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Chapter 10

A preliminary survey of amphibians and reptiles on the Nassau and Lely plateaus Eastern Suriname

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INTRODUCTION

Amphibians and reptiles are a species-rich and often conspicuous component of many neotropical forests. Three aspects of amphibians and reptile biology make them a valuable focal group for biological surveys: (1) the small body size of many species often results in high population densities, making it possible to collect a large amount of data in a relatively short period of time; (2) they perceive their environment on relatively small scales and many species show strict habitat requirements, making it possible to compare diversity patterns across finely-defined habitats; (3) their intermediate role in food webs ties them to both primary and secondary consumers. Amphibians are of particular interest because their moist, permeable skin makes them more sensitive to changes in their environment (e.g., contamination, climate change) than other vertebrate groups, and the biphasic lifestyle of many species exposes them to changes in both aquatic and terrestrial environments. Widespread reports of enigmatic amphibian declines in seemingly pristine locations are of urgent conservation concern (Lips 1998), and it appears that amphibians as a group are more threatened than other terrestrial vertebrates (Stuart et al. 2004, Beebee and Griffiths 2005). As part of the CI RAP survey in eastern Suriname, we surveyed the herpetofauna of Nassau and Lely mountains for six days each. Here we compare three response metrics (species richness, species composition, and an estimate of density) between the two mountains, and place these preliminary observations in a regional context by making comparisons with other sites in the Guayana Shield and the Amazon Basin. We also describe the distribution of species at a regional scale and among macrohabitats at the two sites, and discuss the conservation implications of our observations.

METHODS

We surveyed amphibians and reptiles for six days each at the Nassau mountain (25 – 30 October 2005) and Lely mountain (1 – 6 November 2005) using a combination of opportunistic surveys and time-constrained Visual Encounter Surveys (VES). Opportunistic surveys require actively searching for animals over large areas (i.e., up to several square kilometers) in order to increase the probability of encountering as many different species as possible. This method is effective for sampling species richness (Donnelly et al. 2004), but because not all individuals encountered are recorded, and cryptic or inactive individuals may be easily overlooked, the method is inappropriate for comparing density. In contrast, VES involve intensive sampling over small areas (i.e., a few hundred square meters) and all individuals encountered are recorded, making it possible to calculate an index of density by comparing the number of individuals encountered per unit time (Crump and Scott 1994). We conducted opportunistic surveys throughout the range of habitats available at each site, walking trails, forest creeks, and searching in natural and anthropogenic clearings both day and night throughout our stay. We conducted ten VES (eight nocturnal and 2 diurnal) at each site, concentrating effort in forest and forest stream habitats (Table 10.1).

Species richness

Because observed species richness is almost always an underestimate of true species richness (Colwell and Coddington 1994, Hellmann and Fowler 1999), we used program EstimateS (Colwell 1997) to calculate extrapolated estimates of amphibian and reptile richness of each site. There is considerable debate as to which of the many species richness estimators provides the most robust results (Hellman and Fowler 1999, Herzog et al. 2002), so we included four of the most commonly used estimators (ACE, ICE, Chao1 and MMMean). We included observations from both VES and opportunistic encounters in our analysis because few reptiles were encountered during VES surveys at Lely, making it impractical to estimate species richness from only that data set. Although not all individuals of all species were recorded during opportunistic surveys, the combined data set accurately reflects observed species abundances (i.e., rare species only occur once or twice in the entire data set, whereas the most commonly encountered species appear frequently), so we assume that the combined data set provides a reasonable basis for comparing species richness between sites.

