento de Recursos Naturales y Ambientales, 2004). The IUCN lists ER as Critically Endangered: A3ce (IUCN). The US Forest Service also lists ER as Vulnerable (rank G3) in currently designated sensitive species that are not listed or proposed under the Endangered Species Act (United States Forest Service, 2005). ER is definitely an amphibian species of conservation priority. The objective of this study was to identify and map ER populations in the Maricao State Forest. This effort will serve to review historical, current and possibly new population ranges and their status. It is imperative to search for more populations to further understand their vulnerability status and extinction threat.

SPECIES DESCRIPTION

Commonly known as "Richmond's" or "Ground" coqui, *E. richmondi* was first collected and described by Leonard Stejneger in 1900 and 1904 respectively (Joglar 1998). Its size is medium to large, with a chestnut to mahogany dorsal color (Fig. 1). It has a pair of golden yellow to white dorsolateral lines extending from the snout towards the cloaca and below these lines there is a thicker dark band with a series of dark spots or variegations beneath them; forelimbs and thighs are marbled or spotted and small digital disks are present (Schwartz and Henderson, 1991; Rivero, 1998). ER's call sounds like a low "tic" and Villanueva (2006) determined peak calling activity is between sunset and midnight, declining steadily after midnight.

Figure 1. *Eleutherodactylus richmondi* calling on leaf litter.

ER distribution is primarily described from localities of the interior uplands of Puerto Rico from 40 to 1158 meters (Schwartz and Henderson, 1991). Population localities have been reported from the mountains of El Yunque, Cayey, Toro Negro, Maricao, Sierra Pandura, some populations from Arecibo and the Guajataca and Susúa State Forests (Joglar, 1998; Rivero, 1998). Villanueva (2006) assembled a table of ER populations reported in the literature which includes other sites like Arecibo, Guayama and Ciales. Villanueva (2006) also generated in GIS a habitat distribution map of ER for the whole Island. He used six layers (landcover type, soil type, elevation, average minimum temperature of coldest month, average maximum temperature of hottest month, and average precipitation of driest month) that represent environmental and habitat characteristics that may limit the distribution of *Eleutherodactylus* frogs.

Microhabitat has been described generally as forest floor, stone crevices and under logs (Drewry and Rand, 1983); fossorial-low boulders, leaf litter and around large fallen logs (Stewart and Woolbright, 1996); occurring in pockets associated with mud slopes and boulders (Woolbright, 1997); terrestrial and diurnally occurring under roots, logs, rocks and even trash (Schwartz and Henderson, 1991; Rivero 1998). Calling sites have been described from crevices, sometimes climbing plants 0.2- 0.6 meters (Drewry and Rand, 1983); from near or on ground surface (Schwartz and Henderson, 1991); from under or atop boulders and forest debris (Stewart and Woolbright, 1996); on horizontal leaves from shrubs and low vegetation in El Yunque, to leaf litter and above ground vegetation in Maricao (Joglar, 1998).

The only published density estimate for ER is based on nine years of nocturnal counts in El Yunque, which described the general abundance as sparsely clumped from 0-1 adults per 100 m^2 or 100 individuals per hectare as maximum density (Stewart and Woolbright, 1996). The first detailed study on ecology of amphibian communities for the Maricao State Forest comes from Fogarty and Vilella (1999). This study revealed several possible populations of ER along six of eight call survey transects placed along established trails or streams. They describe that ER was found in small populations restricted to rocky banks of upper portions of streams. No ER individuals were recorded from seven point counts and eight automated recorder sites.

Scarce data on reproduction exist for this species. Egg clutches have been found on decayed logs, but it is not known which parent exhibits care (Rivero 1998). Clutches are reported in February, March, and June; gravid females have been collected in May, August, and September, while juveniles in January and August. These data suggest that ER reproduces year round, even in the coldest and driest months (January, February, and March) of the year (Joglar 1998). Joglar (1998) examined the oviducts of preserved gravid females where he found an average of 24.5 eggs. Stewart and Woolbright (1996) collected stomach contents for this species in El Yunque revealing arachnids, hymenopterans, homopterans, lepidopteran larvae and diplopods.

