Amazonian frog diversity and microhabitat use

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ABSTRACT - Upper Amazonian forests offer some of the highest species diversity in the world due in part to their complex habitats created by fluctuating water levels. In the Pacaya-Samiria National Reserve within the upper Amazonian forest of Peru, forty species of anuran belonging to seven families were recorded in 2009 and 2010 over forty survey days. A species accumulation curve indicated that most species present were detected after ten days of surveying. On land, frogs were most frequently observed among leaf litter. In the river, floating rafts of vegetation may be an important mechanism for the dispersal of frogs.

THE Amazon rainforest contains some of the greatest species diversity on Earth (Salo et al., 1986; Osborne, 2000; Bodmer, 2008). It is a complex ecosystem combining different strata from emergent layer through to canopy, shrubs and forest floor. This wealth of niches has enabled many species to evolve specialist adaptations to their environment. Consequently a huge diversity of amphibian and reptile species exist in the Amazon, with over 250 amphibian and reptile species described as "commonly seen" (Bartlett & Bartlett, 2003).

Surveys indicate that the upper Amazonian forests offer high species diversity due to complex habitats created by fluctuating water levels (Salo et al., 1986; Gentry, 1988; Bodmer, 2008). Gentry (1988) surveyed a series of 1 ha plots in Peru, and found 580 individual trees representing 283 species per plot. The Amazon rainforest would not function without the Amazon river which forms at the confluence of the Maranon and Ucayali rivers. These rivers border the Pacaya-Samiria National Reserve, a 8,042 km^2 protected area located in the upper Amazonian forests of Loreto, Peru. This region contains one of the highest anuran diversities in the world. Rodriguez & Duellman (1994) describe 112 species from the Iquitos region alone. The number of anuran species in this area is constantly increasing as new species are discovered (Perez-Pena et al., 2010). The Pacaya-Samiria reserve has been degraded in the past through overhunting, deforestation and overfishing (Bodmer, 2008). However, wildlife monitoring in the reserve has noted increases in woolly monkeys *Lagothrix lagothrica*, black caiman *Melanosucus niger*, manatees *Trichechus inunguis*, dolphins *Inea geoffrensis* and macaws (Bodmer, 2008).

Despite ongoing monitoring of wildlife in this reserve, little research on diversity and populations of amphibians has been published. The aims of this research were to create a baseline anuran species list for the Pacaya-Samiria reserve and describe the habitat and microhabitat use by them.

MATERIALS AND METHODS

Site Description

This study was undertaken in the Pacaya-Samiria National Reserve, a site with a complex ecosystem. The reserve does not have strictly defined wet and dry seasons and more often has high and low water seasons. As a result of extreme seasonal water changes 92% of the reserve comprises low lying flooded forest know as varsea (Myers, 1990; Talling & Lemoalle, 1998). Inundation and run-off of tannins from trees likely creates the blackwaters of the Samiria River (Bodmer et al., 2010). Periodically, the forest becomes flooded with white water from the Maranon river. The sediment from this water is dropped and tannins from decomposing leaves are taken in. This water then flows back out of the forest into the Samiria River as tannin rich blackwater (Bodmer, pers. comm.).

The Samiria River is an old channel of the Manranon River, therefore the Samiria river bed contains nutrient rich alluvial soils (Kvist & Nebel, 2001). This hydrological system, combined with the alluvial soils, helps create an environment that is very nutrient rich and therefore able to support a diverse range of species across many taxa.