Species composition

In addition to comparing species richness on the two mountains, we also wanted to describe overlap in species identity. We began simply by comparing the number of species occurring at only one of the sites with the number occurring at both sites. We conducted a formal test of the compositional difference between the two mountains using analysis of similarity (ANOSIM) based on the Bray-Curtis dissimilarity index (Clarke and Warwick 2001), and present these results in a non-metric multidimensional scaling nMDS) graph. Species composition is known to vary with geographic distance (Steinitz et al. 2005), so in addition to establishing that a compositional difference between the two sites exists, we also wanted to determine whether the difference in species composition between Nassau and Lely was more or less than would be expected given the distance between the two mountains. We compiled data on amphibian and reptile surveys from five sites in the Guayana Shield: Nouragues and Arataye, French Guiana (Born and Gaucher 2001); Petit Saut, French Guiana (Duellman 1997), Piste Ste. Elie, French Guiana (Born and Gaucher 2001); and Iwokrama, Guyana (Donnelly et al. 2005). Distance between these sites ranged from 64 – 713 kilometers. Herpetofaunal survey data are available for eight sites separated by a maximum distance of 263 kilometers in the Madre de Dios region of southeastern Peru (Duellman and Thomas 1996, Morales and McDiarmid 1996, Doan and Arriaga 2002), and because distances among sites in Madre de Dios are more similar to those of interest here (straight-line distance between Nassau and Lely is approximately 63 kilometers), we include a comparison with those sites as well. Although some species certainly remain undetected at sites in the Guayana Shield and Peru, those sites are relatively well-sampled compared with Nassau and Lely. For all pairs of sites, we calculated straight-line distance based on coordinates included in the primary literature cited above. We compiled a species by site presence/absence matrix for all sites and calculated dissimilarity among all pairs of sites using the Bray-Curtis dissimilarity index in Program Primer (Clarke and Warwick 2001).

Density

In order to have maximal flexibility and not be constrained to surveying fixed transects that may have resulted in the observation of few individuals, we opted to constrain our VES by time rather than area. At each site we conducted ten VES, eight nocturnal and two diurnal. As an index of density, we calculated the number of individuals encountered per survey minute (# individuals/# minutes surveyed),

Table 10.1. Schedule of herpetofaunal sampling at Nassau and Lely, October-November, 2005.

Nassau			Lely		
25-Oct	AM	Arrive	1-Nov	AM	Arrive
	PM	VES: Forest		PM	Opportunistic survey: Forest & Clearing
26	AM	Trap Preparation			VES: Forest
	PM	VES: Stream & Forest	2	AM	Opportunistic survey: Forest & Stream
27	AM	Opportunistic survey: Forest & Plateau A		PM	VES: Stream
	PM	Opportunistic survey: Stream	3	AM	Prepare specimens
		VES: Stream & Forest		PM	Opportunistic survey: Forest
28	AM	Prepare specimens			VES: Forest
	PM	VES: Stream	4	AM	VES: Forest
		Opportunistic survey: Forest		PM	VES: Stream
29	AM	VES: MSF			VES: Forest
	PM	VES: Swamp Forest	5	AM	Prepare specimens
		VES: Forest		PM	Opportunistic survey: Forest
30	AM	VES: Forest			VES: MSF
	PM	VES: MSF			VES: Forest
		VES: Forest	6	AM	VES: Forest
				PM	VES: Forest

averaged this value across all ten surveys, and multiplied this average by 60 to provide an average number of individuals encountered per hour of survey at each site.

Species-specific data

When individuals of new species were encountered during opportunistic surveys, we noted the habitat in which the observation occurred. Similarly, we noted the habitat where VES occurred. Thus, we are able to assign species occurrences to one or more habitat categories: forest, forest stream, clearing, berg forest (Nassau only), swamp forest (Nassau only), savannah forest (Lely only), or forest clearing (Lely only). Because of the complex interdigitation of savannah forest and high forest around the camp at Lely, we refer to both as 'forest'. We did survey a discreet patch of berg forest east of the main camp at Nassau, and a patch of savannah forest with many bromeliads near the northeastern corner of the airstrip at Lely. We assigned each species to one of two regional distribution patterns: Guayana Shield for those species endemic (or nearly so) to the Guayana Shield, and Widespread for species that also occur beyond the boundaries of the Guayana Shield. Distributional data were taken from Ceñaris and MacCulloch (2005) for amphibians and Ávila Pires (2005) for reptiles. Threat status for each species was established based on IUCN Red List guidelines (www.iucnredlist.org). Data for amphibians were taken from the Global Amphibian Assessment online database (www.globalamphibians.org). Data on the crocodilian were extracted from the IUCN website. For the lizards and snakes (for which no IUCN specialist group currently exists) we used our knowledge of probable distributions and potential threats to assign a threat status based on IUCN criteria. We did not include threat status for unidentified species thought to represent new species for science, because determination of threat status will require more survey work to establish the geographic range of those species.

Table 10.2. Herpetofaunal richness at nine sites in the Guayana Shield, including Nassau and Lely mountains. In each column, data are presented as raw species number/percentage of total herpetofauna.

