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Natural and Cultural History of the Golfo Dulce Region, Costa Rica

Anton Weissenhofer, Werner Huber,
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Gerhard Aubrecht (scientific editors)

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Historia natural y cultural de la región del Golfo Dulce, Costa Rica

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Anton Weber, Gerhard Aubrecht (scientific editors)

BMWF
lebensministerium.at
Fakultät für Lebenswissenschaften
OMV
universität wien
Tropenstation La Gamba, Costa Rica

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Due to the orographic formation of its interior and its humid climate, the Golfo Dulce Region is rich with biodiversity, containing very dense flora and fauna. After HOLDRIDGE (1971), the region was subdivided into different zones, including the tropical rainforest, the tropical wetland forest, and tropical premontane rainforest. The biogeographical situation in this area shows many similarities to the flora and fauna in the Amazon and the Colombian Chocó Region and serves as a land bridge with a valuable genetic base between North and South America. After unregulated seizure of land by agricultural settlers, lumberjacks, and large landowners in the 1940s and 1950s, regulated, state-subsidised settlement reform intended to support agricultural exports in the 1960s, and intensification of the livestock industry in the 1970s, primary and secondary forest reserves have shrunk to a minimum. The constant expansion of monocultures on new land has far-reaching consequences for the local ecosystem.

The conservation and sustainable use of tropical forests is established in the Forest Declaration, Convention on Climate Protection, and Convention on the Protection of Species, which demonstrate worldwide concern for these issues. As a regional example, in the 4,304.80 km^2 drainage basin, the ACOSA (Área de Conservación OSA), which covers an area spanning the Cantons Osa, Golfito und Corredores, aims to protect species diversity within the 17 game preserves, which are 44.7% covered by forest, through integration and an alliance with the Parques Nacionales, Vida Silvestres y Forestales (Fig. 2). The main sector of the Corcovado National Park on the Osa Peninsula covers 424 km^2 and the Piedras Blancas National Park covers 148 km^2. The altitude ranges from sea level to 745 m on the Osa Peninsula (Cerro Rincón and Cerro Mueller in the Fila Matajambre) and to 579 m in the Esquinas forest (Cerro Nicuesa). The Golfo Dulce Forest Reserve (592 km^2) was established between the two parks, thereby forming a natural forest corridor.

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Addresses of authors:

Anton WEISSENHOFER
Werner HUBER
Department of Palynology and Structural Botany
Faculty Center of Botany
University of Vienna
Rennweg 14
A-1030 Vienna, Austria
E-mail: anton.weissenhofer@univie.ac.at
werner.huber@univie.ac.at

Michael KLINGLER
Workgroup Development Studies
and Sustainability Science
Institute of Geography
University of Innsbruck
Innrain 52
A-6020 Innsbruck, Austria
E-mail: michael.klingler@uibk.ac.at

Mammals of the Piedras Blancas National Park, Costa Rica: species composition, habitat associations and efficiency of research methods – a preliminary overview

Mamíferos del Parque Nacional Piedras Blancas, Costa Rica: composición de especies, asociaciones de hábitat y eficiencia de métodos de investigación – una panorámica preliminar

Armin Landmann, Christoph Walder, Anton Vorauer & Timm Emser

Abstract: This paper summarises the current knowledge about non-flying mammals and research activities so far dedicated to this group in the area of the Piedras Blancas National Park, SW Costa Rica. A first commented species list of the small national park area (< 150 km²) comprises 52 species from 21 families, excluding bats. The majority of mammals found at Piedras Blancas National Park are widespread species typical of neo-tropical rainforests or of disturbed semi-open landscapes at Costa Rican lowlands. However, the local fauna still harbours a diverse mammalian community and carnivores in particular are still well represented (14 species), including some endangered species which show high vulnerability to human impact, like the River Otter, the Jaguar, the Ocelot or the Margay. The paper also includes an overview of the accuracy and effectiveness of methods that have been applied for collecting data about mammals in the area, and a comparison of species diversity in the main habitats (primary rainforest, secondary forest, cultivated landscapes).

Key words: Costa Rica, mammalian diversity, tropical lowland rainforest, rodents, carnivores, effectiveness of sampling methods.

Resumen: Este trabajo recoge el conocimiento actual sobre los mamíferos no-voladores y actividades de investigación hasta ahora dedicadas por este grupo en el área del Parque Nacional Piedras Blancas, Sudoeste de Costa Rica. Una primera lista comentada del área reducida del parque nacional (< 150 km²) contiene 52 especies de 21 familias, que no son murciélagos. La mayoría de los mamíferos encontrados en el Parque Nacional Piedras Blancas son especies de amplia distribución en bosque lluvioso neotropical o en paisajes perturbados semiabiertos en las bajuras de Costa Rica. Sin embargo, la fauna local alberga no obstante una comunidad diversa de mamíferos y especialmente de carnívoros, que están exquisitamente representados (14 especies), incluyendo algunas especies amenazadas, altamente vulnerables a impacto antropogénico, como la nutria, el jaguar, el ocelote y el margay. El trabajo también incluye una síntesis sobre la precisión y eficiencia de métodos que han sido utilizados para colectar datos sobre mamíferos en el área, y una comparación de la diversidad de especies en sus hábitats principales (bosque lluvioso primario, bosque secundario, paisajes cultivados).

Palabras clave: Costa Rica, diversidad de mamiferos, bosque lluvioso en las tierras bajas, roedores, carnívoros, eficiencia de métodos para colectar datos sobre mamíferos.

Introduction

General patterns of biodiversity among major rainforest regions of the globe and even small scale regional differences in diversity are well known for mega-diversity groups like beetles or butterflies or for conspicuous vertebrates such as frogs or birds. In contrast, the dimensions, patterns and causes of mammal diversity variation are much less well understood (Ginsberg 2001, Voss & Emmons 1996).