E. richmondi DECLINES

The most recent information on ER population declines, reports a 79% decline in the Maricao State Forest after Hurricane Georges in 1998 (Villela and Fogarty, 2005). Several other publications have reported declines or disappearances of ER populations (Drewry, 1986; Joglar and Burrowes, 1991; Moreno, 1991; Woolbright, 1991; Joglar, 1992; Stewart, 1995; Joglar and Burrowes, 1996; Woolbright, 1997; Joglar, 1998; Rivero, 1998; Burrowes et al., 2004). Three publications have indicated sites in the Maricao State Forest (Joglar, 1992; Joglar, 1998; Vilella and Fogarty, 2005). Declines or disappearances along the Island are occurring primarily at high elevations and have been potentially attributed to: post-hurricane effects on forest composition and microclimate conditions, climate change, increases in the number of dry days, natural population fluctuations, habitat fragmentation, and environmental contamination. IUCN describes ER's population trend as decreasing, probably because of chytridiomycosis and the effects of climate change. Hedges (1993) reported that there is no information available to indicate that introduced predators are having an adverse effect on the native West Indian frogs, although predation may be a factor involved in the disappearance and decline of two Puerto Rican species (*E. karlschmidti* and *E. richmondi*, respectively).

METHODS

Microhabitat descriptions for ER suggest that the populations are small, clustered and limited to certain patches within a broader environment. My main objective is to verify existence of ER populations by sampling possible population clusters. Literature reports of ER populations from the Maricao State Forest were used to asses their current distribution and status (Table 1). From these reports, line transects were established and digitized; except for areas 6, 8, 9 and 11, which have not been reported as ER sampling sites. Sampling areas were created in the map with an acoustical buffer zone of 25 m (Fig. 2). At 25 m from the transect line, it was estimated that any ER calling would be heard. These areas were integrated into GIS (ArcMap 9.2, Environmental Systems Research Institute, California) and associated with a potential suitable habitat map generated by Villanueva (2006) for the whole Island (Fig. 3). From this map, the total potential suitable habitat area was calculated for the forest boundaries and for each of the sampling areas. Following Fogarty and Vilella (1999), total number of ER calling was verified in each sampling area and a mean calculated for each. ANOVA was used to verify significance between sampling sites and seasons. If possible, calling males were photographed to create a visual record of calling sites. Whenever an ER individual was detected, its location was recorded using a GPS device and later imported into the map. From July 2005 to December 2006 (see Appendix 1 for specific dates), all areas were visited at least three times during the wet season (July - December) and twice during the dry season (January - June). No individuals were handled during this investigation.

Table 1. Populations of *Eleutherodactylus richmondi* reported in the literature from the Maricao State Forest.

Reference	Date	Location	Notes
Joglar, 1992	July 1992	Rte. 120, Entrance to Casa de Piedra*	Least abundant of 3 species recorded; only 4 individuals
		Rte. 120 km 11.8*	Least abundant of 3 species recorded; few individuals
Joglar, 1998	August 1996	Rte. 120, Entrance to Casa de Piedra	No individuals found
		Rte. 120 km 11.8	7 individuals
	July 1998	Various localities along Rte. 120	Individuals calling
Rivero, 1998	No data	General distribution map	
Fogarty and Vilella, 1999	July 1997 to June 1998	Transects along forest trails or streams*	10 surveys during the dry season reported 24 individuals in 3 of 7 transects and 15 surveys during the wet season reported 133 individuals in 6 of 8 transects
Vilella and Fogarty, 2005	April – May 1998 and May 1999	Transects along forest trails or streams	79% population decline after Hurricane Georges
Villanueva, 2006	2003 - 2004	18.16140 ^{o}N* 66.99812 ^{o}W	Species detected with Automated Digital Recording System

* These sites were used to establish some of the sampling areas (Fig. 2).

