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TRABAJOS ORIGINALES

Tropical rainforest palm communities in Madre de Dios in Amazonian Peru

Comunidades de palmas en los bosques tropicales de Madre de Dios de la Amazonía Peruana

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Abstract

We studied palm communities, in particular species-richness and abundance, in the tropical rainforests in southeastern Peru in 54 transects (5×500m) covering an area of 13.5 hectares in flood plain, *terra firme*, terrace and premontane hills. We found 42 palm species in 18 genera in the transects. *Terra firme* forest had the highest species richness (38 species) followed by floodplain and premontane hills with 27 species and terrace forests with 26 species. The highest palm abundances were found in premontane hill forest which had 3243 palms per hectare and *terra firme* forest which had 2968 palms per hectare. The floodplain forests were intermediate in palm abundance with 2647 and the terrace forests had the lowest abundance with 1709 palms per hectare. Intermediate sized palms were the most common being represented by 18 species, while large palms were represented with 16 species. There were only eight species of small palms of which one was acaulescent. Only one species of liana palm was registered. Of the 42 species observed in the 54 transects, 20 were cespitose, 21 solitary and two had colonial growth. Seven species were found 40–320 km outside of their previously known range.

Keywords: Abundance of palms; Arecaceae; species richness; growth form; community structure.

Resumen

Estudiamos las comunidades de palmas de los bosques pluviales tropicales del sur de Perú, con especial énfasis en su riqueza de especies y abundancia, utilizando 54 transectas (5×500m), que cubrieron un área de 13.5 hectáreas en planicie inundable, *terra firme,* terraza y colinas premontanas. Encontramos 42 especies de palmas en las transectas. En el bosque de *terra firme* se encontró la mayor riqueza de especies (38 especies), seguido por la planicie inundable y las colinas premontanas con 27 especies y los bosques de terraza con 26 especies. Las mayores abundancias se encontraron en el bosque de colinas premontanas, con 3243 palmas por hectárea, y en el bosque de *terra firme* con 2968 palmas por hectárea. Los bosques de la planicie inundable presentaron una abundancia intermedia con 2647 palmas por hectárea y los bosques de terraza presentaron la menor abundancia con 1709. Las palmas de tamaño intermedio fueron las más comunes, estando representadas por 18 especies, mientras que las palmas grandes estuvieron representadas por 16 especies. Se encontraron solamente ocho especies de palmas pequeñas, una de las cuales era acaulescente. Sólo se registró una especie de palma trepadora. De las 42 especies observadas en las 54 transectas, 20 fueron cespitosas, 21 solitarias y dos presentaron crecimiento colonial. Siete especies se encontraron 40–320 km fuera del rango de distribución conocido previamente.

Palabras clave: Abundancia de palmas; Arecaceae; riqueza de especies; forma de crecimiento; estructura de comunidad.

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Introduction

The palm family (*Arecaceae*) has 182 currently accepted genera with around 2600 species, most of which are restricted to tropical and subtropical climates (Dransfield et al. 2008; Baker & Dransfield 2016). Palms are abundant throughout the tropics, and thrive in almost every possible habitat, but their diversity is highest in wet, lowland rainforests. The vast Amazon basin houses 151 species of palms (Henderson 1995). Colombia's 247 native palms (Galeano & Bernal 2010) may be the highest number of palm species in any tropical American country, whereas Peru counts 149 species (Balslev et al. 2015). Palms inhabit a variety of ecosystems in tropical America. More than two thirds of palm species live in tropical forests, where some grow tall enough to form part of the canopy and shorter ones form part of the mid- and understories (Balslev et al. 2011). Some species form pure stands, usually in areas with poor drainage or regular flooding. In the Amazon basin the most common and widespread of these palms that form monodominant stands is *Mauritia flexuosa* L.f. that is very abundant in swamps, particularly in the western parts of the Amazon basin. Other palms live in tropical mountain habitats up to 3000 meters above sea level, such as species in the genus *Ceroxylon* which are all native to the Andes (Sanín & Galeano 2011). Palms also inhabit grasslands and scrublands, and are then usually associated with a water source, sometimes under periodical flooding, such as *Copernicia alba* Morong ex Morong & Britton, which is common in seasonally flooded savannas in northern Argentina, Paraguay, southwestern Brazil and central and southern Bolivia (Moraes 2004).