With more than 200 species of mammals, Costa Rica has the second highest species richness of any country in Central America, after Panama (World Conservation Monitoring Centre 1992). However, species diversity and population sizes are likely to show strong regional variation within the country and even species lists for well-studied sites are incomplete and taxonomically biased because of inadequate sampling. In La Selva, Costa Rica, for example, the mammal list comprises

Stapfia **88**, zugleich Kataloge der oberösterreichischen Landesmuseen Neue Serie **80** (2008): 409-422

116 species but at least 20 additional species are expected to occur there based on the general geographical distributions of species (TIMM 1994, ADLER 2001).

Due to the exceptional diversity of bats in the tropics, mammalogical work in the neotropics including Costa Rica has so far focused mostly on that group (see LANDMANN et al. 2008, this book), and (to a lesser extent) on some monkeys and a few larger herbivores and carnivores (for literature collection for Costa Rican mammals, see http://www.inbio.ac.cr/en/default.html).

Thus, our knowledge about mammals in the neotropics is still limited. This is especially true for small and medium-sized nocturnal species like opossums, shrews, most rodents and small carnivores. For most species of these groups, we lack not only detailed knowledge about their biology and life history traits, we even have no understanding of their basic habitat requirements and distribution patterns. Given this background, data about general habitat requirements, local species richness and regional distribution patterns are urgently needed to evaluate and monitor the results of rapid changes in natural and environmental conditions for the neotropical mammal fauna.

In addition to our more detailed overview about the bat communities of the Esquinas forest (LANDMANN et al. 2008, this book) we therefore focus in this paper on less conspicuous smaller mammals in a region that might well be one of the hotspots of mammalian diversity in Central America (JANZEN & WILSON 1983, REID 1997, WAINWRIGHT 2002). Since almost nothing has been published about the mammal fauna of the "Regenwald der Österreicher" ("Rainforest of the Austrians"), our goals here are restricted and results will be kept at a merely descriptive level. In this first overview, we use field data sampled and additional information gathered from local experts in the course of our pilot project: "Mammals of the Costa Rican Rainforest of the Austrians" (LANDMANN et al. 2003).

Our main goals are:

a) the foundation of a basis for further and more detailed mammal studies in the national park area, by:
(1) presenting a preliminary species list of the (non-bat) mammal fauna of the Piedras Blancas NP, including information about relative species abundances and local habitat associations, and
(2) evaluating the effectiveness and practicability of different methods of recording mammals in tropical lowland habitats.
b) supporting efforts for more effective protection and management of the "Regenwald der Österreicher" in the future. As mammals attract more attention from the broader public than most other organisms, they are a perfect vehicle for arousing interest in the conservation of rainforests, and deepening the knowledge of the local mammal fauna should be valuable in fostering sustainable ecotourism in the region.

Materials and Methods

Investigation area and study sites

Our own systematic field data collection mainly took place in an area of approximately 6 km^2 within a diameter of 2 km around the La Gamba Biological Field Station (8°42´N, 83°12´W) at the eastern edge of the Piedras Blancas National Park. Details about the climate, landscape and vegetation of the area are given in WEISSENHOFER & HUBER 2001, WEISSENHOFER et al. 2001, and in other chapters of this book. Data were mainly sampled in the same locations and sites as described in detail in LANDMANN et al. 2008 (this book). Additional data stem from other scattered locations within the national park (mainly coastal forests near San Josecito). Data from local experts refer to the entire national park area (148 km^2).

Mammal Sampling

To collect data and to identify mammals in the field a combination of methods has been applied, following the recommendations of WILSON et al. 1996 and by the ANIMAL CARE AND USE COMMITTEE (1998).

Specific data sampling took place mostly in the dry season from the 12th of January until the 11th of April 2004. Data were sampled by three of us (AL, AV, CW) from January until mid-February, and from there on until mid-April under the surveillance of CW with the aid of TE. Additional data were collected by CW with the aid of local helpers until the end of June 2004. Each of the following methods was applied over at least two weeks of the entire investigation period.

Snap traps

We used older, "worn out" units (without odour) of two sizes of snap traps (Fig. 1a, b) for small (mice-size) and larger target species (e.g. opossum, rats). Snap traps were set between January 12 and January 30 in a standardised manner at six 1 ha study sites in three different main habitats (primary forest, secondary forest, cultivated land near the edge of the NP). Within each study site nine trapping stations, each consisting of four small and five rat-sized traps, were selected. The centres of each trapping station were at least 30 m apart and distances between traps were 10 m. Most traps were set on the forest floor – e.g. Fig. 1b) but (where possible) at each trapping station one rat-sized trap was located higher up (mostly from 1.5 to 2 m) on trees (on inclined trunks or strong branches; see Fig. 1a). Traps were baited with a

Fig. 1: Methods applied for sampling data about mammals of the Piedras Blancas National Park. From upper left to bottom right: (**a**) arboreal rat-sized snap-trap; (**b**) mouse-sized bottom-trap impaired by earth mounds of ants; (**c**) bucket-trap in an abandoned cocoa plantation; (**d**) cam-tracker installed at a game pass near the forest edge; (**e**) track identification lessons with local experts (J. Angel, V. Garcia with CW) at a scent station; (**f**) visual search for mammals often turns out to be a neck-stretching and frustrating exercise in rainforest habitats (AL & CW); (**g**) self-constructed trapdoor-cage; (**h**) juvenile *Philander opossum* released from such a cage trap. Photos: AV (a-b, e-f); AL (c-d); TE (g-h).

Fig. 2: A selection of mammals "captured" with sampling methods shown in Fig. 1. From upper left to bottom right: (**a**) *Sigmodon hispidus* (live-capture – La Gamba); (**b**) *Dasyprocta punctata* ("caught" by a cam-tracker in primary forest; (**c**) *Procyon lotor* – track; (**d**) *Tamandua mexicana* spotted on *Virola* spp., Myrsiticaceae (primary ridge forest); (**e**) *Nyctomis sumichrasti* (snap-trapped in secondary forest, (**f**) *Leopardus pardalis* (cage-trapped in primary forest). Photos: AV: (a, c. e), TE (f) and P. Weish (3d).

peanut butter and banana mash and were checked twice a day (before sunset and after sunrise). Each trap station was operated for four consecutive days (and nights). Snap-trapping was repeated at each of the same six study sites and at exactly the same trapping stations in a second 4-day period from February 16 to March 5. However, in order to sample more arboreal species only one third of the traps were set on the ground this time, with the rest (mostly rat-sized traps) mounted on bamboo rods (attached to trees) at a height of two to six metres. An additional 15 to 20 traps were also set in a line along the Quebrada Negra (creek, forested area) behind the Biological Field Station from January 22 until February 9 2004 (7.100 trap hours). All together the snap-trap effort amounts to 96.700 trap hours and 64 trapping days/nights. Alcohol-preserved samples of reference specimens are archived in the "Biologiezentrum der Oberösterreichischen Landesmuseen", Linz (Table 3).