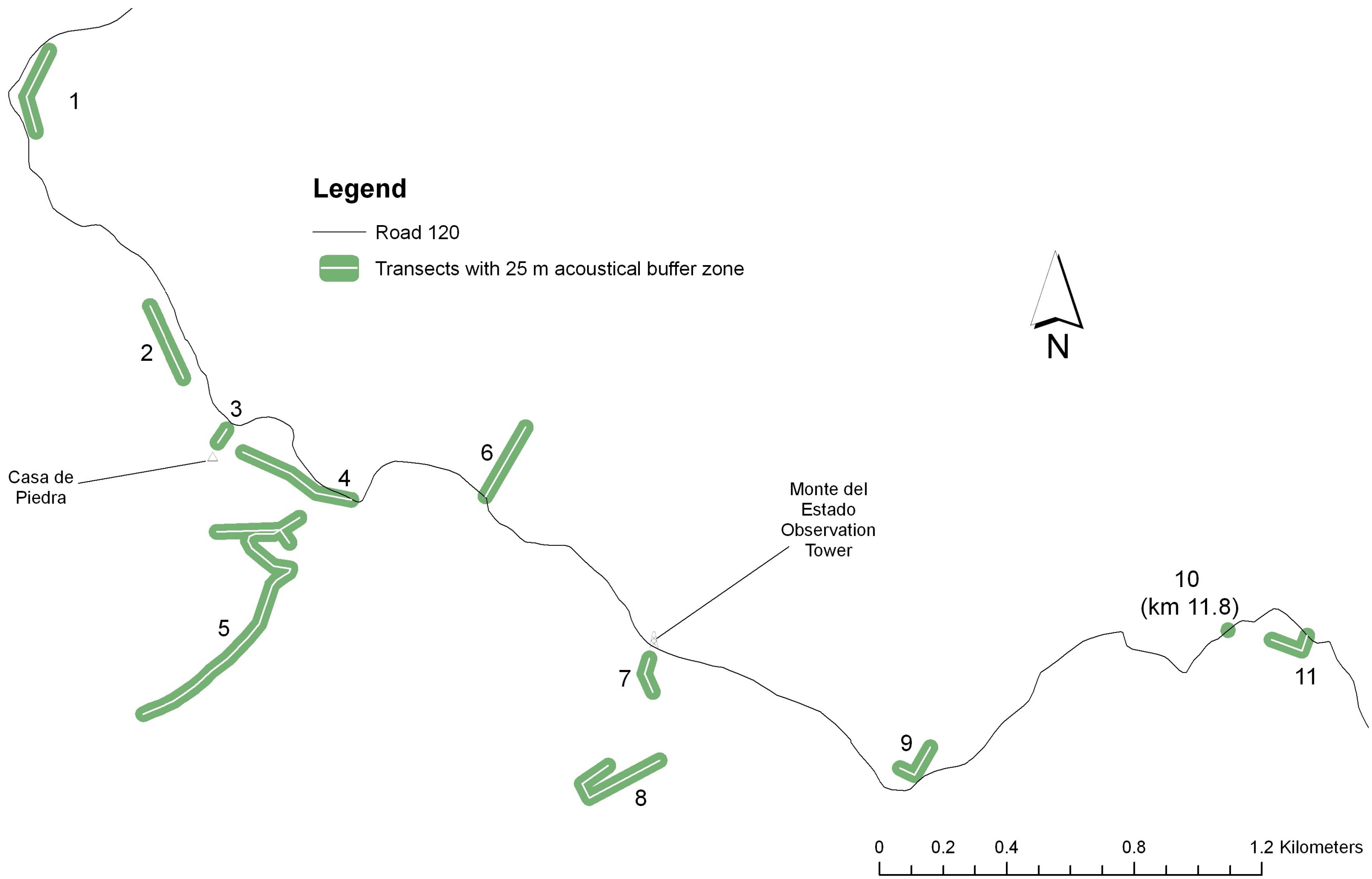


Figure 2. Map of digitized sampling areas in the Maricao State Forest.

RESULTS

Out of 1265 km^2 of potential suitable habitat (Villanueva, 2006) for the whole Island, the Maricao State Forest represents 2% of suitable habitat area. The total area of the Maricao State Forest is approximately 40 km^2, of which 24 km^2 contains potential suitable habitat for ER; 60% of the forest area (Fig. 3). Each sampling site's coverage and potential suitable habitat areas were calculated (Table 2). The total sampling area was roughly 0.18 km^2, of which 0.13 km^2 was considered potential suitable habitat; 73% of the sampled area. An altitudinal range for the sampling areas was extracted in GIS from a digital elevation model. Mean elevation between sampling areas was 757 m (610-894 m, S.D.= 62.23).

Table 2. Sampling and potential suitable habitat areas of digitized transects.

Sampling sites	Transect length (m)	Sampling area (ha)	Potential suitable habitat (ha)	% Potential suitable habitat
1	300	1.57	0.89	57
2	250	1.45	0.70	49
3	50	0.45	0.44	98
4	400	2.08	1.75	84
5	1200	6.14	4.50	73
6	250	1.45	1.30	90
7	150	0.76	0.35	46
8	400	2.17	1.44	66
9	150	0.94	0.70	75
10	Point count	0.19	0.19	100
11	150	0.93	0.88	95
Total	3300	18.13	13.14	73