Methods (2009)

Surveys were carried out adjacent to a location known as PV3, a guard post on the Samiria River, at Hungurahui. Land (walking) and river (canoe) transects were conducted within the vicinity of PV3. Data were collected over 18 days between the 30 May to 16 June 2009. During this time 104 transects of 100 m were completed in 52.5 hours. Transects were alternated between land (52 surveys) and river (52 surveys) with equal numbers at day and night in a variety of habitats and temporal zones. River transects were alternated between banks, with a GPS used to calculate distance travelled. For land transects, a tape measure was used with random numbers applied to a compass to determine the direction of travel. Sampling was undertaken no higher than 2 m from the ground or river surface and transect width was 4 m. Day surveys began at 08:00 lasting until approximately 13:00. Night surveys were from 19:00 to 22:00. A team of three to four people walked each land transect and canoed each river transect using a visual encounter survey method (VES) which has been shown to give a good representation of species in tropical forests over a short time period (Doan, 2003). There was no time limit on each transect. They were travelled at the same speed of 0.5 km an hour. Each individual amphibian was captured to collect data. Date, time and transect number were recorded as well as habitat, microhabitat, and substrate. The individuals were then measured (1 mm precision) and weighed (0.1 g precision). Additional factors including temperature, rainfall, detection method, light level and ecologically relevant notes (e.g. sitting on a foam nest) were also recorded. Identification was undertaken using three guide books; Rodriguez & Duellman (1994), Bartlett & Bartlett (2003) and Duellman (2005). Where possible identification was confirmed by local experts.

Methods (2010)

Data were collected from the 15 June to 10 July 2010 (22 survey days). A total of 31 sampling transects was undertaken comprising four permanent land and five permanent river transects, each of 1000 m, surveyed both nocturnally and diurnally. A total of 64 hours of survey was completed. Transects began at 10:00 for the dawn transects and 20:00 for the night transects. VES method was used. The land surveys involved scanning leaf litter and vegetation whilst walking along the transect, using sticks to tap the leaf litter during the day and using torches to spot frogs at night. River surveys involved using torches to scan the riverbank and floating vegetation. All other methods were the same as described for 2009.

RESULTS AND DISCUSSION

Diversity of Amphibians

Forty amphibian species belonging to seven families were recorded in Pacaya-Samiria during 2009 and 2010. They included; Arobatidate (1 species), Bufonidae (3 species), Dendrobatidae (2 species), Hylidae (23 species), Leptodactylidae (8 species), Microhylidae (1 species), Strabomantidae (2 species). Appendix 1 shows a full list of species and the corresponding years in which they were recorded. The highest number of species was recorded in 2009 (29 species). Twenty-seven species were recorded at the same site in 2010. Between these two studies a total of 845 anurans were caught in just 40 days of surveys.

The species list compiled from the 2009 and 2010 research shows possible absences as well as new discoveries in some species. However, the differences in methods and timing make comparisons in abundance difficult without long-term monitoring. Nevertheless, the Pacaya-Samiria reserve has an extremely high anuran diversity (40 species recorded), which can be compared with other anuran hotspots. For example, 52 amphibian species have been recorded in just 45 hectares of Costa Rica (Kubicki, 2010), 27 species representing 5 families were found in Borneo (Keller at al., 2009) and studies on woodlands in western Tanzania found 4247 individuals representing 28 amphibian species (Gardner et al., 2007). The Gibraltar Range National Park in Australia is also