Live traps

were used to a lesser extent as additional method. Two techniques were used for small and medium-sized mammals respectively:

(1) Pit-fall traps (buckets measuring 25 cm in diameter at the rim and in depth – see Fig. 1c) were dug flush with the ground in two secondary habitats near the field station (within an abandoned cocoa plantation and at a shrub-covered cattle pasture near a forest edge). Three such unbaited pitfalls at each site were opened for 14 days (January 22-February 5 2004) and inspected twice a day, giving a total of about 1.000 bucket hours.

(2) Up to 27 self constructed cage traps of different types (tilting traps, trapdoor traps – see Fig. 1g, 2f) and sizes (from small: 50 × 20 × 20 cm to large: 150 cm, cubic) were operated over 21 days from May 28 to June 20, giving a total of about 11.500 cage trap hours.

These traps were baited with a mixture of chicken meat and egg-mash or with a peanut butter and meat mash. Traps were set at two transects in gallery and secondary forest along the Quebrada Negra from May 28 to June 2, and from June 4 to June 20 along a 600 m-long transect leading from semi-open shrubbery at the edge of a cattle pasture through secondary forest into the primary forest about 0.5 km to the north-west of the La Gamba Biological field station.

Camera Trapping

We used this method from February 16 to March 14 2004 at our six main study sites (three in primary forest, and three at disturbed sites) within and at the edge of the national park area around the field station. Two camtrackers (passive infrared system TM55 with camera-kits TM-35) per study site were placed at locations where we expected trespassing of mammals, i.e. near forest rivers and small forest trails; see Fig. 1d). Up to six cameras were operated simultaneously. Altogether cameras were operated for 155 days (approx. 3.700 camera hours).

Track-traps

A systematic track-trapping program around the La Gamba area, lasting from March 15 to April 11 2004 (conducted by CW and TE) was preceded by a two-week test phase (January 22 to February 6) with two scent stations (e.g. Fig. 1e). These two stations were located along the pit-fall traps at forest edges near the biological station (see above). From mid-March onwards, 30 standardised scent stations at 10 sites were opened, and track sampling took place there every morning. These ten sites were arranged along two about 1.5 km-wide transects from primary forests of the Piedras Blancas National Park across the open (cultivated) valley of the Río Gamba to secondary forest edges (outside the national park) near the valley floor in the foothills of the Fila Gamba (see LANDMANN et al. 2008 for detailed descriptions and a map of the study sites). At each site, three baited track stations (1.6 × 1.6 m; distances from one another: 20-50 m) were set up. Trap surfaces were cleared of leaves and debris, and the ground was raked and watered to take clear animal footprints (see Figs. 1e, 2c). All tracks were identified to species during the morning using the field guide of REID (1997).

Observations and interviews

Our trap data can be complemented with information from three different sources: (1) our own visual day observations (Fig. 1f, 2d) mainly in the course of setting, checking and picking up traps and during bat netting at dawn and in the night, (2) observations (erratic data) from biologists who have visited or worked in the national park area (partly for many years), and (3) systematic interviews conducted with local experts with long experience and good knowledge of the Esquinas forest and its mammals (local hunters, nature guides and park game wardens).

Results and Discussion

Species composition and diversity

Thirty-four non-bat mammal species belonging to eight orders and 21 families were recorded directly by our own sampling (including visual observations) in the Piedras Blancas National Park area from January to June 2004. For three additional species (*Sciurus variegates*, *Galictis vittata*, *Mustela frenata*) we have only (slightly insecure) track records and for an other species (Silky Anteater) there are recent reliable sightings from other scientists working in the national park area. The actual

Table 1: Preliminary list of the mammals of the Piedras Blancas National Park – SW Costa Rica, with special reference to the La Gamba region[1]. Bats excluded (see list in LANDMANN et al. 2008, this volume)

Species (order / family)	English name	Occurrence stated by local experts	Occurrence proved by scientists	Occurrence in the La Gamba area
DIDELPHIMORPHIA				
Didelphidae	**American Opossums**			
Caluromys derbianus	Central American wooly opossum	+		+
Chironectes minimus	Water opossum	+		+
Philander opossum	Grey Four-eyed opossum	+	*	*
Didelphis marsupialis	Common opossum	+		
Marmosa mexicana	Mexican mouse opossum	+	*	*
XENARTHRA				
Myrmecophagidae	**Anteaters**			
Cyclopes didactylus	Silky anteater	+	*	*
Myrmecophaga tridactyla	Giant anteater	+ (extinct)		
Tamandua mexicana	Northern tamandua	+	*	*
Megalonychidae	**Sloths**			
Bradypus variegatus	Three-toed sloth	+	*	*
Choloepus hoffmanni	Two-toed sloth	+		
Dasypodiadae	**Amardillos**			
Dasypus novemcinctus	Nine-banded amardillo	+	*	*
Cabassous centralis	Northern naked-tailed amardillo	+	*	+
PRIMATES				
Cebidae	**New World Monkeys**			
Alouatta palliata	Mantled howler	+	*	*
Ateles geoffroyi	Central American spider monkey	+		
Cebus capucinos	White-faced capuchin	+	*	*
Saimiri oerstedii	Red-backed squirrel monkey	+	*	*
RODENTIA				
Sciuridae	**Squirrels**			
Sciurus granatenis	Red-tailed squirrel	+	*	*
Sciurus variegatoides	Variegated squirrel		*?	*?
Microsciurus alfari	Alfaro's pygmy squirrel	+	*	*
Geomyidae	**Pocket Gophers**			
Orthogeomys underwoodi	Underwoods pocket gopher	+		+
Heteromyidae	**Pocket Mice**			
Heteromys desmarestianus	Forest spiny pocket mouse		*	*
Muridae	**Rats and Mice**			
Nyctomys sumichrasti	Vesper rat		*	*
Rattus rattus	Roof rat	+	*	*
Oligoryzomys fulvescens	Northern pygmy rice rat		*	*
Sigmodon hispidus	Hispid cotton rat		*	*
Tylomis watsoni	Watson's climbing rat	+		+
Zygodontomys brevicauda	Common cane rat		*	*
Echimyidae	**Spiny Rats**			
Hoplomys gymnurus	Armoured rat		*	*
Proechimys semispinosus	Tome's spiny rat		*	*
Erethizontidae	**New World Porcupines**			
Coendou mexicanus	Mexican porcupine	+		
Dasyproctidae	**Agoutis**			
Dasyprocta punctata	Agouti	+	*	*
Agoutidae	**Pacas**			
Agouti paca	Paca	+	*	*
INSECTIVORA				
Soricidae	**Shrews**			
Sorex saussurei	Saussure's shrew	+		