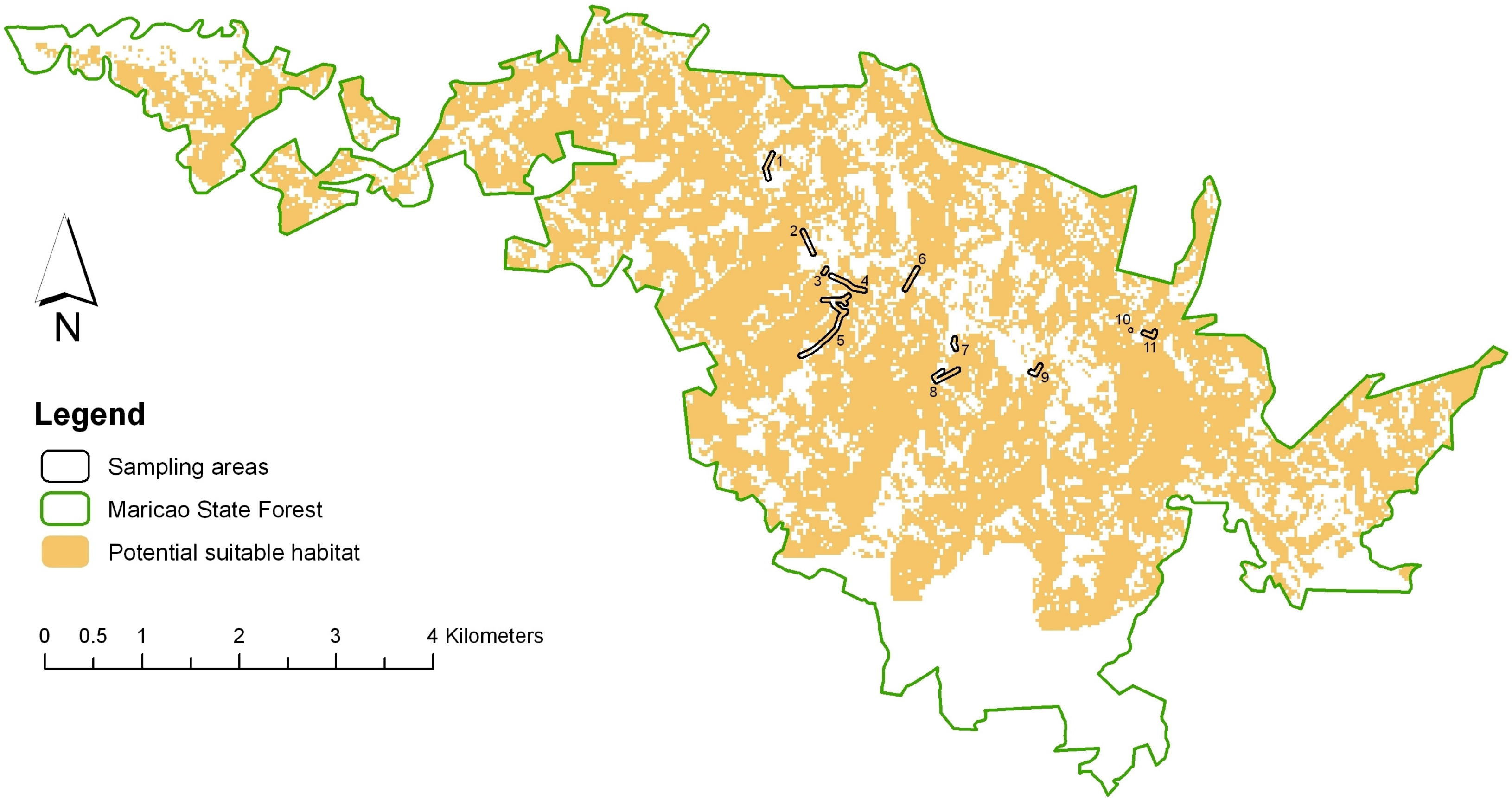


Figure 3. Potential suitable habitat map of *E. richmondi* in the Maricao State Forest (modified from Villanueva, 2006).

ER individuals were only found in three of the sampling areas (Table 3). Sampling area 1 had the highest ER mean count of all the surveys. In area 5, two individuals were last seen and heard calling in September 2005 and August 2006, respectively. Only one individual was seen in area 8 in July 2005. Besides two more visits during the wet season, no more frogs were counted from this area. A point density plot was constructed to visually interpret the data (Fig. 4). There seems to be a difference of ER counts between sampling areas and between seasons. For statistical analysis, ER counts were presented as counts per 100 m to eliminate the bias caused by different transect lengths between the sampling areas (Table 3). ANOVA tests confirm a significant difference of ER counts only between sampling areas and not between seasons (Table 4). ER counts per 100 m are significantly different between area 1 and the other two areas (Table 5). There was no difference between areas 5 and 8.

During the wet season a total of three females and six juveniles were observed in sampling area 1. Juvenile's snout vent lengths were visually estimated between 8 to 13 mm (Appendix 2). A photographic record of calling sites describes several different calling microhabitats (Appendix 3). Other species heard calling along the sampling areas were: *Leptodactylus albilabris*, *Eleutherodactylus brittoni*, *Eleutherodactulys coqui*, *Eleutherodactylus wightmanae*, and a very small population of *Eleutherodactulys gryllus* in sampling area 5. This population was first noted in August 2005 and consists of no more than five or six calling males.