The edible fruits of palms make them keystone species for the survival of many animals living in the tropics (Peres 1994, Kinnaird 1992). Palms are also used by humans and provide a variety of products such as oil, palm heart, building materials and material for basketry (Balslev 2011). A few species like *Mauritia flexuosa* and *Oenocarpus bataua* Mart. even have the potential to be economically important for large scale export activities (Brokamp et al. 2011, Kahn 1988). In order to use this potential of the palms in the most sustainable way, it is necessary to know more than just the distribution of each species.

The palm communities of the Madre de Dios region in Peru are essentially unknown and their composition and structure remains to be documented. Kahn and Moussa (1994) assessed the diversity and conservation status of palms in Peru (including Madre de Dios) and reported 140 species in 34 genera for the entire country. About 43% of the species occurred at very low or low frequencies and about 9% were insufficiently known *in situ* for their conservation status to be defined. This is yet another reason for more in-depth studies of the palm communities in Peru. Other than Kahn and Moussa's study of Peruvian palms and Henderson's treatment of the palms of the entire Amazon basin (Henderson 1995), no palm studies have included the Madre de Dios region. Our study provides insight on how common or rare the palm species are in that region, and about how they are grouped in communities, which species occur together, how many species occur in different habitats, and how the different life forms are represented in different habitats. This information allows us to update and complement our knowledge about the distribution of the Peruvian palm flora. This contribution, in addition to providing new information and exploring the nature that surrounds us, is important for conservation and sustainable management of the palms in the Madre de Dios region and elsewhere.

Study area

Peru houses many different vegetation types that are assembled in complex ecological environments. These are shaped by large variations in both altitude and rainfall. Here, we focus on the Madre de Dios region in eastern Peru (Fig. 1). The study area is located in lowland tropical forest at altitudes between 100 – 500 m. The climate is warm and damp, with average temperatures around 26 °C (variation 21 – 34 °C). The rainy season is from December to March, when torrential rainfall causes rivers to swell and often overflow their banks. Annual precipitation can be as much as 3000 mm (Cochrane & Cochrane 2011).

The great extent of Amazonian forests, together with the regional peculiarities of the soil types and river systems within the basin, allows for a number of very distinctive forest types to exist, each with its own specialized flora. These forest types are recognized in many publications, but here described based on our experience from making close to 600 transects in the western Amazon basin from Colombia to Bolivia and also in the Brazilian state of Acre.

By far the largest area is taken up by *terra firme* forest, which is the 'standard' forest type that one usually has in mind when referring to the Amazon rainforest. *Terra firme* forest occupies well-drained soils that are relatively poor in available nutrients. The dense forest canopy reaches 40 m height and is usually very rich in tree species, while the interior is relatively dark and open.

The floodplain is the area along the rivers that is inundated when the water level in the river rises. It is flat land and the soils are alluvial (sand, silt, and clay) deposited during floods. Usually, the river winds its way through the floodplain, forming loops, a process known as meandering and braiding, where the water erodes the landscape on the outside of the turn and deposit material into the inside of the turn. In this way, the river erodes its way through the floodplain and can move several hundred meters per year (Salo et al. 1986). Because of this river dynamics, the floodplain forest is usually not as old as the other types of forest.

The terraces are adjacent and similar to floodplains, also lying along the river, but outside the flooding zone. Terraces are flat and originated as floodplains, but have been raised higher due to tectonic movements. Consequently, they are no longer subjected to river erosion and the forest is therefore generally older and taller than the floodplain forest.

Premontane hills are the outer slopes of the transition between a plain and a mountain range formed by uplifting. The soils there are loamy and often rich in nutrients. Like the flat plains below, the hills are covered with dense, tall broadleaf forest with a high diversity of trees, shrubs, epiphytes, herbs and also some lianas.