Table 1 continued.

Species (order / family)	English name	Occurrence stated by local experts	Occurrence proved by scientists	Occurrence in the La Gamba area
LAGOMORPHA				
Leporidae	**Hares and Rabbits**			
Sylvilagus brasiliensis	Forest rabbit	+		+
CARNIVORA				
Procyonidae	**Racoons & allies**			
Bassaricyon gabbii	Olingo	+		+
Potos flavus	Kinkajou	+	*	*
Nasua narica	White-nosed coati	+	*	*
Procyon cancrivorus	Crab-eating raccoon	+	*	*
Procyon lotor	Northern raccoon	+	*	*
Mustelide	**Weasels, Skunks & allies**			
Conepatus semistriatus	Striped hog-nosed skunk	+	*	*
Eira barbara	Tayra	+	*	*
Galictis vittata	Greater grison	+	*?	+,*?
Lutra longicaudis	Northern river otter	+		+
Mustela frenata	Long-tailed weasel		*?	*?
Felidae	**Cats**			
Herpailurus yaguarondi	Jaguarundi	+	*	*
Leopardus pardalis	Ocelot	+	*	*
Leopardus wiedii	Margay	+	*	*
Pantherea onca	Jaguar	+		
ARTIODACTYLA				
Tayassuidae	**Peccaries**			
Dicotyles pecari	White-lipped peccary	+	*	
Tayassu tajacu	Collared peccary	+	*	*
Cervidae	**Deer**			
Mazama americana	Red brocket deer	+	*	*
CETACEA				
Delphinidae	**Dolphins**			
Tursiops truncates	Bottlenose dolphin	+	*	
Numbers of species				
9 orders, 21 families, 52 species	43	35-38	40-43	

1 La Gamba region = vicinity of the field station and of the Esquinas Rainforest Lodge and surrounding primary and secondary forest areas (Piedras Blancas National Park, private forests). Data from open to semi-open cultural landscapes and riverain habitats adjoining the La Gamba village and valley (including settlements, Rio Bonito valley) are included.
+ Local experts: = statements of experienced local hunters, nature guides and park game wardens (mainly J. Angel, A. Z. Alvarez, V. Garcia).
* scientists: mainly data from own investigations from January until June 2004, complemented with observations of various researchers and guests of the biological station (W. Huber, U. Karpfen, P. Weish and others.)

occurrence of 14 further species has been stated by local experts (mostly visual observations within the last 10 years or so) – see Tables 1 and 3. This means that in addition to the 49 bat species (see LANDMANN et al. 2008, this book) and at least one marine species (records of Bottlenose Dolphins at the mouth of the Esquinas river), there are about 50 different terrestrial mammals living in (or near) the Piedras Blancas National Park, boosting the total local mammal list to 100 species.

According to the game warden A. Z. Alvarez, the Giant Anteater *Myrmecophaga tridactyla* lived in the national park area until about 20 years ago, but is likely to be extinct now.

Although identification of some species is still somewhat insecure (Table 3, see below), with about 45 to 50 (and in fact may be well over 50) species of terrestrial to arboreal mammals, the Piedras Blancas National Park area certainly can be regarded as species rich. This statement even holds when the diversity of the area is compared to conservation areas of larger size and/or a much longer history of mammalian data collection, like La Selva, or the Las Cruces forest reserve and its surroundings to the east of the Golfo Dulce region (cf. Table 2). When comparing the data presented in Table 2, it should be kept in mind that Piedras Blancas National Park only covers a small area and that in addi-

Table 2: Comparison of the extant terrestrial mammalian faunal diversity between Costa Rica and Costa Rica lowland rainforests in total, the well known rainforest La Selva (E – Costa Rica), a mixed agricultural and premontane forest-landscape around the Valle de Coto Brus (SW Costa Rica near to Golfito), the entire Osa Region (including Corcovado National Park, Osa Peninsula) and the study area: Numbers in brackets show the proportion of occurring species in comparison to the fauna of all of Costa Rica.

Taxon	Costa Rica[1]	Costa Rica lowland RF[2]	La Selva Nat. Park[1]	Las Cruces, Coto Brus[4]	Osa Region[4] (total area)	Piedras Blancas (this study)
Didelphimorpha	8	8	5 (63%)	4 (50%)	8 (100%)	5 (63%)
Xenarthra	7	7	7 (100%)	5 (71%)	7 (100%)	6 (86%)
Primates	5	4	3 (60%)	2 (40%)	4 (80%)	4 (80%)
Insectivora	5	2	0 (0%)	1 (20%)	0 (0%)	1? (20%)
Lagomorpha	3	1	1 (33%)	1 (33%)	1 (33%)	1 (33%)
Rodentia	45	22	16 (36%)	20 (44%)	23 (51%)	16? (36%)
Carnivora	22	16	14 (64%)	18 (82%)	17 (77%)	14 (64%)
Artiodactyla	4	4	4 (100%)	3 (75%)	4 (100%)	3 (75%)
Perissodactyla	1	1	1 (100%)	- (0%)	1 (100%)	- (0%)
Total	205	65	51 (25%)	54 (26%)	65 (32%)	50 (24%)

[1] after TIMM (1994); [2] after ADLER 2001; [3] after DAILY et al. 2003; [4] after JANZEN (1983)

tion, only a much smaller area around La Gamba has been methodically sampled and observed so far. Overall, it seems that even all larger mammal species which can be expected at lowland regions in SW Costa Rica – maybe with the exception of the Puma, the Tapir and the Giant Anteater – are still (at least locally or seasonally) extant in Piedras Blancas National Park.