Table 3. *E. richmondi* counts for each sampling area.

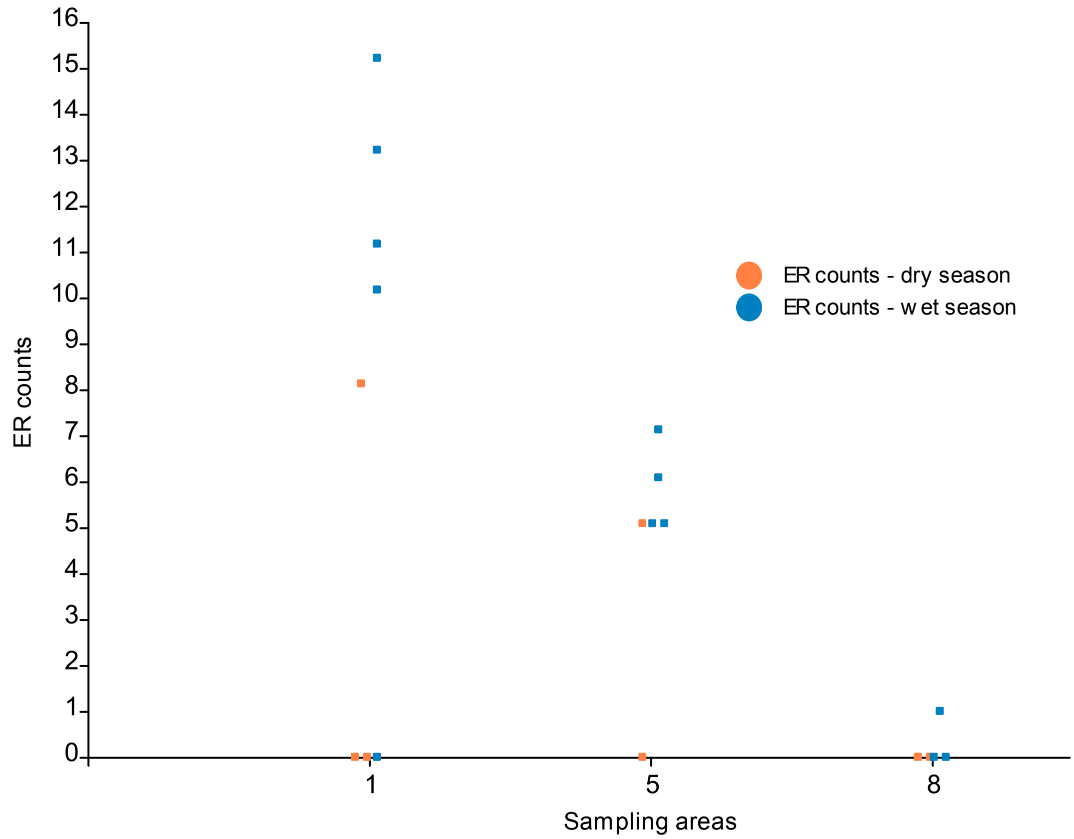
Sampling areas (transect length)	Season[a]	ER counts	Mean ER calling ± S.D.	ER per 100 m
1 (300 m)	Dry (3)	0 8 0	2.67 ± 4.62	0 2.67 0
	Wet (5)	13 15 0 10 11	9.80 ± 5.81	4.33 5 0 3.33 3.67
2 (250 m)	Dry (2)	0 0	0	0
	Wet (5)	0 0 0 0 0	0	0
3 (50 m)	Dry (2)	0 0	0	0
	Wet (5)	0 0 0 0 0	0	0
4 (400 m)	Dry (2)	0 0	0	0
	Wet (4)	0 0 0 0		
5 (1200 m)	Dry (2)	0 5	2.50 ± 3.54	0 0.42
	Wet (4)	7 5 6 5	5.75 ± 0.96	0.58 0.42 0.5 0.42
6 (250 m)	Dry (2)	0 0	0	0
	Wet (3)	0 0 0		

Table 3. (Continuation).

Sampling areas (transect length)	Season[a]	ER counts	Mean ER calling ± S.D.	ER per 100 m
7 (150 m)	Dry (2)	0 0	0	0
	Wet (4)	0 0 0 0		
8 (400 m)	Dry (2)	0 0	0	0
	Wet (3)	1 0 0	0.33 ± 0.58	0.25 0 0
9 (150 m)	Dry (2)	0 0	0	0
	Wet (4)	0 0 0 0		
10 (point count)	Dry (2)	0 0	0	0
	Wet (4)	0 0 0 0		
11 (150 m)	Dry (2)	0 0	0	0
	Wet (4)	0 0 0 0		
Total	Dry (23)	86		
	Wet (45)			

[a] Number of times sampling areas were surveyed during a season.