Site	Amphibians	Reptiles	Total
Iwokrama	37/0.34	71/0.66	108
Nourague	51/0.47	58/0.53	109
Arataya	62/0.49	65/0.51	127
Piste Ste. Elie	33/0.38	53/0.62	86
Trois Saut	56		
Petit Saut	37/0.28	94/0.72	131
	mean = 46 species	mean = 68 species	mean = 112 species
Brownsberg	64/0.44	80/0.56	144
Nassau	16/0.55	13/0.45	29
Lely	20/0.55	16/0.45	36

RESULTS

We observed a total of 49 species in 12 days of sampling at the two sites (Table 10.2). The data presented herein include only species observed by the two authors; species observed by other members of the RAP team and on a herpetological expedition to Lely in 1979 are included in Appendix 16. Comparison with other well-studied sites in the Guayana Shield indicate that many species remain undetected on the two mountains, and that reptiles were undersampled on the RAP relative to amphibians (because they represent a smaller percentage of the total herpetofauna at RAP sites than at more well-sampled sites, Table 10.2). Despite the fact that many species remain to be detected on both mountains, preliminary observations indicate that Lely appears to be the richer of the two mountains; we observed 36 species there and 29 at Nassau (Figure 10.1). Extrapolated species richness estimates were largely consistent with the notion of higher richness at Lely than Nassau (Table 10.3). However see Chapter 11 for additional data from Nassau.

A simple review of the species list for the two sites indicates that species composition differs between Nassau and Lely, with only 15/49 = 31% of all species occurring on both mountains. Forty-eight percent of the species at Nassau were unique to Nassau, whereas the percentage was 57% at Lely. As expected, the species occurring at the two sites represented a mix of widespread species that occur throughout lowland portions of much of the Amazon Basin, in addition to species known from lowland forest of the Guayana Shield (Appendix 16). Five records are particularly noteworthy because they represent taxa that could not be assigned to any known species. Four of these records were species of the genus *Eleutherodactylus*; one species was encountered at both Lely and Nassau, whereas the other three new species of *Eleutherodactylus* were found at Lely. We also collected what appears to be an undescribed species of *Adenomera* at Lely. Bray-Curtis dissimilarity between Nassau and Lely is 51.7% for reptiles and 44.4% for amphibians, and the two mountains are compositionally distinct (Global R = 0.669, P = 0.002; Figure 10.2). Comparison of the regression

Table 10.3. Observed and estimated species richness for amphibians and reptiles at Nassau and Lely.

Group	No. individuals	Species (observed)	ACE	ICE	Chao 1	MMMeans	Mean (estimates)
Lely frogs	91	19	21.91	22.91	20.2	27.65	23.1675
Lely reptiles	32	16	35.62	52	29.75	43.04	40.1025
Nassau frogs	88	16	18.26	18.68	22	21.37	20.0775
Nassau reptiles	32	15	23.96	25.99	29	25.47	26.105

lines describing the relationship between compositional dissimilarity and geographic distance among sites in the Guayana Shield and Tambopata, Peru reveal that observed dissimilarity between Nassau and Lely is greater than would be expected based on observations from the reference sites (Figure 10.3).

Like richness, herpetofaunal density was higher at Lely (mean = 7.4 individuals/hour) than at Nassau (4.5 individuals/hour). At Nassau, the highest density of individuals occurred in transects running through the IJskreek and forest adjacent to the stream, and lowest in savannah forest. At Lely, density was greatest in forest streams, slightly lower in forest, and lowest in savannah forest.

Habitat use, distribution, and threat status for each species are presented in Appendix 16. We draw particular attention to the observation that forest streams are important habitat for many species encountered during our surveys. Just under half of the species occurring at each site made use of forest streams, and one quarter of the species encountered at Lely and one third of the species encountered at Nassau were only found in or along forest streams. In addition, two of the five new species encountered during our surveys were associated with forest streams. At Lely, density was higher in forest streams than in any other habitat, whereas at Nassau, density was broadly similar between forest and streams, but higher there than in other habitats. Overall, we suggest that forest streams be considered keystone habitat structures (Tews et al. 2004) of paramount biological and conservation value at the two sites because (1) they cover a small proportion of the total habitat at each site, (2) house a substantial fraction of overall herpetofaunal richness at the two sites, (3) are an important habitat for undescribed and probably narrowly endemic taxa recorded during our surveys, and (4) at Lely, have a greater herpetofaunal density than any habitat surveyed.