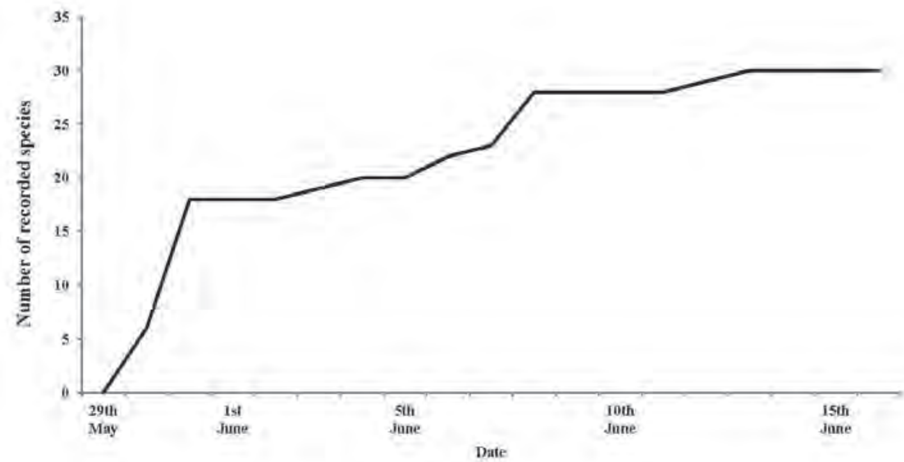

Figure 1. The species accumulation curve for the 2009 Pacaya-Samiria study

home to 30 anuran species (Mahony, 2006). These studies all had longer survey periods than that of the Pacaya-Samiria research and are therefore more extensive. Despite these caveats, 40 amphibian species were recorded in just 40 days; representing a higher diversity than three of these four studies. Fig. 1 shows the species accumulation curve for the 18 days spent in the field in 2009. The curve stabilised after 10 days of surveying. This suggests the majority of species present in the habitats surveyed had been observed.

Microhabitat Use

Fig. 2 shows the number of individuals of the five most abundant species found in the terrestrial habitat in each of the three main micro-habitats on the forest floor (2009 data only). The five species were found in differing frequencies across the three microhabitats suggesting differential usage (Chi-squared = 24.09, df = 8, $P < 0.01$). Most frogs were found in leaf litter. *Leptodactylus discodactylus* showed no preference for a single habitat type. *Rhinella margaritifera* was most commonly found in the leaf litter.

The high diversity of species may present the possibility of resource partitioning on a spatial scale. Many microhabitats were available within the terrestrial habitat including leaf litter, bare ground, puddles, tree trunks and fallen logs. When foraging, frogs may utilise a range of microhabitats as they travel through their range. Leaf litter was the microhabitat utilised most often in this study, a finding supported by Morales & McDiarmid (1996). Leaf litter may reduce the risk of detection by predators (Vonesh, 2001). *Rhinella margaritifer* and *Rhinella daphillis* were often recorded in the leaf litter and have coloration and morphology that resembles leaves of the region (Marent, 2008).

All but one dendrobatid species found in 2009 were active in open spaces during the day. This is commonly recorded behaviour for frogs of the family as they produce toxins which are unpalatable to potential predators; a point broadcast by their striking colours (Symela et al., 2001). A single *Ameerega trivittata* was observed on the same log for three consecutive days. As dendrobatids defend small territories that contain good breeding sites (Poelman & Dicke 2008), this *Ameerega trivittata* may have been the same individual, however, without marking for recapture this could not be confirmed.

The Floating Meadows

Due to the high level of flood water in Pacaya-Samiria in 2009 the only habitat available on the river was floating meadow (2009 data only). Fig. 3 shows the number of individuals representing each species in each of the three main microhabitats found on the floating meadow (Fig. 4 illustrates these microhabitats). The floating meadow habitat and its microhabitats were able to support a large number of species. Sixteen species were found

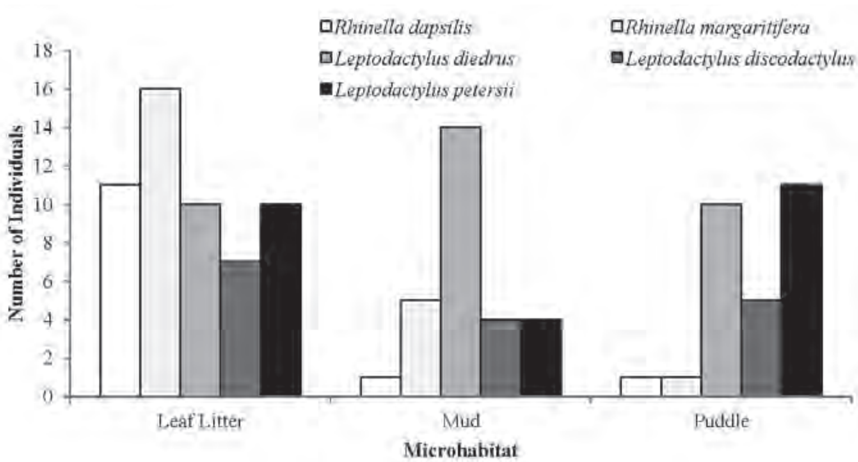

Figure 2. The number of individuals, of each species, recorded on the three main microhabitats on the land transects (2009).