Figure 4. Point density plot of ER counts in sampling areas 1, 5 and 8.



DISCUSSION

Most of the sampling areas are comparable to the sites mentioned in Table 1. Area 1 is the same area reported by Villanueva (2006), although he does not mention the number of individuals calling. Area 3 and 10 are the same mentioned by Joglar (1992) and no ER was heard. Areas 2, 4, 5 and 7 include some of Fogarty and Vilella's (1999) transects. They found ER calling in all of these, which they report as total ER heard calling (sum of ER counts for the number of times transects were surveyed during each season). Sampling area 5 contains Fogarty and Vilella (1999) longest transect (500 m), which they visited 3 times during the wet season and reported a total of 51 ER, the highest count of all in their study. Although transect 5 was 1200 m and was surveyed four times during the wet season, a total of 23 ER was reported (Table 7). It is evident that that ER populations have changed for this area, although these numbers are difficult to compare because of transect length differences and because it can be assumed that mostly the same ER males are being counted in every visit. Fogarty and Vilella's (1999) do not differentiate counts per visit for each transect. Nevertheless, one can calculate a mean 17 ER (51/3) per visit to their transect 1 (500 m) which transforms into 3.4 (17/5) ER counts per 100 m in the wet season. We can compare this number to transect 5 of this investigation, having 0.48 (5.75/12) ER counts per 100 m; roughly one seventh of Fogarty and Vilella's (1999) estimate. No individuals were found in the other areas comparable to

Individuals were only heard calling in sampling areas 1, 5 and 8 (Table 3). Area 1 seems to contain an active reproductive population. In several occasions one could hear from a random point 5 to 6 males calling. Females and juveniles were also found in this area. Individuals in area 5 were mostly heard calling in three different groups isolated from each other. In fact two of these males were never heard again after encountering them at least twice before. Only one individual was encountered in area 8. This might have been a male migrating from a nearby population or the remnant of a declining population. To the author's knowledge, ER had never been reported from area 8. It is suspected that more individuals might occur in the surrounding areas. This statement applies for the other areas as well. Of the 24 km^2 that represent potential suitable habitat, the total sampled area contains less than 1%. In addition, sampling area 1 has 43% of non suitable habitat, which suggest that ER might also occupy areas outside of those proposed by the model. Areas 5 and 8 lie south of Road 120, while area 1 is situated east, on the other side of the road (Fig. 2). The shortest straight distance was 1075 m between sampling areas 5 and 8. Between areas 1 and 5 there are approximately 1395 m. If no intervening populations exist, these areas appear to contain separate populations, as it is unlikely that they interact.

In general, amphibians (especially the more terrestrial species) are found in patches of suitable habitat surrounded by conditions that are relatively harsh to them (Blaustein et al., 1994). Microhabitat descriptions for ER suggest that the populations are small, clustered and limited to certain patches within a broader

Table 4. ANOVA (2-way) of ER counts per 100 m between seasons and among sampling areas in which frogs were detected.

Source	DF	SS	MS	F	P
Sampling areas	2	21.527	10.764	6.437	0.0096
Seasons	1	5.489	5.489	3.28	0.0901
Error	15	25.083	1.672		
Total	18	52.1			

Note: SS are marginal sum of squares.
CV 113.83

Table 5. LSD Fisher comparison test of ER counts per 100 m among sampling areas (Alpha = 0.05, 15 DF).

Sampling areas	Mean	Homogeneous groups
1	2.08	A
5	0.34	B
8	0.04	B

Table 6. LSD Fisher comparison test of ER counts per 100 m between seasons (Alpha = 0.05, 15 DF).

Seasons	Mean	Homogeneous groups
Wet	1.28	A
Dry	0.37	A

Fogarty and Vilella's (1999) transects (Table 7). All of these comparisons suggest possible declines.

Table 7. Comparison of ER counts with Fogarty and Vilella (1999)*.

Transect number (length)	Season[a]	ER counts	Transect number (length)	Season[a]	ER counts
2 (250 m)	Dry (2)	0	2 (250 m)	Dry (1)	0
	Wet (5)	0		Wet (3)	19
4 (250 m)	Dry (2)	0	3 (250 m)	Dry (2)	7
	Wet (4)	0		Wet (2)	13
5 (1200 m)	Dry (2)	5	1 (500 m)	Dry (0)	
	Wet (4)	23		Wet (3)	51
7 (150 m)	Dry (2)	0	5 (250 m)	Dry (3)	14
	Wet (4)	0		Wet (2)	8
Total	Dry (8)	28	Total	Dry (6)	112
	Wet (17)			Wet (10)	