Status and habitat associations of species

At present, data about the local abundance and occurrence patterns are very sketchy for most species. Although, in principle, most of the specific sampling methods applied by us in 2004, could be used (and have been in many mammalian studies) for estimates of relative abundances, we here refrain from going into a detailed quantitative analysis of our data. Instead, we confine ourselves to a raw (preliminary) status assessment based on the combined impressions of all sources of information available. In addition, Table 3 also gives an overview of the distribution of records of each species over the main types of habitats in the national park area and its vicinity. For a deeper understanding of the data gathered in Table 3 the following remarks on a few selected species groups and single species may be helpful:

Opossums

Only two species seem to be widespread and common in different forested habitats around the NP (see Table 3). The Mexican Mouse Opossum *Marmosa mexicana* was the only small mammal which could be trapped at all secondary and primary forest sites by snap traps, albeit infrequently and in low numbers (7 specimens). As stated by WAINWRIGHT (2002), this opossum is not restricted to primary forests and is not strictly arboreal. This is also indicated in our material by captures in the garden area of the abandoned "old biological station" and by three (out of seven) captures on the ground. The other more common species in the area, *Philander opossum* (see Fig. 1h), seems to be rare in primary forests but is obviously quite abundant at forest edges and in cultivated land, and even intrudes into settlements (one record from 2004 in the hamlet of Bolsa: an individual killed by a dog). Tracks of this species have also been found at scent stations along the La Gamba river in the middle of the La Gamba valley, indicating larger movements of this species, which have also been reported from Panama and French Guiana (see WAINWRIGHT 2002 with further references).

Primates

Of the four species in the list (Table 1, 3) one, the Red Backed-Squirrel Monkey, to our knowledge, until know has only been recorded outside the Piedras Blancas National Park. For instance, a group of up to 30 animals roamed the El Chorro secondary forest area and nearby plantations at the opposite side of the La Gamba valley from March until June 2004. None of the other primate species seem to be abundant in the national park, although White-faced Capuchins were frequently spotted at forest edges near the field station in 2004, and a group of about 12 Mantled Howlers obviously is resident in the forest near the mouth of the Río Esquinas (fide A. Alvarez).

Small rodents

According to our snap-trap results, species diversity and densities of forest dwelling rodents seem to be extremely low in secondary as well as in primary forests in the Piedras Blancas National Park area. Of the only four species of small rodents captured at all forested sites, no single individual was captured in well over 40.000 snap-trap hours on the forest floor. A single specimen each of

Heteromys desmarestianus, and of the larger spiny rats *Hoplomys gymnurus* and *Prooechymis semispinosus* (captured in live-traps at secondary forest sites) are the only records of bottom-dwelling rodent species near the rainforest, but the fourth forest species, the strictly arboreal Vesper Rat, *Nyctomys sumichrasti* (see REID 1997), was also caught with very low frequency (3 captures at heights between 1.6 and 2.5 m; compare Figs 1a, 2e).

Although relatively low species diversity and densities of terrestrial rodents in neotropical rainforests have been reported (and explained) in other studies (e.g. JANZEN & WILSON 1983, TIMM 1994), such low numbers of terrestrial rodents in our forest sample are surprising. At least *Heteromys desmerarestinus* is stated to be "*abundant in wet forest throughout Costa Rica*" (WAINWRIGHT 2002). T. H. Fleming in his classical studies (cited in TIMM 1994) of this mouse in La Selva, has not only reported densities from 9 to 18 individuals per hectare, but also showed its importance as seed disperser and seed predator in lowland rainforest systems.

Rodent species numbers and densities may be slightly higher in cultivated land at the border of the national park. However, with only two additional species trapped in plantations and pastures (*Zygodontomys brevicauda*: 3 captures; *Oligoryzomys fulvescens*: 1 capture), our sampling success in such habitats was still disappointingly low (compare much higher capture rates in the Coto Brus area about 20 km to the east of La Gamba: DAILY et al. 2003). Other rodents (*Sigmodon hispidus* – Fig. 2a, *Rattus rattus*, and Tome's Spiny Rat *Proechymis semispinosus*) were caught in houses in La Gamba and near the forest (La Bolsa) respectively. Tracks of rats (presumably of *R. rattus*) were also recorded in other habitats (plantations, forest edges).

Carnivores

The high species diversity of carnivores (Order Carnivora) in the area of the Piedras Blancas National Park is specifically remarkable because of its small area and somewhat isolated position. Overall the occurrence of more than 85% of all species which could be expected in Pacific lowland areas of SW Costa Rica is documented (see Table 3, cf. Table 2). The species list includes not only small species but also endangered larger predators, like the River Otter, the Ocelot and the Jaguar, which are known to be sensitive to human impact (e.g. DAILY et al. 2003). The Jaguar was sighted several times during our stay within the National Park area (January 7 – April 13 2004: forest near Playa San Josecito and Río Bonito valley) and was also recorded there three years ago (Río Bonito valley, one animal preying on dogs: J. Angel). The Ocelot, which is known to occur also in disturbed habitats (WAINWRIGHT 2002), is likely to have retained a vital population within the park. Frequent records not only stem from primary forest sites but also from forest edges and cultivated land near and at the Biological Field Station La Gamba. For 2004 alone, we have sightings, track records and even live captures (see Fig. 2f) from 10 different sites, including one secondary forest at the opposite side of the La Gamba valley. The River Otter has been observed several times in recent years by the local experts J. Angel and A. Z. Alvarez at the Río Bonito and Río Gamba and even at a pond near the village of La Gamba.