Our transects were surveyed in three different areas of the Madre de Dios region (Fig. 1). The first area was located 5–40 km south of the town of Iñapari, about 200 km north of the Madre de Dios river, and included exclusively *terra firme* forests. The second area was located around the town of Puerto Maldonado (ca. 100 km west to 60 km east) and included mainly surveys on floodplains, but also some on *terra firme* forests. The third area was at s slightly higher altitude and located some 150 km west

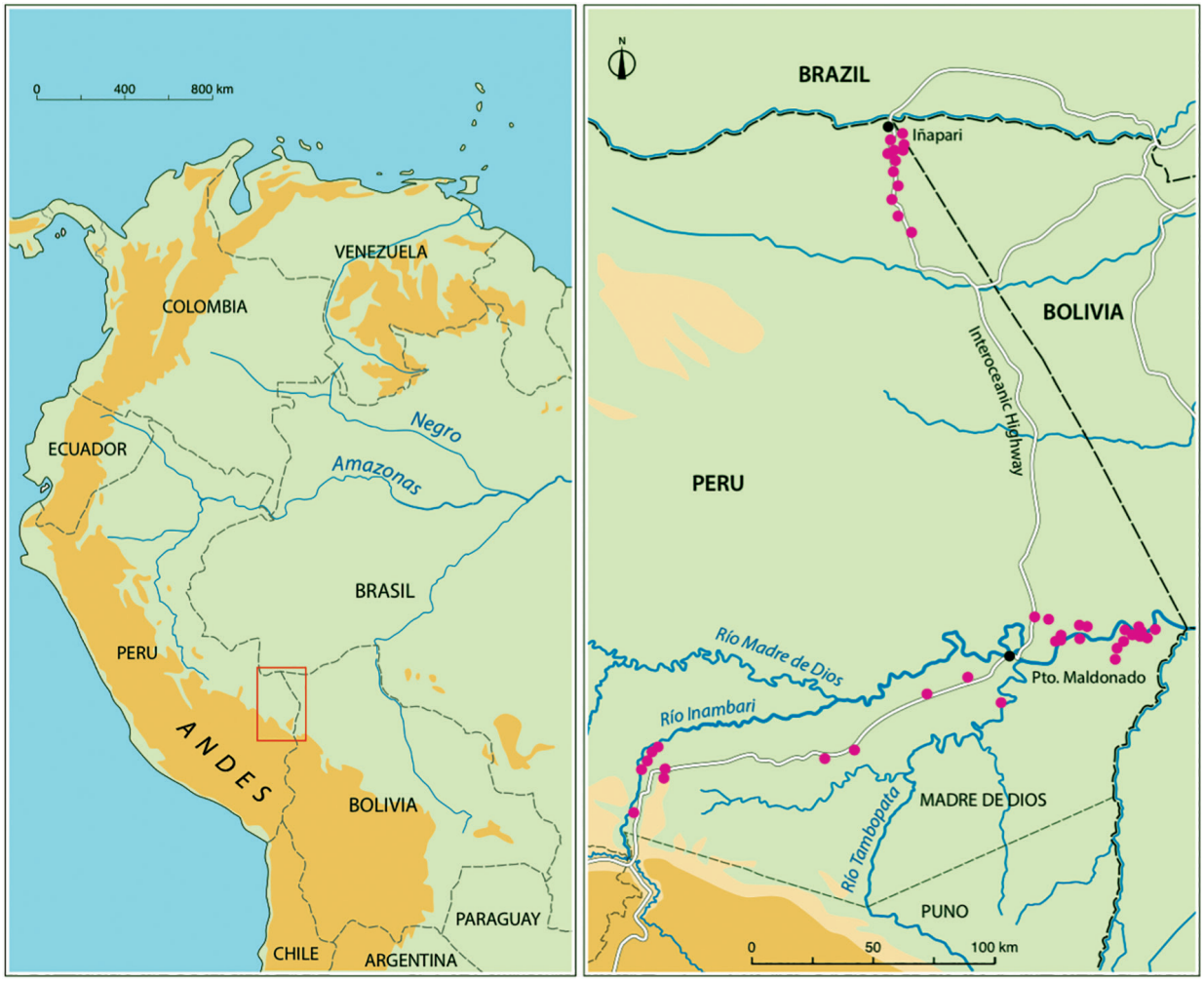

Figure 1. Map of the tri-state region between Peru, Brazil and Bolivia showing the Madre de Dios region with location of 54 5×500 m transects (red dots).

of Puerto Maldonado, near the Inambari river, and included mainly terrace and premontane hill forest (with some additional *terra firme* forest transects).