[a] Number of times sampling areas were surveyed during a season.
* Fogarty and Vilella (1999) data in grey cells.

environment. ER distributions within the sampling areas seem to follow this description. For example, area 1 appears to contain two clusters. Calling male observations were mostly made around Villanueva’s (2006) point and at approximately 200 m south closer to the end of the sampling area. Area 5 appears to contain two or three clusters. Observations were made on both sides of a trail and in the same rocky portions of streams described by Fogarty and Vilella (1999). Understory vegetation, leaf litter and rock cavities seem to be important factors in ER microhabitat use. All areas had one or both of these factors present. Another observation is that all areas presented a variably inclined landscape. Most of the individuals in area 5 were heard in relatively steep inclines beside the trail. Area 1 observations were made in both flat and inclined landscape. No area sampled was entirely flat. Nevertheless, it is difficult to assess landscape differences among sampling areas without a rigorous habitat characterization study.

ER count differences for sampling areas 1, 5 and 8 can be viewed in the point density plot (Fig. 4). Highest counts per 100 m came from area 1. Statistical tests confirm these differences between sampling areas 1 and the other two areas, and none between 5 and 8 (Table 5). Some areas may promote higher densities or wider distributions with changing landscapes. ER counts differences and similarities among sampling areas is a function of limited resources and microhabitat use for each population cluster. No differences were found between dry and wet season ER counts (Table 6). Although one might expect differences between seasons, ER’s non explosive reproductive strategy might explain why none was found. There is evidence that ER breeds during dry and wet season and parental care increases survival of offspring. It is advantageous to maintain a relative constant reproductive effort throughout the year. If humidity is available for ER to reproduce and be active during the dry season, the frogs will exploit these opportunities. Sampling areas 1 and 5 each have counts during the dry season and the numbers are similar to wet season counts (Table 3).

One might discuss if ER lives in metapopulations, where local populations could be linked together through dispersal. Metapopulation models take into account the fact that individuals do move among sites and that such movement is potentially important to the persistence and survival of populations (Gotelli, 2001). If local ER populations are in fact becoming extinct and recolonization does not readily occur, then persistence and survival of the population might be threatened. If these populations make up a metapopulation, the question is if there are enough subpopulations where interactions can occur and what factors affect their distribution throughout the landscape. Although hurricane and chytridiomycosis effects operate in short time frames for the Island, these disturbances may decrease the persistence of subpopulations through time. Recolonization of sites vacated due to extinctions of a local population may be difficult for amphibians because of physiological constraints, the tendency of amphibians to move relatively short distances, and because many amphibians species show extreme site fidelity (Blaustein et al., 1994). Woolbright (1995) studied patterns of nocturnal movement in *E. coqui* and total nightly movements averaged 3 to 4.5 m. Joglar (1998) also studied common coqui movements.

From 121 marked and recaptured individuals 10.9% of males and 15% of females moved more than 15.1 m. Alford and Richards (1999) discuss that fully understanding the dynamics of amphibian metapopulations will require much more information on movements and dispersal among local populations. Understanding these factors should be the ultimate goal of studies aiming to prevent or reverse declines.

ER population declines in the Maricao State Forest have been documented before (Joglar, 1998; Vilella and Fogarty 2005). Post hurricane effects seem to be the only consistent evidence contributing to these declines. Following a major hurricane, changes in forest composition may promote population increases of habitat generalists (e.g., *E. coqui*), while specialists (e.g., *E. richmondi*) experience declines (Vilella and Fogarty, 2005). Why are some populations persisting while others seem to disappear? It should be a matter of how much disturbance is caused by a hurricane to a certain area or the ability of ER to migrate to a suitable habitat after the disturbance. Hurricane effects on ER have also been documented from El Verde Field Station in The Caribbean National Forest. The aftermath of Hurricane Hugo, which included obvious drying of the understory, could have been the ultimate cause of ER extinctions in that area (Woolbright, 1997).

Burrowes et al. (2004) reported an analysis of weather data which indicated a significant warming trend and an association between years with extended dry periods of drought and the decline of amphibian populations in Puerto Rico.. It is also the first report of the chytrid fungus, *Batrachochytrium* *dendrobatidis*, in the Caribbean. They suggested a possible synergistic interaction between drought and the pathological effect of the chytrid fungus on amphibian populations. No chytrid fungus was found in five preserved ER tested. IUCN also has suggested chytridiomycosis as a possible cause of decline of ER populations. The fungus has been reported from the Maricao State Forest, although the report does not specify on which species they found it (Joglar and Burrowes, 2005). The effects of the fungus on ER populations are not completely understood. If the fungus is having a negative effect on ER populations, one would expect to find some of the symptoms (death, lethargy, epidermal hyperplasia, abnormal sitting positions) within the individuals. In fact, to my knowledge none of these symptoms have been documented for any of the amphibian species in PR.

