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Amphibian diversity in Guayacán, Limón province, Costa Rica

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ABSTRACT. Herein I describe the amphibian richness of a relatively unknown low to mid-elevation site on the Caribbean versant of Costa Rica. With a total of 66 species the area of Guayacán de Siquirres has an extremely rich amphibian diversity. The high amount of annual rainfall, stable intermediate temperatures, abundant coverage of secondary and old-growth forest, and varied topography at Guayacán's low to mid-elevations create conditions that are favorable for a high diversity of flora and fauna, especially amphibians.

RESUMEN. Se describe la riqueza de anfibios en un sitio relativamente desconocido en la vertiente Caribe de Costa Rica. Con un total de 66 especies el area de Guayacán de Siquirres tiene una extrema riqueza en diversidad de anfibios. La alta precipitación annual, la estabilidad de temperaturas y la abundante cobertura, tanto de bosque secundario como denso, además de la variada topografía que va desde elevaciones bajas a medias, crean condiciones que favorecen esta alta diversidad en flora y fauna, especialmente anfibios

KEY WORDS. Amphibians, Amphibia, Costa Rica, Biodiversity, Guayacán

Costa Rica is internationally recognized as one of the 20 richest countries in biodiversity (Obando 2002). Amphibians form a crucial part of this impressive flora and fauna. With 188 species of amphibians known from Costa Rica's 51 100 square kilometer national territory it is recognized as the tenth richest country in America and 19th richest in the world for total amphibian species (Frost 2007). This number might not seem very impressive, especially compared to countries like Brazil (751 species), Colombia (697 species), Ecuador (447 species), Peru (411 species), and Mexico (363 species) (G.A.A. 2007), but when one compares the total number of species per 1,000 square kilometers of national territory Costa Rica stands out quite impressively with 3,68.

On the northeastern edge of Costa Rica's Talamancan mountain range lies a relatively unknown region called Guayacán. A small representation of the herpetofauna was known from this area via deposited museum specimens in the Museum of Zoology at the University of Costa Rica. When I started my fieldwork in Guayacán in 1999 there were 31 known species for the region. Following intensive field studies in the region from November 1999 to January of 2008 that number has risen to 66. The purpose of this work is to describe the amphibian diversity of this site and to highlight its importance for conservation.

MATERIAL AND METHODS

Study Site. Guayacán is located on the Caribbean foothills of northeastern Talamanca, on a ridge between the Reventazón and Pacuare rivers, between the coordinates 10° 03′ N and 83° 35′ W. The overall survey region covers approximately 3 100 hectares, but large sections of this area still remain unexplored. The region has a rough topographic aspect, with altitudinal extremes varying from approximately 100-800 meter above sea level (m.a.s.l.). The average altitudinal range for the region lies between 400-650 m.a.s.l. The majority of inventory work included herein took place between 400-700 m.a.s.l. Numerous ridges and valleys makeup the landscape surrounding Guayacán, and three principal hydrological drainages are represented in the area.

The first principal drainage is found in the northern section of the study area, that of the Siquirres River. This river originates on the northern face of the ridge known as Alto Guayacán, at an

altitude of roughly 700 m.a.s.l. The river starts in a remnant patch of old-growth forest, as a small high-gradient lotic stream. Upon reaching an altitude of roughly 550 m.a.s.l. the river changes its characteristics to that of a medium-gradient lotic situation. The substrate types of the Siquirres River remain quite homogeneous throughout its course, consisting principally of large rocks and boulders of a volcanic origin. Secondary substrates found in the river are a mixture of sand, gravel, and small-medium stones. The water in this river is very clean and clear, having very low levels of organic and dissolved solid compounds. Siquirres River has a temperature ranging from 23-25°C. Numerous smaller streams and the Siquirritos River join the Siquirres River. The Siquirres River flows north and connects to the Pacuare River below the city of Siquirres approximately 10 kilometers from the point where it originates. The Siquirres River is the main source of municipal water for the city of Siquirres, and in the year 1995, 681 hectares encompassing its headwater region were declared a protected watershed, known locally as the "Zona Protectora Cuenca Rio Siquirres". The second principal drainage is Quebrada Quebradón, also known locally as Quebrada la Mona. This stream passes through the center of an area known locally as "Bajo Huacas". There are numerous smaller streams that are part of this drainage, and they start in the ridges surrounding the area (i.e. southern face of the Alto Guayacán ridge, and the northern face of Alto Colorado). The substrate of this stream is a mixture of different sized igneous boulders, rocks, pebbles, stones, and sand in the headwaters region, but on the lower half of the drainage, due to the crossing of a geological transition zone, the substrate changes to a mixture of igneous rock and marine sediments. The water temperatures of Quebrada Quebradon are similar to those found in that of the Siquirres River. This drainage flows in an easterly direction, and joins the Pacuare River approximately six kilometers from its point of origin.