Methods

We visited the Madre de Dios region during February-April 2011 to explore its palm flora and palm communities with the objective to determine the abundance of palm species in different habitats.

We surveyed 54 transects of 5×500 m. Each transect was divided into hundred 5×5 m subunits, in which we identified all palm species and counted the number of individuals, noting if they were seedlings, juveniles, subadults or adults. Seedlings were the very young plants with their first seedling leaves; juveniles were young plant that had not reached the mature size; subadults were palms that had reached the size of reproductive individuals but did not show any sign of having reproduced; and adults were plants that showed signs of having reproduced or actually had reproductive structures. The transects were laid out so that they would represent the variation in vegetation as recognized on satellite images. After selecting a site we would approach its position as closely as we could on the Madre de Dios river or by road, and then walk to the site guided by a GPS. Once at the site, we cut a straight trail, avoiding damage to the palms along the trail, and placed sticks every five meters, marking each stick with a pre-printed paper label with the transect number and subunit number.

We collected 123 herbarium specimens that are deposited in the Herbarium Amazonense (AMAZ) of the Universidad Nacional de la Amazonia Peruana in Iquitos (Peru) and at Aarhus University (AAU, Denmark). We collected and took pictures of most of the species including specimens of seedlings, juveniles and adults. A few palms that were common and well documented were not collected. Detailed collection data and photos of each of the 123 specimens are uploaded on the Aarhus University Herbarium webpage and can be viewed at www.au.bot.dk (enter collector "Balslev" and number range "8349-8471").

Results

Palm species.- In total we counted and identified 37181 individuals. These represented 42 species and 18 genera of palms in the 54 transects in the Madre de Dios region (Table 1). Seven of the observed species were collected beyond their previously reported ranges (Bjorholm et al. 2005, Henderson et al. 1995). The largest range extensions were for *Geonoma maxima* var. *chelidonura* (Spruce) A.J. Hend. and *Bactris hirta* var. *spruceana* (Trail) A.J. Hend. which were found 320 km and 250 km, respectively, beyond their previously known ranges, and *Chamaedorea angustisecta* Burret, *Chelyocarpus ulei* Dammer, *Geonoma laxiflora* Mart., *Socratea salazarii* H.E. Moore and

Table 1. The Madre de Dios region's palm community with indication of name, collecting number, number of individuals encountered in 54 5×500m transects (total 13.5 hectares), and the average number of individuals/species in each of four habitat types (terra firme, floodplain, terrace and premontane hills). The growth form of each species is indicated as LaT (=large tree), MsT (=medium sized tree), Shr (=shrub), Aca (=acaulescent), Lia (=liana), and the palm architecture is given as Col (=colonial), Sol (=solitary), Ces (=cespitose), and the leaf form is given as pal (=palmate), pin (=pinnate) and cop (=costapalmate).