DISCUSSION

In our short surveys we sampled only a fraction of what is likely a rich herpetofauna on both mountains. Estimated species richness estimates for amphibians and reptiles were not much greater than observed richness (Table 10.3). Our impression is that low estimated richness is a function of seasonal fluctuations in activity (for amphibians) and small sample sizes (for both amphibians and reptiles), rather than being indicative of a depauperate herpetofauna on the two mountains. The rapid accumulation of species during a dry period during which many amphibians and reptiles were likely inactive is suggestive of potentially high richness, as is the geographic proximity to sites in western French Guiana with the highest known richness of amphibians and reptiles in the Guayana Shield (Petit Saut and the Nouragues reserve; Table 10.2). Comparison of our species accumulation curves with those from other sites indicate that species accumulated faster at Lely and Nassau than at individual camps in the Iwokrama reserve in Guyana (Donnelly et al. 2004), and were more similar to species-rich sites in the western Amazon (Duellman and Mendelson 1995, Cadle et al. 2002, Moravec and Aparicio 2005). Although sampling on the two mountains is far from complete, available evidence suggests that Lely is likely to be the richer of the two sites.

Our observation that compositional dissimilarity between the two mountains is greater than expected given their geographic distance suggests that conservation of both areas is not redundant, but necessary in order to conserve a representative regional fauna. Beyond acting as reservoirs of a rich herpetofauna, the two mountains are home to a suite of endemic taxa that is of great regional importance. Particularly striking was the four *Eleutherodactylus* species encountered during our surveys. Previous to our surveys, five species of *Eleutherodactylus* were known from Suriname; our work on the two mountains has almost doubled the representation of the genus in the country.

Two of the new species encountered during our surveys (*Adenomera sp*. and *Eleutherodactylus* sp. 1) utilized both forest and forest stream habitats and were abundant where they occurred. The three other new species (*Eleutherodactylus* sp. 2, *Eleutherodactylus* sp. 3, and *Eleutherodactylus* sp. 4) were found in the forest at Lely and were represented by only one or two individuals each. Although the forest-inhabiting *Eleutherodactylus* appeared to be rare, they likely occur throughout the forest and because they do not require standing water for breeding, their persistence is not as dependent on particular habitat requirements as the other frogs. Therefore, we consider the species associated with forest streams to be the most in need of conservation attention. Amphibians tend to have limited dispersal abilities, often moving less than 500 m (Smith and Green 2005). Because body size of the remaining four new species is small (< 40 mm, implying relatively limited dispersal abilities; Etienne and Olff 2004) and they appear to be reliant on a habitat type that is relatively scarce in the landscape, it may be unlikely that individuals can move to more suitable habitat (i.e., another stream) if they are disturbed. Amphibians tend to be dietary generalists, feeding on a variety of arthropods (Duellman 1978, Parmelee 1999), so it is unlikely that distributions of any of these species are limited by the availability of food resources. Protection of streams where they are known to occur should be considered the best conservation action for these new species, as well as the other species that utilize forest stream habitat on the two mountains.

Streams are a keystone habitat feature of critical importance for amphibians at Nassau and Lely. Almost half of the species encountered during our surveys made at least some use of streamside habitat. Stream-associated amphibians are of paramount conservation significance because many species in this guild have experienced precipitous population declines (Lips et al. 2003). Like virtually all other taxonomic groups, amphibians have been affected by habitat loss and fragmentation, overharvest, and other anthropogenic disturbances. More alarming are population declines, many to the point of extinction, of amphibians in protected areas where the agent of decline is not so obvious. These enigmatic declines have resulted in the loss of many moderate- to high-elevation anurofaunas (Young et al. 2001), so the presence of abundant, diverse, stream-associated amphibian assemblages at Nassau and Lely is of significant conservation value. The densities we observed at Nassau and Lely are comparable to pre-decline data from forest streams and adjacent forest in Panama (Lips 1999), suggesting that the stream-associated fauna of Nassau and Lely have not experienced the dramatic declines that have occurred in other parts of the Neotropics (Young et al. 2001). This provides an excellent opportunity to protect an intact, upland stream-associated herpetofaunal assemblage.

CONSERVATION RECOMMENDATIONS

Our first and foremost conservation recommendation is to maintain the integrity of forest streams at both Lely and Nassau. Anthropogenic activity at Lely is minimal, so there are no current threats, but every attempt should be made to ensure that future activity at Lely be kept away from stream habitats. The stream at Nassau probably has been impacted and will continue to be impacted by the higher level of human activity. Of most concern is the presence of the camp clearing and a dirt path used by motorized vehicles that crosses the Ijskreek through the clearing. Because of the possibility that human activity may negatively impact stream quality at Nassau, we make the following recommendations:

(1) Because sedimentation and runoff from the clearing and the road have the potential to impact water quality in the stream, we recommend that no further expansion of the existing camp take place, and that vehicular traffic across the stream be reduced to an absolute minimum.