The last of the three principal drainages found in Guayacán is the Quebrada Terciopelo. This stream passes through the southern edge of the study area, but its largest tributary stream, Quebrada San Martín, originates along the western side of Alto Colorado. The geology and chemical and physical parameters of the water of these two principal streams and their corresponding tributaries are similar to those of the Quebrada Quebradón drainage. The Terciopelo drainage flows eastward until joining the Pacuare River approximately six kilometers from the point of its origin.

With the highly variable landscape and high rainfall in the region there is an abundant supply of smaller tributaries joining the three above-mentioned drainages.

Guayacán is located on a geological transition zone. The northwestern part of the region has a makeup of primarily igneous rock, whereas the eastern two-thirds of Guayacán has an origin consisting of primarily marine sediments. While digging in Guayacán's shale based soils it is common to find marine fossils, including on rare occasions shark's teeth (Laurito Mora 1999).

Guayacán has a mild temperature range, with very little seasonal variation. The average temperatures range between a high of 26-29°C, and a low of 17-19°C. With its location on the windward Caribbean slopes the area gets an abundant supply of rainfall due to orographic lifting conditions. The annual rainfall averageis 5000-6000 mm (rain gauge at the Costa Rican Amphibian Research Center, 2004-2008). The region is also often shrouded in fog. The site lacks a prolonged dry season, but typically during the months of February, March, June and August the monthly precipitation drops compared to other months of the year, averaging less than 350 mm. The rainiest months are typically January, May, July, and November. During these months the total precipitation averages 500 mm or greater. In the months of April through August strong convectional showers and thunderstorms occur with greater frequency. Storms producing lightning and thunder are for the most part uncommon during the rest of the year. During the months of November, December, January, and often lasting into February the rainfall can be much more continual. During this time of year constant precipitation and overcast conditions are common, at times lasting a week or more. These prolonged rainy and overcast conditions are caused by cold fronts and are known locally as "temporales". The relative humidity in the region is high, and rarely drops below 75%. The average relative humidity typically ranges from 85-100% throughout the day and evening in forested areas. Strong Wind conditions are unusual to rare in Guayacán, but

light breezes between 1-10 km/hour are common, especially in the afternoons or during changing weather fronts. The sections of Guayacán that receive the highest air movement are the upper ridges, where slight breezes are commonly present.

In the study region two life zones are represented, that of Tropical Wet Forest, and Tropical Premontane Rain Forest (Holdridge 1967). The areas recognized as Tropical Wet Forest are those with an altitude less than 500 m.a.s.l., whereas the areas with an altitude greater than 500 m.a.s.l. are classified as Tropical Premontane Rain Forest. Guayacán has an impressive coverage of secondary to old-growth forest communities. Large sections of relatively undisturbed old-growth forest are very accessible, and this helps facilitate the area's natural history exploration. Guayacán is located on the northeastern edge of one the largest intact sections of forest in lower Central America, that of the Talamancan mountains of Costa Rica, and Central Range of northwestern Panama. Another interesting aspect of Guayacán is that it is one of the few accessible mid-elevation regions of the Atlantic versant of Talamanca, which is likely the most biologically diverse region of Costa Rica, but thus far remains highly unexplored.