Name of species	Collection number; H. Balslev	Number of individuals	Individuals per hectare				Architecture	Growth forms	Leaf form
			Terra firme	Flood plain	Terrace	Premontane hills			
Geonoma deversa (Poit.) Kunth	8360	7099	839	212		19	Ces	MsT	pin
Geonoma occidentalis A.J. Hend.	8361	5579	585	193	74	477	Ces	MsT	pin
Euterpe precatoria Mart.	8382	2290	182	113	234	201	Sol	LaT	pin
Attalea phalerata Mart. ex Spreng.	8412	2216	142	273	75	16	Sol	LaT	pin
Iriartea deltoidea Ruiz & Pav.	8383	2084	121	75	461	264	Sol	LaT	pin
Astrocaryum gratum F. Kahn & B. Millán		1918	46	396	51	19	Sol	LaT	pin
Astrocaryum ulei Burret	8381	1872	65	370			Ces	MsT	pin
Geonoma macrostachys var. acaulis (Mart.)Skov	8379	1749	125	175	77	47	Sol	Aca	pin
Phytelephas macrocarpa Ruiz & Pav.	8409	1532	74	260			Ces	MsT	pin
Geonoma stricta var. *trailii* (Burret)A.J. Hend.	8363	1339	84		171	599	Ces	Shr	pin
Bactris hirta var. *spruceana* Mart.	8418	1243	119	50	8	195	Ces	MsT	pin
Oenocarpus mapora H. Karst.	8463	1079	81	99	45	45	Ces	LaT	pin
Hyospathe elegans Mart.	8388	1024	46		13	884	Ces	MsT	pin
Bactris concinna Mart.	8365	862	33	130	83		Col	MsT	pin
Socratea exorrhiza (Mart.) H. Wendl.	8372	718	52	65	14	80	Sol	LaT	pin
Bactris maraja var. *trichospatha* (Trail)A.J. Hend.	8380	541	72		1		Ces	MsT	pin
Geonoma brongniartii Mart.	8350	499	6	78	81	49	Sol	Shr	pin
Bactris maraja var. *maraja* Mart.	8351	392	1	87	36	5	Ces	MsT	pin
Oenocarpus bataua Mart.	8406	390	48	3	7	11	Sol	LaT	pin
Bactris maraja var. *juruensis* (Trail)A.J. Hend.	8362	376	40	19	1	3	Ces	MsT	pin
Geonoma maxima var. *chelidonura* (Spruce)A.J. Hend.	8397	274	36			1	Ces	MsT	pin
Wendlandiella gracilis Dammer	8438	253	10		81	75	Col	Shr	pin
Socratea salazarii H.E. Moore	8458	238	3		73	143	Sol	LaT	pin
Wettinia augusta Poepp. & Endl.	8471	224	19		30	51	Ces	LaT	pin
Iriartella stenocarpa Burret	8427	189	25				Ces	MsT	pin
Chamaedorea pinnatifrons H. Wendl.	8391	174	15		37	11	Sol	Shr	pin
Mauritia flexuosa L. f.	8422	169	22	<1			Sol	LaT	cop
Aiphanes horrida (Jacq.)Burret	8400	139	19				Sol	LaT	pin
Bactris acanthocarpa excapa Mart.	8384	127	17			4	Ces	MsT	pin
Geonoma camana Trail	8425	110	8		19	32	Sol	MsT	pin
Chamaedorea angustisecta Burret	8373	108	9	10			Sol	MsT	pin
Attalea maripa (Aubl.)Mart.		77	8	4			Sol	LaT	pin
Desmoncus polyacanthos Mart.	8352	74	2	14	2	5	Ces	Lia	pin
Chamaedorea pauciflora Mart.	8419	68	5		18	1	Sol	Shr	pin
Bactris chaveziae A.J. Hend.	8413	47	3		16	3	Ces	MsT	pin
Geonoma laxiflora Mart.	8374	32		9			Ces	Shr	pin
Bactris gasipaes chichagui Kunth	8385	20	2	1			Ces	LaT	pin
Chelyocarpus ulei Dammer	8370	17	2				Sol	MsT	pal
Geonoma interrupta (Ruiz & Pav.)Mart.	8455	17		4		4	Sol	MsT	pin
Bactris simplicifrons Mart.	8405	10	1	1	1		Ces	Shr	pin
Attalea butyracea (Mutis ex L. f.)Wess. Boer		9		2			Sol	LaT	pin
Syagrus sancona H. Karst.	8376	2		1			Sol	LaT	pin
Total number of palm individuals		**37181**	**22260**	**9925**	**2564**	**2432**			
Number of palm individuals per hectare		**2755**	**2968**	**2647**	**1709**	**3243**			
Number of species in each habitat type:		**43**	**38**	**27**	**26**	**27**			
Number of transects		**54**	**30**	**15**	**6**	**3**			