Five members of the family Procyonidae are stated to occur at Piedras Blancas. Whereas *Nasua narica*, *Procyon lotor* and *Potos flavis* can be frequently observed or tracked also at the forest edges (e.g. near Esquinas rainforest lodge), reliable records of the Crab-eating Racoon are rare (one individual at the field station on June 16 2004 – CW) and the occurrence of the Olingo is slightly uncertain. The latter species, which seems to favour cloud forests at middle elevations in Costa Rica (REID 1997), has been observed once in June 2004 at the forest edge at the Esquinas Rainforest Lodge, were the similar species *Pottus flavus* is frequently seen. Although the experienced observer J. Angel persists in his species determination, further proof of the local occurrence of this nocturnal animal would be very welcome.

The status of most small Mustelidae and Felidae at present is only documented by scant data and deserves further investigation. The only species of these groups which is frequently recorded in different habitats form primary and secondary forest to cultivated land at the forest edges is the Tayra. This species regularly visits the gardens of the Esquinas Rainforest Lodge and of the Biological Field Station, and has also been recorded at both scent stations in secondary forests on the opposite side of the La Gamba valley. The Striped Hog-nosed Skunk has been sighted and tracked only a few times in primary and secondary forest near the La Gamba field station.

The Greater Grison, a species which is difficult to spot and "*poorly known in Central America from few scattered records*" (REID 1997) is stated by the local hunter and nature guide (J. Angel) to den in burrows of the Amardillo near the Esquinas Lodge Garden, but this hint needs to be clarified further. This is also necessary for our single track record of the same species at a scent station in secondary forest area at the opposite side of the La Gamba valley and for a isolated track record of a Long-tailed Weasel along the Río La Gamba.

The documentation of the two small cats of the area, the Margay and the Jaguarundi is better. One female Margay was captured three times during our live-

Table 3: Status and habitat associations of terrestrial non-flying mammals in the area of the Piedras Blancas National Park, SW Costa Rica.

Species (Order)	Overall status	RF	CF	SF	RS	CL	SE
DIDELPHIMORPHIA							
Caluromys derbianus	r				+?		
Chironectes minimus	r?			?	?		
Didelphis marsupialis	uc-lc			(+)	(+)		
Marmosa mexicana	lc-c	+§		+§		+	
Philander opossum	c-a			+§, x, *	x	(+)	+§,+?
XENARTHRA							
Cyclopes didactylus	uc	(+)	(+)				
Myrmecophaga tridactyla	(extinct)	(+)					
Tamandua mexicana	uc-lc	(+)					
Bradypus variegatus	uc-lc	(+)	(+)	(+)			?
Choloepus hoffmanni	uc		(+)				
Cabassous centralis	uc	#?		+			
Dasypus novemcinctus	c-a	#,+?		(+), x		*	#
PRIMATES							
Adeles geoffroyi	r?	?	?				
Alouatta palliata	lc	(+)	(+)	(+)			
Cebus capucinos	c	(+)	(+)	(+)			
Saimiri oerstedii	uc			(+)	(+)	(+)	
RODENTIA							
Microsciurus alfari	uc-c	(+)		(+)	(+)		
Sciurus granatenis	c	(+)		(+)	(+)		(+)
Sciurus variegatoides	?			#?			
Orthogeomys underwoodi	?					?	?
Heteromys desmarestianus	uc?	+					
Nyctomys sumichrasti	uc			+§			
Oligoryzomys fulvescens	uc?					+§	
Sigmodon hispidus	uc?						+
Rattus rattus	lc			#		#	+§
Tylomis watsoni	?			?			?
Zygodontomys brevicauda	lc					+§	
Hoplomys gymnurus	r			+			
Proechimys semispinosus	uc			+			+§
Coendou mexicanus	r	(+)	(+)				
Dasyprocta punctata	c	(+*)	(+)	(+)			
Agouti paca	c	(+), x	(+)	(+), x		(+), x	
INSECTIVORA							
Sorex saussurei	?					?	
LAGOMORPHA							
Sylvilagus brasiliensis	uc			(+)		(+)	
CARNIVORA							
Bassaricyon gabbii	?			?			
Nasua narica	c-a	(+*)	(+)	(+)	(+)	(+)	(+)
Potos flavus	lc	(+)		(+)			
Procyon lotor	c-a	#, (+*)	(+)	+, #, (+*)	#	# (+*)	(+)
Procyon cancrivorus	r-uc		?	(+)		(+)	
Conepatus semistriatus	uc	(+*)		(+), #			
Eira barbara	c	(+), #	(+)	(+), #	(+)	(+)	(+)
Galictis vittata	r				#	?	
Lutra longicaudis	r				(+)		
Mustela frenata	r?				#?		
Herpailurus yaguarondi	uc	#	(+)	(+)			(+)
Leopardus pardalis	lc	+, #		+		#	(+)

Table 3 continued.

Species (Order)	Overall status	RF	CF	SF	RS	CL	SE
Leopardus wiedii	uc	+, #		(+)		(+)	
Pantherea onca	uc	(+)	(+)		(+)		
ARTIODACTYLA							
Dicotyles pecari	uc		(+), #				
Tayassu tajacu	lc	(+)	(+)	#			
Mazama americana	lc	#	(+)	#		(+)	
Numbers of species	51	25	18	33	14	19	14

Status: (overall abundance assessment): ? = actual occurrence doubtful; r = rare (only single records over the years and / or stated as rare by local experts); uc = uncommon (irregular records, but probably more regularly occurring in the appropriate habitat); lc = probably locally common, but not recorded in all adequate parts of the NP; c = common, frequently observed; a = abundant: species obviously with good densities in the appropriate habitat.
Habitats: RF = rainforest, primary forest – central inland areas; CF = coastal forest (mangroves and/or rainforest near the coast around San Josecito and Rio Esquinas mouth); SF = secondary forest, forest edges; RS = riverside habitats, gallery forests; CL = cultivated land (plantations, pastures, station, lodge gardens); SE = settlements (village of La Gamba, hamlets, fincas, houses in the La Gamba-valley)
Kind of records: the reliability of occurrences may be assessed over the kind of records so far available: + = dead or live captures (determination by scientists), § = proof specimens archived; +? = kills / dead-findings; determination by local experts; (+) = reliable observations (sometimes including photo documentation, eg. from track-cameras = +*); # = finding of burrows and other indirect evidence of occurrence; x = track records (x? = somewhat doubtful or assignment to species ?); ? = doubtful observations or statements – scientific proof necessary).

trap experiments between June 14 and June 19 in the primary forest; other records stem from tracks and sightings at edges of secondary forests in the La Gamba area. Jaguarundis were not only recorded over tracks in the primary forest but were also observed directly in the La Gamba village in 2004 (fide J. Angel, A. Alvarez).