All the evidence gathered from this and previous investigations denote the fact that ER is a species of conservation priority. The species status categories available are different, but the listing criteria are somewhat analogous as they consider ER to be facing some degree of risk of extinction (extremely high risk, high risk, and moderate risk). Stuart et al. (2004) showed that “enigmatic-decline” species are restricted mostly to South America, Mesoamerica, and Puerto Rico. These species represent the greatest challenge for conservation because there are currently no known techniques for ensuring their survival in the wild. The authors also argue that for a species facing an “enigmatic” decline, the only conservation option currently available is captive breeding. ER population declines certainly fit this argument. Amphibian conservation and captive breeding facilities have been established in other countries facing the same issues (Panama, Costa Rica, Ecuador, USA, Australia). Although habitat conservation is essential, existing protected areas alone are not sufficient to mitigate amphibian declines. The Puerto Rican Crested Toad Recovery Program has led the way in captive breeding agendas around the world. Other Puerto Rican species may be facing the same threats as well, and it is time to consider adding species like ER to those breeding programs.

CONCLUSION

This investigation was an effort to review historical, current and future patterns of ER population trends and distribution. Localized population extinctions are likely to have occurred and no evidence of recovery was found. These localized populations might be part of a metapopulation dynamic. In only three sampling areas were ER individual found calling. The potential suitable habitat model shows that much area remains unsurveyed and that individuals might also occur in non-suitable habitat, although not knowing to what extent. Survey efforts must continue, especially in new areas. An immediate solution towards recovery of declining populations would be to initiate a captive breeding program. Better understanding of ER population dynamics in the Maricao State Forest is crucial to the conservation efforts for this unique species.

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APPENDIXES

Appendix 1. Dates of each ER count per sampling area.

Sampling areas	Season[a]	ER counts	Dates
1	Dry (3)	0 8 0	January 11, 2006 March 20, 2006 March 27, 2006
	Wet (5)	13 15 0 10 11	September 7, 2005 October 3, 2005 December 28, 2005 August 4, 2006 October 11, 2006
2	Dry (2)	0 0	January 11, 2006 March 20, 2006
	Wet (5)	0 0 0 0 0	September 7, 2005 October 3, 2005 December 28, 2005 August 4, 2006 October 11, 2006
3	Dry (2)	0 0	January 11, 2006 March 20, 2006
	Wet (5)	0 0 0 0 0	September 7, 2005 October 3, 2005 December 28, 2005 August 4, 2006 October 11, 2006
4	Dry (2)	0 0	January 26, 2006 March 21, 2006
	Wet (4)	0 0 0 0	August 16, 2005 September 14, 2005 August 16, 2006 November 15, 2006
5	Dry (2)	0 5	January 26, 2006 March 21, 2006
	Wet (4)	7 5 6 5	August 16, 2005 September 14, 2005 August 16, 2006 November 15, 2006
6	Dry (2)	0 0	February 1, 2006 March 27, 2006
	Wet (3)	0 0 0	August 24, 2005 September 30, 2005 September 6, 2006

Appendix 1. (Continuation).

Sampling areas	Season[a]	ER counts	Dates
7	Dry (2)	0 0	January 3, 2006 March 26, 2006
	Wet (4)	0 0 0 0	July 24, 2005 November 10, 2005 October 3, 2006 December 9, 2006
8	Dry (2)	0 0	January 3, 2006 March 26, 2006
	Wet (3)	1 0 0	July 24, 2005 November 10, 2005 October 3, 2006
9	Dry (2)	0 0	February 1, 2006 March 4, 2006
	Wet (4)	0 0 0 0	August 24, 2005 September 30, 2005 September 6, 2006 December 9, 2006
10 (point count)	Dry (2)	0 0	February 1, 2006 March 4, 2006
	Wet (4)	0 0 0 0	August 24, 2005 September 30, 2005 September 6, 2006 December 9, 2006
11	Dry (2)	0 0	February 1, 2006 March 4, 2006
	Wet (4)	0 0 0 0	August 24, 2005 September 30, 2005 September 6, 2006 December 9, 2006

[a] Number of times sampling areas were surveyed during a season.

Appendix 2. Some juveniles of *E. richmondi*.

Two of the six juveniles observed in sampling area 1 were photographed and snout-vent length estimated visually between 8 to 13 mm.

Appendix 3. A photographic record of observed *E. richmondi* calling sites.

2a. Calling above ground on different size and shaped leaves from dissimilar plant species.

2b. Calling above ground on bare and rotten stems and branches.

2c. Calling on leaf litter and from inside cavities formed by rocks and roots.