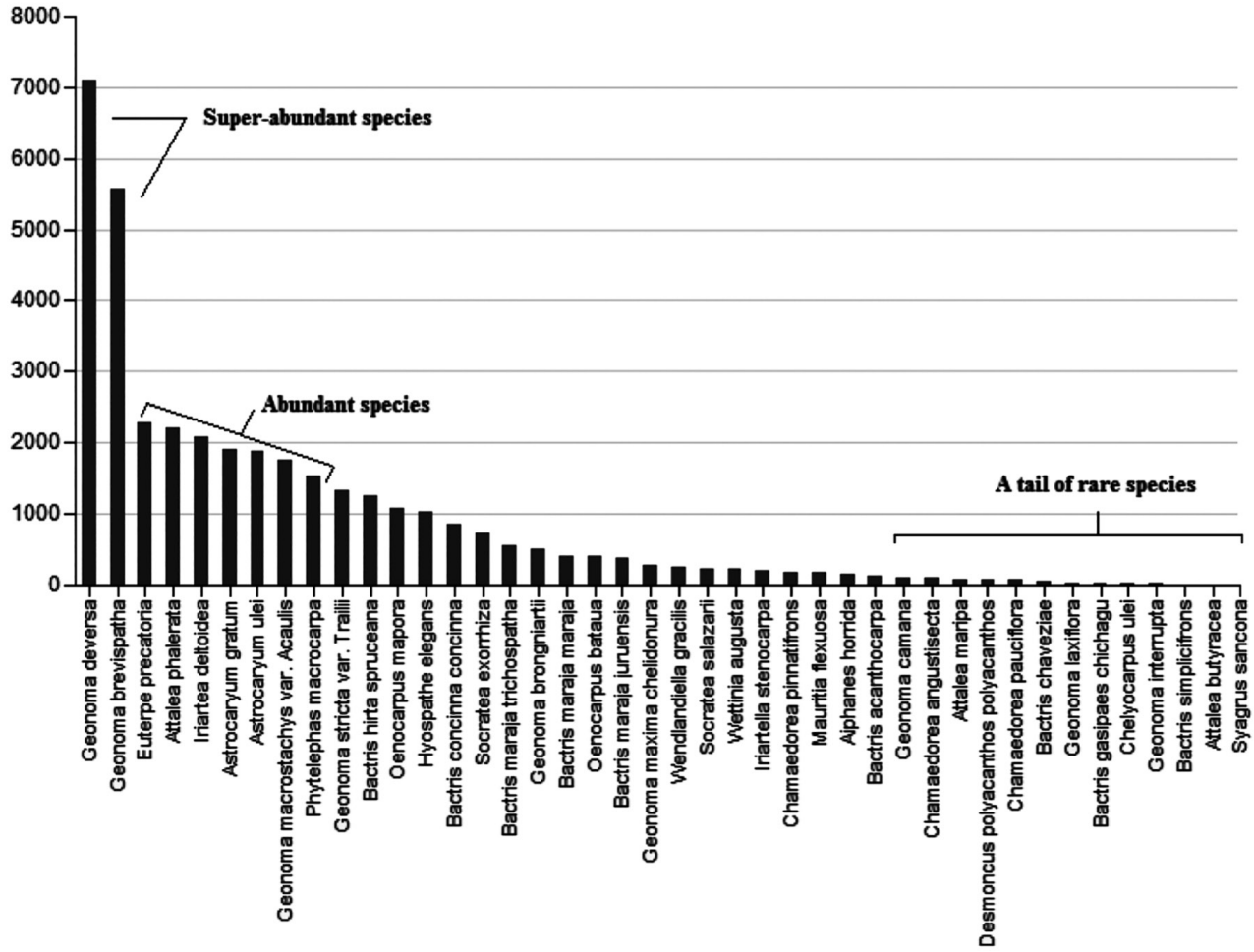

Figure 2. The abundance of palm species in 54 transects in the Madre de Dios region of Peru.

Wettinia augusta Poepp. & Endl. which were found 40 – 160 km beyond their previously known ranges. *Cocos nucifera* L. was observed in two transect but disregarded since it is an introduced species that had invaded the forest near the river.

Palm communities.- Each habitat (floodplain, *terra firme,* terrace, premontane hill) had its own species composition, suite of dominant species and palms density values (Table 1).

In the *terra firme* forest (30 transects) we found a density of 2968 individuals per hectare and 38 palm species, the highest in any of the habitats. *Geonoma deversa* (Poit.) Kunth and *G. occidentalis* (A.J.Hend.) A.J.Hend. were the most abundant species and at least three times as abundant as any of the other palm species in this forest. *Iriartella stenocarpa* Burret*, Aiphanes horrida* (Jacq.)Burret and *Chelyocarpus ulei* Dammer were only registered in *terra firme* forests. In the floodplain forests (15 transects) we found a density of 2647 palm individuals per hectare and 27 species. *Astrocaryum gratum* F. Kahn & B. Millan and *Astrocaryum ulei* Burret had the highest abundances. Three species were exclusive to these forests: *Geonoma laxiflora* Mart.*, Attalea butyracea* (Mutis ex L.f.)Wess. Boer and *Syagrus sancona* H. Karst. In the terrace forest (6 transects) we found a density of 1709 palm individuals per hectare and 26 species, which were the lowest density and species richness values found in any of the habitats. *Iriartea deltoidea* Ruiz & Pav. was the most dominant species in the terrace forest, followed by *Euterpe precatoria* Mart. and *Geonoma stricta* var. *trailii* (Burret) A.J.Hend, with no species exclusive to it. The premontane hill forest (3 transects) had a density of 3243 palm individuals per hectare, which was the highest palm density registered. The premontane hill forest contained 27 species, of which *Hyospathe elegans* Mart. was the most abundant species followed by *G. stricta* var. *trailii* and *G. occidentalis.* No species was restricted to the premontane hill forest.