Accuracy and efficiency of research methods

Figure 3 – on a simple qualitative level – compares the effectiveness of our main sampling methods with respect to species records.

Of course, the different success rates must be related to the sampling effort and to the work load and costs of the appliance of each method. As shown in Fig. 3, direct (invasive) sampling methods (snap, pitfall and larger live traps) yielded comparatively low species numbers in relation to the high effort for transport, setting, building and checking those traps. However, it is also obvious that the proportion of species recorded exclusively by such direct sampling is comparatively high (Fig. 3), and this is especially true for snap traps.

Non invasive methods like track (scent) stations, cam-tracking, or visual observations and especially the collecting of local knowledge through interviews on the other hand provided many species records (with the exception of camera tracking) but also comparatively high proportions of uncertain determinations. The efficiency, problems and benefits of the different methods can be summarised as follows:

Snap traps

Such traps were claimed to provide more mammal individuals and species in the tropics than other sampling methods (WOODMAN et al. 1996). This claim does not hold true for our investigation. As already mentioned above, capture rates of small terrestrial and arboreal mammals were extremely low at all sites. Capture rates per capture unit (= trapping stations with 9 single traps each) were slightly higher at disturbed habitats (3 sites; 9 trapping stations, two capture-periods, 45.200 trap hours: 0.16 individuals / unit-hour) than at our primary rainforest sites (3 sites; 9 trapping stations, two capture-periods, 44.390 trap-hours; 0.1 individuals / unit hour). Capture success was close to zero on the forest floor (1 species with 2 individuals vs. 3 species with 5 individuals for the fewer traps set higher up on trees and trunks).

It is unlikely that these disappointingly low capture rates are caused solely by correspondingly low mammal densities in our investigation area. In our experience, the following methodological problems diminish the accuracy of the snap-trapping method in tropical lowland habitats:

1. small animals, especially ants, constantly remove the bait from traps without triggering them. This problem was specifically evident at most rainforest sites, where on average 15-20% (sometimes up to 50%) of all un-triggered traps had no bait left when checked.
2. ants start building small earth mounds (nests) over the trap around the bait thereby impairing the function of the traps (compare Fig. 1b). This problem (with up to 10% of traps out of function) was more

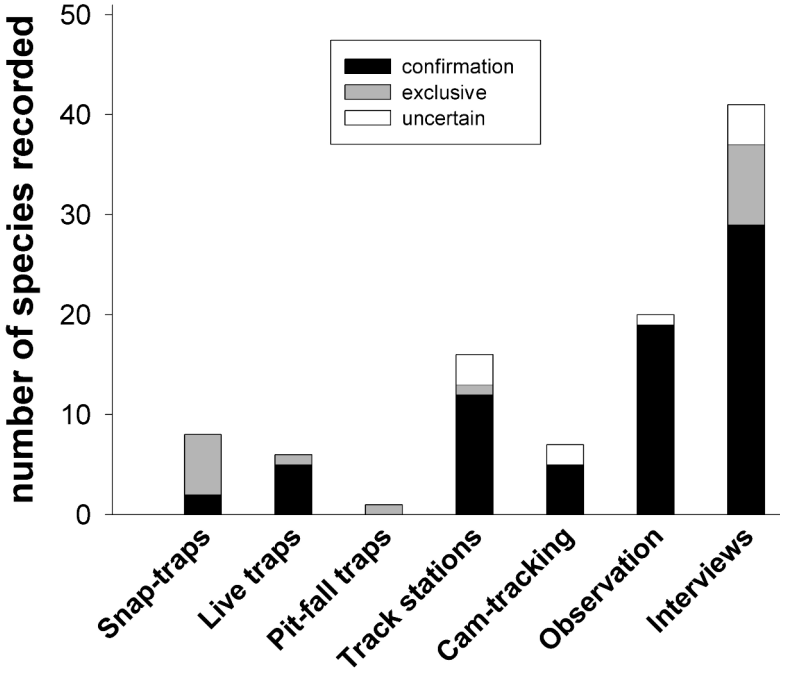

Fig. 3: Efficiency of methods used to sample data about the occurrence of non-flying terrestrial mammals in the area of the Piedras Blancas National Park. Three types of data regarding the quality of records are distinguished: confirmation = species which were also recorded with other methods; exclusive = species only recorded with this method, and uncertain = clear assignment to species level was not possible or doubts about the correctness of the species identification remain.

prominent at disturbed habitats (secondary forest sites, cultivated land with trees) than at rainforest sites.

3. traps are triggered by falling leaves, land crabs and other ground dwelling small animals (mostly ants?). Again this problem was more often noticed at disturbed sites (4.7% of all controls) but was still significant at rainforest sites (2.1% of cases).

Thus, all in all, the balance between effort and results of the employment of the snap traps seems to be skewed to the wrong side. However, as only dental or skull features allow the determination of some species, we still believe that dead-trapping was justified and appropriate for our goals.