Prior to my fieldwork in the area only 31 species of amphibians were known for Guayacán via voucher specimens at the Museum of Zoology in the University of Costa Rica. During the period from November 1999 to January 2008, I have conducted species inventories throughout the region. My field studies, combined with the help and sharing of information regarding observations or collections by herpetologically experienced locals from Guayacán have increased the known diversity to 66 species.

RESULTS

Amphibians of Guayacán. Guayacán has representatives of all three extant orders of the Class Amphibia. To date 58 species of Anurans (order Anura), six species of salamanders (order Caudata), and two species of caecilians (order Gymnophiona) have been identified in the zone. The order Anura makes up 87.87% of the amphibian diversity of Guayacán, with the order Caudata having 9.09% and Gymnophiona with 3.03%.

Of the 16 families of amphibians present in Costa Rica (Savage 2002; Frost *et al*. 2006; Grant *et al*. 2006, Frost 2007) 15 are known for the region of Guayacán. The only Costa Rican family lacking representation in the area is Rhinophrynidae (Table 1). The family with the highest diversity is Hylidae with 20 species, or 30.30% of the total diversity.

Table 1. Amphibian diversity by family for Guayacán.

Order	Family	No. of species	% of diversity
Gymnophiona	Caeciliidae	2	3.03
Caudata	Plethodontidae	6	9.09
Anura	Amphignathodontidae	1	1.52
	Aromobatidae	1	1.52
	Bufonidae	4	6.06
	Centrolenidae	8	12.12
	Craugastoridae	9	13.63
	Dendrobatidae	4	6.06
	Eleutherodactylidae	1	1.52
	Hylidae	20	30.30
	Leiuperidae	1	1.52
	Leptodactylidae	2	3.03
	Microhylidae	2	3.03
	Ranidae	2	3.03
	Strabomantidae	3	4.55
Totals		**66**	**100**

Guayacán has a high representation of species associated with riparian habitats; this is likely due to the abundant supply of seepages, streams, and rivers in the region. Nearly 35% of the species are associated with, either via breeding habitat, or simply being commonly seen in or near riparian situations. Due to the highly erratic topography of the region, ponds are a much more limited resource. Only a handful of naturally occurring ponds are known, but even with this low number Guayacán has an impressive representation of pond breeding species, roughly 30% of its amphibians. The remaining 35% that are not associated with ponds or moving water have more specialized breeding habits such as being direct developers or using water-filled tree holes or other small water bodies to deposit eggs and/or larvae.

The species presented herein are those that have been found in Guayacán. There are numerous additional species that possibly exist in the region or at least at one time did. It is possible that following the discovery of additional species the amphibian diversity for the region of Guayacán may surpass 70 species. Additional species that are possibly present, or possibly were present are the following: *Dermophis gracilior*, *Bolitoglossa epimela*, *B. nigrescens*, *Oedipina alfaroi*, *O. collaris*, *O. cyclocauda*, *O. gracilis*, *O. poelzi*, *O. pseudouniformis*, *Atelopus varius*, *Craugastor gollmeri*, *C. mimus*, *Pristimantis caryophyllaceus*, *P. altae*, *P. moro*, *Centrolenella prosoblepon*, *Cochranella euknemos*, *Hyloscirtus colymba, Hypsiboas rufitelus*, *Smilisca puma*, and *Lithobates taylori* (Savage 2002).

Of the 66 species that are now known from this site there are six that I have been unable to see a living specimen for, they are the following: *Bolitoglossa* sp. (possibly *B. nigrescens*), *Oedipina* sp., *Duellmanohyla uranochroa*, *Gastrotheca cornuta*, *Ecnomiohyla miliaria*, and *Craugastor ranoides*). Three of these species are known from deposited museum material in the University of Costa Rica (*D. uranochroa*, *E. miliaria*, and *C. ranoides*. The remaining three species have been seen or collected by local people with extensive experience in herpetology. *G. cornuta* is said to have been fairly abundant in the riparian forests of Bajo Huacas and Alto Colorado up till the mid 1990's (Miguel Solano Arrieta pers. comm.). Miguel Solano also found a large robust solid black *Bolitoglossa* species in the sector of Bajo Huacas. In discussing this situation David Wake, it is believed the salamander species Miguel found was very possibly *B. nigrescens*. The unidentified *Oedipina* salamander was found by Maximo Flores while digging up a yucca tuber on a neighbors land. Maximo and his father Maximiliano Flores have worked with me conducting amphibian surveys in the region of Guayacán since 2002.