(2) The immediate initiation of a water-quality monitoring project in conjunction with herpetofaunal surveys. We suggest twice yearly surveys of the stream-associated herpetofauna at Nassau using fixed monitoring points established throughout the watershed. Species may be located visually and/or acoustically, but we recommend the utilization of a visual method (i.e., VES) in order to estimate population density as accurately as possible. Because interspecific variation in detection probabilities may compromise results (Mackenzie and Royle 2005), it will be necessary to incorporate methods that will allow for robust density estimation (discussed in Schmidt 2004). Concomittant with the faunal surveys, we recommend the collection of basic water quality data (dissolved oxygen, conductance, temperature, pH, and turbidity) at the beginning of each transect or monitoring point.

(3) An ongoing monitoring project to detect the presence of *Batrachochytrium dendrobatidis* in adult frogs along forest streams. *Batrachochytrium dendrobatidis* is a chytrid fungus that has been linked to amphibian declines in many parts of the Neotropics (Lips et al. 2005), and although we are not aware of reports of amphibian declines from the Guianas, conditions favorable for the occurrence of *B. dendrobatidis* are predicted to occur in the vicinity of Nassau and Lely mountains (Ron 2005). The presence of *B. dendrobatidis* can be detected via analysis of dermal swabs from live animals. We recommend collecting 300 swabs/visit (i.e., one swab per individual from the first 300 individuals encountered). To detect the presence of *B. dendobatidis*, analysis may be conducted on pooled samples of 10 swabs. If the fungus is detected, individual analysis of all swabs will be necessary to identify infected species. Should *B. dendrobatidis* be detected, the Declining Amphibian Population Task Force (http://www.open.ac.uk/daptf/index.htm) may be contacted for recommended action.

(4) We recommended expanded surveys of streams on the two mountains and in adjacent lowlands in order to more accurately quantify abundance and extent of occurrence of stream-associated frogs, particularly new species whose distributions are unknown. Determining the IUCN red list status of these five species will hinge on estimating the geographic range of these species, so a special effort should be made to determine their extent of occurrence.

(5) It is difficult to provide meaningful guidelines for the area required to effectively protect amphibian populations because the availability of breeding habitat is probably more important than area per se (Zimmerman and Bierregaard 1986). Reptiles, on the other hand, probably benefit more from larger areas, though relative to endothermic vertebrates their energetic needs (and therefore area required to sustain populations; Pough 1980) are low. It has been suggested that the 1500 ha of the La Selva reserve in Costa Rica is sufficient to protect the herpetofauna at that site (Guyer 1994), although population declines of both amphibians and reptiles have occurred there (S. Whitfield pers. com.). We therefore regard 1500 ha as the 'minimum critical area' necessary to protect a reasonably intact sample of the local herpetofauna, and suggest that at least this amount be preserved within the concessions at Lely and Nassau. Additionally, because we have identified streams as keystone habitat whose importance is disproportionate to their area, we recommend a forest buffer of at least 50 m (Lee et al. 2004) on both sides of all creeks running through the concessions.

Authors' note: As this chapter was going to press, we became aware of a record of the toad *Atelopus* cf. *spumarius* from the forest near the basecamp at Nassau. *Atelopus spumarius* is a polymorphic taxon, and it is possible that more than one species is included under the name (some authors recognize the Guayana Shield taxon to be a distinct species, *A. hoogmoedi*). Although *A. spumarius* (as either *A. spumarius* sensu stricto or *A. hoogmoedi*) has a larger geographic range than many species of *Atelopus,* these toads have experienced precipitous population declines in much of Latin America, most likely due to infection by *B. dendrobatidis*, and *A. spumarius* senso lato is classified as vulnerable by the IUCN. A population of *Atelopus* at Nassau would therefore be of significant conservation concern. We recommend that efforts to establish the extent of occurrence of the new taxa encountered during our surveys include *A.* cf. *spumarius*.

REFERENCES

Ávila Pires, T. C. S. 2005. Reptiles. *In*: Hollowell, T. and R. P. Reynolds (eds.). Checklist of the terrestrial vertebrates of the Guiana Shield. Bulletin of the Biological Society of Washington. USA. Number 13. Pp. 25-40

Beebee, T. J. C. and R. A. Griffiths. 2005. The amphibian decline crisis: a watershed for conservation biology? Biological Conservation. 125:271-285.