using this habitat, while both Hödl (1977) and Goulding (1989) recorded 15 species on floating meadow at different Amazon sites. These meadows are created from extensive macrophyte stands that grow along the banks of rivers and in lakes (Schiesari et al., 2003). In some parts the meadows covered the entire water channel from one bank to the other, a feature that could aid dispersal across the river. The floating meadows may have been formed at a lake up-river from the study site and therefore facilitate dispersal downstream as well. However, further research is required to confirm this.

The water lettuce microhabitat was dominated by *Sphaenorpyhchus dorisae* and *Sphaenorhynchus lacteus*. Both of these were found most often on this microhabitat, with small numbers recorded in the other two microhabitats. *S. lacteus* was found mainly on this microhabitat possibly due to its morphology. *S. lacteus* was one of the largest species found on the floating meadows. It also lacks adhesive disks on its fingertips (Rodriguez & Duellman, 1994). The emergent vegetation and water hyacinth were very spindly and weak and therefore may only be able to support smaller hylid species.

Calling site partitioning has been observed on floating meadows (Hödl, 1977). Four of the species recorded herein also featured in Hödl's (1977) study, with each observed frog calling from one

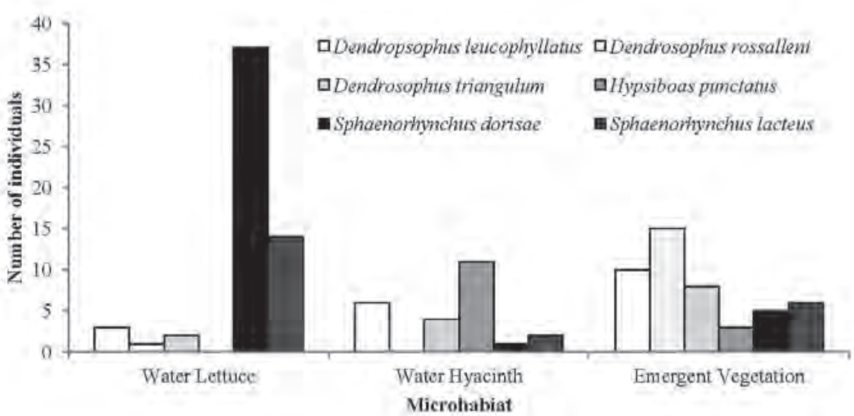

Figure 3. The number of individuals, of each species, recorded on the three main microhabitats on the river transects (2009).

Figure 4. A small section of the floating meadow habitat connected to the flooded forest. In this photograph water lettuce, water hyacinth and emergent vegetation are all present.

particular microhabitat, possibly attracting mates for breeding. In addition to calling adults, froglets were also observed on the floating meadow habitat. Many species in the central Amazon tropical forest breed all year round (Hödl, 1990). Frogs may also have been exploiting the abundance of insect prey available on the floating meadow habitat (Schiesari et al., 2003). The meadows grow very rapidly thus producing a lot of detritus and shelter in the root zone that provides suitable habitat and food for a wide variety of invertebrates (Schiesari et al., 2003). Many frogs observed on the floating meadow habitat were hylid species that would usually be expected to be found in the canopy. Thus this habitat could offer a rare opportunity to study their ecology.