The high amount of rainfall, stable intermediate temperatures, high relative humidity, and varied topography create conditions that are favorable for a high diversity of flora and fauna. To date few detailed surveys into other groups of flora and fauna have been carried out in the region of Guayacán, but such work is needed for biological and conservational awareness. Having a low to intermediate altitude, with an average from 400-650 m.a.s.l. Guayacán presents an interesting assemblage of biological diversity. At these altitudes many plant and animal assemblages of lowland, mid-elevation, and highland species, overlap, this plays a key factor in the rich biological diversity of the region.

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Table 2. Amphibians of Guayacan, Limon province, Costa Rica.
Habitat:
D= Disturbed open habitats
S= Secondary forest
P= Primary forest
T= Terrestrial
R= Rotting trunks, and under moss mats
L= Low-lying vegetation (0-5 meters)
A= Arboreal (5+ meters)
F= Fossorial
Aq= Aquatic
Rs= Rocks in or near streams

Activity:
D= Diurnal
N= Nocturnal
U= Unknown

Breeding Mode:
Af= Aquatic foam nests
Ap= Eggs laid in the water of ponds
As= Eggs laid in the water of streams
Sv= Eggs laid principally on the vegetation overhanging streams
Pv= Eggs laid principally on the vegetation overhanging ponds
Lld= Eggs laid in the leaf litter, rotting trunks, or vegetation, and having direct development
Lla= Eggs laid in the leaf litter, and tadpoles are later carried to water
U= Unknown
T= Eggs laid in the water of tree holes
Tt= Eggs laid on the bark, wood, or vegetation above a water-filled cavity in a tree or trunk
M= Eggs and larvae contained in a specialized pouch on the mother's back
L= Bearing live young

Status in Guayacan:
A= Abundant; with sightings being expected on almost any visit to the species living or breeding habitat
C= Common; sightings are frequent, and normally expected while visiting a species living or breeding habitat
O= Occasional; sightings are not expected on every visit to the species living or breeding habitat
U= Unusual; Sightings are unusual on a visit to the species living or breeding habitat
R= Rare; Sightings are exceptional
Pg= Possibly gone; Species has not been seen or heard in the area of Guayacán in more than 10 years

Order	Family	Species	Habitat	Activity	Breeding Mode	Status in Guayacán
Gymnophiona	**Caeciliidae**	*Dermophis parviceps*	S, P, F	U	U (L?)	U
		Gymnopis multiplicata	S, P, F	N	L	U
Caudata	**Plethodontidae**	*Bolitoglossa alvaradoi*	S, P, A	N	Lld	U
		Bolitoglossa colonnea	S, P, L	N	Lld	C
		Bolitoglossa striatula	D, S, P, L, A	N	Lld	U
		Bolitoglossa sp. "*nigrescens*?"	U	U	U (Lld?)	R
		Oedipina carablanca	D, S, P, R, L	U	U (Lld?)	R
		Oedipina sp?	U	U	U (Lld?)	R
Anura	**Amphignathodontidae**	*Gastrotheca cornuta*	P, L, A	N	M	Pg
	Aromobatidae	*Allobates talamancae*	S, P, T	D	Lla	O
	Bufonidae	*Incilius coniferus*	S, P, L, A	N	Ap	U