Born, M. and P. Gaucher. 2001. Amphibian and reptile species at the Nouragues Nature Reserve. *In*: Bongers, F., P. Charles-Dominique, P-M. Forget, and M. Théry (eds.). Nouragues. Dynamics and plant-animal interactions in a neotropical rainforest. Kluwer Academic Publishers. Pp. 371-381

Cadle, J., J. Icochea, J. P. Zúniga, A. Portilla, and C. Rivera. 2002. La herpetofauna encontrada en el Refugio Juliaca y en el Puesto de vigilancia Enahuipa del Santuario Nacional Pampas del Heath. *In*: J. R. Montambault (ed.). Informes de las evaluaciones biológicas Pampas del Heath, Perú Alto Madidi, Bolivia y Pando, Bolivia. RAP Working Papers Number 24. Washington, D.C.: Conservation International. Pp. 52 – 57

Ceñaris, J. C. and R. MacCulloch. 2005. Amphibians. *In*: Hollowell, T. and R. P. Reynolds (eds.). Checklist of the terrestrial vertebrates of the Guiana Shield. Bulletin of the Biological Society of Washington, USA. Number 13. Pp. 9-23

Clarke, K. R. and Warwick, R. M. 2001. Change in marine communities: an approach to statistical analysis and interpretation. Second edition. PRIMER-E. Plymouth, U.K.

Colwell, R. K. 1999. EstimateS version 5.0.1. Statistical Estimation of species richness and shared species from samples. Web site: viceroy.eeb.uconn.edu/estimates.

Colwell, R. K. and J. A. Coddington. 1994. Estimating terrestrial biodiversity through extrapolation. Philosophical Transactions of the Royal Society of London B. 345:101-118.

Crump. M. L. and N. J. Scott, Jr. 1994. Visual Encounter Surveys. *In*: Heyer, W.R., M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster (eds.). Measuring and Monitoring Biological Diversity Standard Methods for Amphibians. Washington D.C.: Smithsonian Institution Press. Pp. 84-91

Doan, T. M. and W. A. Arriaga. 2002. Microgeographic variation in species composition of the herpetofaunal communities of Tambopata region, Peru. Biotropica. 34:101-117.

Donnelly, M. A., M. H. Chen, and G. G.Watkins. 2004. Sampling amphibians and reptiles in the Iwokrama Forest ecosystem. Proceedings of the Academy of Natural Sciences of Philadelphia. 154:55-69.

Donnelly, M. A., M. H. Chen, and G. G. Watkins. 2005. The Iwokrama herpetofauna: an exploration of diversity in a Guayanan rainforest. *In*: Donnelly, M. A., B. I. Crother, C. Guyer, M. H. Wake, and M. E. White (eds.). Ecology and Evolution in the Tropics. Chicago, Illinois: The University of Chicago Press. Pp. 428-460

Duellman, W. E. 1978. The biology of an equatorial herpetofauna in Amazonian Ecuador. University of Kansas Museum of Natural History Miscellaneous Publication. 65:1-352.

Duellman, W. E. 1997. Amphibians of La Escalera region, southeastern Venezuela: taxonomy, ecology, and biogeography. Scientific Papers. Natural History Museum. The University of Kansas. 2:1-52.

Duellman, W. E. and J. R. Mendelson III. 1995. Amphibians and reptiles from northern Departamento Loreto, Peru: taxonomy and biogeography. The University of Kansas Science Bulletin. 55:329-376.

Duellman, W. E. and R. Thomas. 1996. Anuran amphibians from a seasonally dry forest in southeastern Peru and comparisons of the anurans among sites in the upper Amazon basin. Occasional Papers of the Natural History Museum. The University of Kansas. 180:1-34.

Etienne, R. S. and H. Olff. 2004. How dispersal limitation shapes species-body size distributions in local communities. The American Naturalist. 163:69-83.

Funk, W. C., A. E. Greene, P. S. Corn, and F. W. Allendorf. 2005. High dispersal rates in a frog species suggests that it is vulnerable to habitat fragmentation. Biology Letters. 1:13-16.

Guyer, C. 1994. The reptile fauna: diversity and ecology. *In*: McDade, L. A., K. S. Bawa, H. A. Hespenheide, and G. S. Hartshorn (eds.). La Selva. Chicago, Illinois: University of Chicago Press. Pp. 210-216

Hellmann, J. J. and G. W. Fowler. 1999. Bias, precision, and accuracy of four measures of species richness. Ecological Applications. 9:824-834.