Abundance.- Overall, *Geonoma deversa* (Poit.)Kunth and *G. occidentalis* were the two most abundant (super-abundant) palms with more than twice as many individuals as any of the other palm species (Table 1, Fig. 2). Some of the more common and abundant species included *Euterpe precatoria, Attalea phalerata* Mart. ex Spreng.*, Iriartea deltoidea, Astrocaryum gratum* and *Astrocaryum ulei*. In contrast, species like *Geonoma interrupta, Bactris simplicifrons, Attalea butyracea* and *Syagrus sancona* were rare in this region of the Madre de Dios (Table 1, Fig. 2).

Palm architecture and growth forms.- Intermediate sized and large palms were the most common, being represented by 18 and 16 species, respectively. There were only eight species of small palms in the sample and one of them was acaulescent. We found only one species of liana palm (Table 1, Fig. 4). Out of the 18 intermediate sized palms four were solitary, one

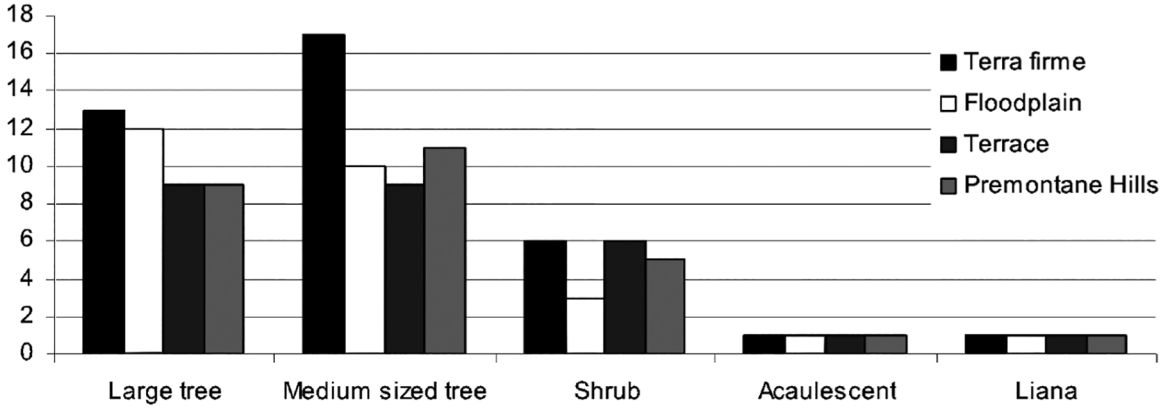

Figure 3. Number of palm species in each growth form and each habitat in 54 transects in the Madre de Dios region of Peru, divided by four different habitats of five growth forms.

colonial and 13 were cespitose. Of the eight small palms half were solitary, one colonial and three cespitose. None of the large palms were colonial, 13 were solitary and three were cespitose (Table 1, Fig. 4).

Growth forms and habit type.- All five growth forms (large, intermediate, small, acaulescent and liana) were present in each of the four habitats studied (Table 1, Fig 3). There was only one acaulescent (*Geonoma macrostachys* var. *acaulis*) and one liana (*Desmoncus polyacanthos*) species, both present in all habitats. *Terra firme* and premontane hill forest were both represented by more medium sized palms than large and small palms. Small palms were the least represented growth form with only 5 – 6 species. We found more species in *terra firme* forest, than in any other habitat, mainly because of the high number of medium sized palms there (Table 1, Fig. 3). The floodplain forest had more large palms than medium sized palm species, but the small palms were still the least represented with three species (Table 1, Fig. 3). Terrace forest had equal numbers of tall and medium sized palm species. Six small palms were found in the terrace forest, which represented a little fewer species than the two other growth forms (Table 1, Fig. 3).