Order	Family	Species	Habitat	Activity	Breeding Mode	Status in Guayacán
		Incilius melanochlorus	S, P, T,	N	As	O
		Rhaebo haematiticus	S, P, T, Rs	D, N	As	O
		Rhinella marina	D, S, T	N	Ap	C
	Centrolenidae	*Centrolenella ilex*	S, P, L, A	N	Sv	C
		Cochranella albomaculata	S, P, L, A	N	Sv	C
		Cochranella granulosa	S, P, L, A	N	Sv	C
		Cochranella pulverata	S, P, L, A	N	Sv	O
		Cochranella spinosa	S, P, L	N	Sv	C
		Hyalinobatrachium fleischmanni	D, S, P, L, A	N	Sv	C
		Hyalinobatrachium talamancae	S, P, L, A	N	Sv	U
		Hyalinobatrachium valerioi	D, S, P, L, A	N	Sv	U
	Craugastoridae	*Craugastor bransfordii*	D, S, P, T	D, N	Lld	A
		Craugastor crassidigitus	S, P, T, L	N	Lld	C
		Craugastor fitzingeri	D, S, P, T, L	D, N	Lld	A
		Craugastor megacephalus	S, P, T	D, N	Lld	U
		Craugastor noblei	S, P, T, L	D, N	Lld	U
		Craugastor persimilis	S, P, T	D, N	Lld	U
		Craugastor ranoides	S, P, Rs	N	Lld	Pg
		Craugastor talamancae	S, P, L	N	Lld	R
	Dendrobatidae	*Dendrobates auratus*	D, S, P, T	D	Lla	O
		Oophaga pumilio	D, S, P, T	D	Lla	A
		Phyllobates lugubris	D, S, P, T	D	Lla	O
		Silverstoneia flotator	S, P, T,	D	Lla	U
	Eleutherodactylidae	*Diasporus diastema*	D, S, P, L, A	N	Lld	A
	Hylidae	*Agalychnis callidryas*	D, S, P, L, A	N	Pv, Tt	A
		Agalychnis saltator	S, P, L, A	N	Pv	O
		Agalychnis spurrelli	S, P, L, A	N	Pv	O
		Anotheca spinosa	S, P, L, A	N	T,Tt	R
		Cruziohyla calcarifer	S, P, L, A	N	Tt	O
		Dendropsophus ebraccatus	D, S, P, L	N	Pv	C
		D. phlebodes	D, S, L	N	Ap	O
		Duellmanohyla rufioculis	S, P, L, Rs	N	As	O
		D. uranochroa	S, P, L, Rs	N	As	Pg
		Ecnomiohyla miliaria	S, P, A	N	U (T?)	R
		Ecnomiohyla sp.	S, P, A	N	U (T?)	U

Order	Family	Species	Habitat	Activity	Breeding Mode	Status in Guayacán
		Hylomantis lemur	D, S, P, L	N	Pv	R
		Hyloscirtus palmeri	S, P, L, Rs	N	As	O
		Isthmohyla lancasteri	S, P, L, Rs	N	As	O
		Scinax boulengeri	D, S, P, L, A	N	Ap	R
		Scinax elaeochrous	D, S, P, L, A	N	Ap	A
		Smilisca baudinii	D, S, P, L, A	N	Ap	U
		Smilisca phaeota	D, S, P, Aq, L	N	Ap	A
		Smilisca sordida	D, S, P, L, Rs	N	As	O
		Tlalocohyla loquax	D, S, P, L, A	N	Ap	C
	Leiuperidae	*Engystomops putulosus*	D, Aq, T	N	Af	R
	Leptodactylidae	*Leptodactylus melanonotus*	D, S, Aq	D, N	Af	O
		Leptodactylus savagei	D, S, P, T	N	Af	C
	Microhylidae	*Gastrophryne pictiventris*	S, P, F, T	N	Ap	R
		Nelsonophryne aterrima	S, P, F, T	N	Ap	R
	Ranidae	*Lithobates vaillanti*	D, S, P, Aq, T	D, N	Ap	C
		Lithobates warszewitschii	D, S, P, Aq, T, Rs	D, N	As, Ap	A
	Strabomantidae	*Pristimantis cerasinus*	S, P, T, L	D, N	Lld	A
		Pristimantis cruentus	S, P, L, A	N	Lld	R
		Pristimantis ridens	S, P, L	N	Lld	A