Herzog, S. K., M. Kessler, and T. M. Cahill. 2002. Estimating species richness of tropical bird communities from rapid assessment data. The Auk. 119:749-769.

Lee, P., C. Smyth, and S. Boutin. 2004. Quantitative review of riparian buffer width guidelines from Canada and the United States. Journal of Environmental Management. 70:165-180.

Lips, K. R. 1998. Decline of a tropical montane amphibian fauna. Conservation Biology. 12:106-117.

Lips, K. R. 1999. Mass mortality and population declines of anurans at an upland site in western Panama. Conservation Biology. 13:117-125.

Lips, K. R., J. D. Reeve, and L. R. Witters. 2003. Ecological traits predicting amphibian population declines in Central America. Conservation Biology. 17:1078-1088.

Lips, K. R., P. A. Burrowes, J. R. Mendelson III, and G. Parra-Olea. 2005. Amphibian population declines in Latin America: a synthesis. Biotropica. 37:222-226.

Mackenzie, D. I. and J. A. Royle. 2005. Designing occupancy studies: general advice and allocating survey effort. Journal of Applied Ecology. 42:1105-1114.

Morales, V. R. and R. W. McDiarmid. 1996. Annotated checklist of the amphibians and reptiles of Pakitza, Manu national park Reserve Zone, with comments on the herpetofauna of Madre de Dios, Perú. *In*: Wilson, D. E. and A. Sandoval (eds.). Manu. Washington, D. C.: Smithsonian Institution Press. Pp. 503-522

Moravec, J. and J. Aparicio. 2005. Notes on the herpetofauna of Bioceanica and Bolpebra (Provincia Nicolas Suaréz, Departamento Pando, Bolivia). Journal by the National Museum. Natural History Series. 174:95-113.

Parmelee, J. R. 1999. Trophic ecology of a tropical anuran assemblage. Scientific Papers. Natural History Museum. The University of Kansas. 11:1-59.

Pough, F. H. 1980. The advantage of ectothermy for tetrapods. American Naturalist. 115: 92-112.

Ron, S. R. 2005. Predicting the distribution of the amphibian pathogen *Batrachochytrium dendrobatidis* in the New World. Biotropica. 37:209-221.

Schmidt, B. R. 2004. Declining amphibian populations: the pitfalls of count data in the study of diversity, distributions, dynamics, and demography. Herpetological Journal. 14:167-174.

Smith, M. A. and D. M. Green. 2005. Dispersal and the metapopulation paradigm in amphibian ecology and conservation: are all amphibian populations metapopulations? Ecography. 28:110-128.

Steinitz, O., J. Heller, A. Tsoar, D. Rotem, and R. Kadmon. 2005. Predicting regional patterns of similarity in species composition for conservation planning. Conservation Biology. 19:1978-1988.

Stuart, S. N., J. S. Chanson, N. A. Cox, B. E. Young, A. S. L. Rodrigues, D. L. Fischman, and R. W. Waller. 2004. Status and trends of amphibian declines and extinctions worldwide. Science. 306:1783-1786.

Tews, J., U. Brose, V. Grimm, K. Tielbörger, M. C. Wichmann, M. Schwager, and F. Jeltsch. 2004. Amphibian species diversity driven by habitat heterogeneity/diversity: the importance of keystone structures. Journal of Biogeography. 31:79-92.

Young, B. E. et al. 2001. Population declines and priorities for amphibian conservation in Latin America. Conservation Biology. 15:1213-1223.

Zimmerman, B. L. and Bierregaard, R. O. 1986. Relevance of the equilibrium theory of island biogeography and

Appendix 16

List of Reptiles and Amphibians recorded on the Nassau and Lely plateaus.

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Data include habitat use, Distribution (W=Widespread Amazonian, GS=Guayana Shield), and IUCN Threat Status (LC = least concern, NE = not evaluated). 'X' indicates presence of species not observed by the authors.