Floating meadows are not permanent habitats. Sections break away, creating floating rafts of vegetation carried down river after rainfall (Schiesari et al., 2003) (Fig. 5). This transport of individuals can be very important to downriver dispersal, facilitating gene flow (Schiesari et al., 2003). Species found on these floating rafts include *Rhinella marinus*, *Leptodactylus leptodactyloides*, *Dendropsophus leuchophyllatus*, *Hypsiboas punctatus* and *Sphaenorhynchus carneus* (Schiesari et al., 2003), all of which were present in this habitat during this study. A further four species were found on floating rafts by Schiesari et al. (2003). However, their survey methods were more intensive. Surveying included eight floating rafts collected in their entirety, with all vertebrates counted and identified. These rafts were collected in Brazil on the Solimões River, which prompts the question of whether such rafts could travel this far. Schiesari et al. (2003) calculated that a vegetation raft could travel 4000 km in as little as 31 days. These rafts also have a great abundance of prey species as the submerged root zone of 1 m^2 of floating meadow will usually support over 500,000

Figure 5. Rafts observed floating down river transporting anuran species. This raft contained *Dendropsophus triangulum* and *Hypsiboas punctatus* individuals.

invertebrate individuals (Goulding, 1989). Therefore, rivers may not be barriers to the dispersal of terrestrial amphibians, but actually aid population dispersal.

Further impacts like disease should be considered potential threats to herpetofauna of floodplains, especially chytridiomycosis. If present in aquatic environments, infected frogs could spread the disease easily when they are breeding further downstream. The potential impact of climate change in the area could also threaten dramatic changes in the water levels and flooding patterns that may have far-reaching impacts on amphibian diversity and abundance.

Further research would be required to fully investigate amphibian population trends in Pacaya-Samiria National Reserve. Such work will hopefully form the basis of a Ph.D. conducted by the senior author commencing September 2011, that seeks to assess the suitability of amphibians in tropical environments as indicator species.

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APPENDIX

Numbers of individuals of each species observed in Pacaya-Samiria National Reserve.

Family	Scientific Name	2009	2010
Arobatidate	*Allobates femoralis*	1	2
Bufonidae	*Rhinella dapsilis*	14	-
	Rhinella margaritifera	25	2
	Rhinella marina	1	17
Dendrobatidae	*Ameerega hahneli*	1	-
	Ameerega trivittata	3	1
Hylidae	*Dendropsophus haraldschultzi*	-	2
	Dendropsophus leucophyllatus	20	-
	Dendropsophus parviceps	-	5
	Dendropsophus rossalleni	16	7
	Dendropsophus triangulum	15	58
	Dendropsophus allenorum	-	1
	Hypsiboas boans	-	9
	Hypsiboas fasciatus	2	2
	Hypsiboas geographicus	-	1
	Hypsiboas lanciformis	-	7
	Hypsiboas punctatus	14	22
	Osteocephalus buckleyi	1	-
	Osteocephalus cabrerai	1	-
	Osteocephalus leprieurii	1	-

	Osteocephalus planiceps	-	1
	Osteocephalus taurinus	3	11
	Scarthyla goinorum	-	7
	Scinax ruber	1	-
	Scinax pedromedinae	-	19
	Sphaenorhynchus carneus	5	-
	Sphaenorhynchus dorisae	43	8
	Sphaenorhynchus lacteus	22	-
	Trachycephalus resinifictrix	-	2
Leptodactylidae	*Leptodactylus andreae*	3	9
	Leptodactylus diedrus	43	-
	Leptodactylus discodactylus	16	24
	Leptodactylus hylaedactyla	6	6
	Leptodactylus leptodactyloides	13	265
	Leptodactylus mystaceus	5	-
	Leptodactylus pentadactylus	1	6
	Leptodactylus petersii	31	36
Microhylidae	*Hamptophryne boliviana*	2	-
Strabomantidae	*Pristimantis altamazonicus*	-	4
	Pristimantis carvalhoi	2	-