Live traps

As standard live-capture traps (e.g. Sherman, Tomahawk traps) are comparatively expensive, heavy and complicated to transport, we used (constructed) simple traps (trap cages) from material easily available in the investigation area. However, results (number and quality of species records) are comparatively few for both techniques applied (Fig. 3) in relation to the effort needed for constructing (cages), setting (e.g. digging large buckets into the ground) and maintaining these traps. Capture rates were again extremely low for pitfall traps (1 individual of one species / 1000 unit hours) as well as for cage-traps (0.12 individuals / cage hour), but were more promising for the latter type (captures of 6 species including secretive, small species like Tome's Spiny Rat and the Forest spiny Pocket Mouse). Such low-cost cage traps (Fig. 1g) seem especially promising for specific research programs with focus on larger rainforest animals, like the Ocelot, the Margay, the Tayra or racoons. These species were caught several times with relative ease with our baited cages. Capture rates would have been even higher with more sophisticated trigger mechanisms, because failures of our self-constructed release mechanisms obviously occurred several times (as indicated by specific tracks at and around the cage and the disappearance of the bait).

Camera trapping

proved to be an efficient, reliable and nearly weather-independent method of detecting inconspicuous and nocturnal species of medium-sized to larger mammals (e.g. STOEN 1998, SILVEIRA et al. 2003). However, this method has high initial costs, requires careful placement of the traps (one camera was stolen during our work) and a larger number of expensive cameras and trapping nights are needed even for simple presence documentation of species (Fig. 2b). In addition, determination may be complicated not only for inconspicuous small species, but also for common animals when photo-distances and angles are inappropriate. In our investigation all of the few species (altogether photos of only 16 individuals of seven species) recorded with cam-trackers (Fig. 3) were already known from the area or were recorded with other sampling methods as well. Thus, in our investigation, cam-tracking was the least satisfying method (few results, high costs and maintaining effort).

Track-traps (scent stations)

have a long tradition in field mammalogy (e.g. LINHART & KNOWLTON 1975) and have been successfully applied in different habitats (e.g. DAILY et al. 2003 for agricultural landscapes of Costa Rica). Footprints give good information on the presence of species including those that are rare or hard to spot. However, as track shapes change with age, the animals gait, and soil substrate, identification of tracks depends on experience and can be error-prone. Especially similarly-sized and small species are hard to distinguish. Species occurrences which are solely based on track records must therefore be handled with some care (see above and Table 3). In addition, if good and reliably determinable footprints (see Fig. 2c) are to be obtained, the effort to set, maintain (e.g. clearing, paving and watering the ground) and check scent stations is high.

Overall we "sampled" 127 tracks which could be assigned to 16 different species. Those tracks were made over 25 nights (approx. 15 hrs) at 30 scent stations (= sampling units). This adds up to a "capture rate" of 1.1 tracks / unit hour which is about ten times higher than that attained by snap-trapping (see above). Although nearly 50% of all tracks belonged to only one species (Northern Racoon – e.g. Fig. 2c), this non-invasive method was nonetheless worth the effort because it provided valuable confirmation of the occurrence of some secretive small felids and mustelids (Long-tailed Weasel, Grison, Margay), and proved to be especially useful in gathering additional information on small-scale local distribution and space use patterns of larger animals, like the Agouti, the Paca, the Red Brocket Deer, pecaris, the Tayra, the Ocelot and racoons (see Table 3).

Observations and interviews

Visual searches for mammals in dense tropical forests can be quite disappointing because the number of species detected and the frequency of animal contacts will be very low under average circumstances, and will be restricted to a few larger ground dwellers and medium-sized arboreal species. Thus, if no systematic surveys like transect counts are carried out (e.g. MENDES PONTES 2004, SILVEIRA et al. 2003), the species list which can be gathered by simple observations will normally be short and depends mainly on the length of the stay and the variety of habitats that can be visited. With regard to the fact that only one of us (CW) stayed for more than two months in the investigation area, and that our excursions were mainly focused on habitats near and around La Gamba, the high number of our own visual records (20 species, Fig. 3) is quite satisfying and may be taken as an additional hint of the local species richness. However, our observations mostly refer to species which use forest edges and semi-open, more or less disturbed habitats at the edges of the national park and do not add significant new data on the local species composition (see Fig. 3).

In contrast, the incorporation of local knowledge collected through interviews with experts who have a year-round and long-term experience of wildlife in the national park area yielded not only valuable ecological information on more widespread species, but also led to a substantial extension of the species list (Table 1, 3, Fig. 3).

Although some of those records, mainly the ones pertaining to small rodents and shrews are somewhat doubtful, and others still require confirmation (cf. Table 3, see above), most of the stated occurrences in our opinion are reliable for the following reasons:

(1) the statements were made by experienced and trained observers who make a living from nature observation (hunting, guiding, wardens), (2) most species were stated to occur independently of each other by more than one expert, (3) most statements could be later confirmed by our own records in 2004 or by records of other scientists in recent years, and (4) the information given in interviews mostly fit the known habitat requirements and regional distribution patterns of the respective species.

All in all, our findings suggest that a systematic incorporation of local knowledge might be an underused source of information in tropical field biology which should be used more intensely in other fields as well. In addition, our results once more emphasise that only the combination of an array of sampling methods (differing as much as possible) and long-term research can give us a sound understanding of species compositions and relative abundances of mammals in tropical landscapes. This overview is therefore only intended to be a starting point and first step to a deeper understanding of the biodiversity and conservation needs of the rich mammal fauna of the Piedras Blancas National Park.

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Addresses of authors:

Armin Landmann (corresponding)
Institute of Zoology
University of Innsbruck
Technikerstr. 25
A-6020 Innsbruck
Austria
E-mail: armin.landmann@uibk.ac.at

Christoph Walder (& T. Emser)
E-mail: christoph.walder@aon.at

Anton Vorauer
E-mail: anton.vorauer@utanet.at

Contents/Indice

PLANT BIOLOGY — BIOLOGÍA DE PLANTAS

Ecosystems and vegetation — Ecosistemas y vegetación

Plant diversity — Diversidad de plantas

Life forms — Formas de vida vegetal

Ecophysiology — Ecofisiología

Ants and plants — Hormigas y plantas

HUMAN ASPECTS — ASPECTOS HUMANOS

History and development — Historia y desarrollo

Ecotourism and local development — Ecoturismo y desarrollo local

APPENDIX — APÉNDICE