	Site		Distribution	IUCN Threat Status
Taxon	**Nassau**	**Lely**		
ANURA				
Bufonidae				
Bufo guttatus	Clearing		W	LC
B. margaritifer	Forest Stream, Forest	Forest, Forest Stream	W	LC
B. marinus	Forest, Clearing	Clearing, Savannah Forest	W	LC
Dendrobatidae				
Colostethus beebei		Forest, Forest Stream	GS	LC
C. degranvillei	Forest Stream, Forest, Swamp	Forest Stream, Forest	GS	LC
Colostethus cf. *brunneus*	Forest Stream, Swamp		W	LC
*Allobates femoralis***		X	W	LC
Epipedobates trivittatus	Forest, Savannah Forest	X	W	LC
HYLIDAE				
Hypsiboas boans	Forest Stream, Forest		W	LC
Hypsiboas crepitans	Forest Stream			
Dendropsophus marmorata	Clearing		W	LC
Dendropsophus minuta		Forest	W	LC
Osteocephalus taurinus	Forest	Forest	W	LC
*Phyllomedusa hypochondrialis***		X	W	LC
Scinax proboscideus **		X	GS	LC
LEPTODACTYLIDAE				
Adenomera cf. *andreae*	Forest Stream, Forest	Forest		
Adenomera sp.		Forest Clearing, Forest, Forest Stream		
Eleutherodactylus chiastonotus	Forest Stream, Forest		GS	LC
Eleutherodactylus cf *inguinalis*		Forest Stream		
*Eleutherodactylus marmoratus***		X	GS	LC
Eleutherodactylus zeuctotylus		Forest Stream	GS	LC

	Site		Distribution	IUCN Threat Status
Taxon	**Nassau**	**Lely**		
Eleutherodactylus sp. 1	Forest Stream	Forest, Forest Stream		
Eleutherodactylus sp. 2		Forest		
Eleutherodactylus sp. 3		Forest		
Eleutherodactylus sp. 4		Forest		
Leptodactylus knudseni		Clearing	W	LC
Leptodactylus leptodactyloides		Forest Stream, Forest Clearing	W	LC
Leptodactylus longirostris		Clearing	W	LC
Leptodactylus mystaceus	Forest	Forest, Forest Clearing	W	LC
Leptodactylus pentadactylus	Swamp Forest, Forest Stream, Clearing	Forest Stream, Forest	W	LC
*Leptodactylus stenodema***		X	W	LC
MICROHYLIDAE				
Chiasmocleis shudikarensis	Forest	Forest	GS	LC
SQUAMATA—SAURIA				
Gekkonidae				
Gonatodes annularis		Forest	GS	LC
Gonatodes humeralis		Clearing	W	LC
GYMNOPHTHALMIDAE				
Arthrosaura kockii	Forest, Forest Stream		W	LC
Iphisa elegans	Forest, Savannah Forest		W	LC
Lepsoma guianense		Forest Stream, Forest	GS	LC
Neusticurus rudis	Forest Stream, Swamp Forest	Forest Stream	GS	LC
Cecrosaura cf. *ocellata*	Forest Stream		W	LC
POLYCHROTIDAE				
Noprops chrysolepis	Forest	Forest, Forest Stream		LC
Noprops fuscoauratus	Clearing		W	LC
Scincidae				
Mabuya nigropunctata	Forest	Clearing	W	LC
TEIIDAE				
Ameiva ameiva	Clearing	Clearing	W	LC
Kentropyx calcarata	Clearing	Clearing, Forest Stream, Forest	W	LC
Tupinambis teguixin		Clearing	W	LC
TROPIDURIDAE				
Tropidurus plica		Forest, Forest Stream	W	LC
Squamata--Sepentes				
COLUBRIDAE				
Chironius sp.	Forest			
Dipsas catsebyi	Forest	Forest	W	LC
Dipsas indica		Forest Stream	W	LC
Imantodes sp. *		X		

	Site		Distribution	IUCN Threat Status
Taxon	**Nassau**	**Lely**		
Liophis sp.	Forest			
Oxyrhopus formosus		Forest	W	LC
VIPERIDAE				
Bothrops atrox	Forest	Forest	W	LC
Bothriopsis bilineatus		Forest	W	LC
CROCODYLIA				
Alligatoridae				
Paleosuchus cf. *trigonatus*	?	Forest Stream	W	LC
CHELONIA				
Bataguridae				
*Rhinoclemys punctularia**	X		W	NE
CHELIDAE				
*Platemys platycephalus**		X	W	NE
Total # species	**32**	**45**		
Total recorded by RAP herpetology team	**29**	**37**		
# amphibians/reptiles recorded by RAP herpetology team	**16/13**	**21/16**		

* species recorded by other members of RAP team
** species recorded from Lely by C. Myers, August 1975