Discussion

The 42 species and 18 genera found in our study of the Madre de Dios palm communities represent around a third of the species and a little more than half the genera reported for Peru (Kahn & Moussa 1994). We went through the list of species compiled by Henderson (1995, 2000) and found 55 species in 19 genera registered for the entire Madre de Dios region (Table 3). Twelve species on these lists were not recorded by us, but we found *Geonoma laxiflora*, which had not been registered in Madre de Dios. Compared to the size of our study area and limited number of habitats investigated, the detected number of species and genera seems high. With additional transects, especially in terrace and premontane hill forests, we might have discovered several more species. Balslev et al. (2012) made 65 transects in five different habitats in adjacent Bolivia and found the same number of genera but fewer species than we found in the Madre de Dios region. Still, there are more diverse places than the Madre de Dios region in Peru. For instance, surveys in the upper Ucayali river valley in northeastern Amazonian Peru recorded 56 palms species in only 35 transects covering the same four habitats (Balslev et al. 2010).

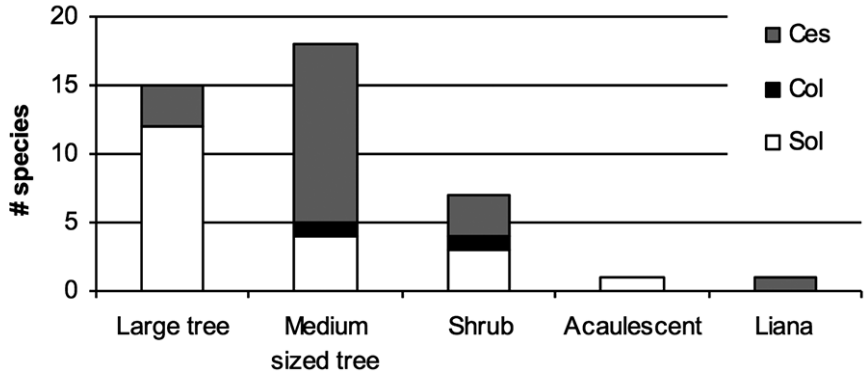

Figure 4. Relative abundance of growth forms of palms found in the forests of Madre de Dios region in Peru, and indication of the relative proportion of solitary (Sol), cespitose (Ces) and colonial species (Col) in each of the growth forms.

Table 2. Data showing the location, altitude and habitat of each transect.

Transect # HB	Province	Locality	Habitat	Altitude (m)	X	Y
406	Madre de Dios	Inka Terra	Floodplain	195	494634	8614309
407	Madre de Dios	Inka Terra	Floodplain	193	494913	8615361
408	Madre de Dios	Reserva Ecologica Taricaya	Floodplain	185	500878	8615674
409	Madre de Dios	Gamitana & Agua Negra & Lo Boyo	Floodplain	186	501073	8619115
410	Madre de Dios	Gamitana & Agua Negra & Lo Boyo	Floodplain	192	502682	8618815
411	Madre de Dios	Inka Terra	Floodplain	191	493738	8614117
412	Madre de Dios	Palma Real	Terra firme	211	518612	8616180
413	Madre de Dios	Palma Real	Floodplain	188	516343	8617324
414	Madre de Dios	Palma Real	Terra firme	200	515501	8613726
415	Madre de Dios	Palma Real	Floodplain	182	520269	8618061
416	Madre de Dios	Palma Real	Floodplain	179	520932	8617035
417	Madre de Dios	Palma Real	Terra firme	194	526057	8617640
418	Madre de Dios	Palma Real	Terra firme	205	512808	8607916
419	Madre de Dios	Palma Real	Terra firme	196	513510	8611258
420	Madre de Dios	Palma Real	Terra firme	212	514977	8621644
421	Madre de Dios	Palma Real	Terra firme	205	520874	8616083
422	Madre de Dios	Palma Real	Terra firme	210	523337	8615042
423	Tahuamanu	Iñapari	Terra firme	300	441497	8779197
424	Tahuamanu	Iñapari	Terra firme	315	441796	8780385
425	Tahuamanu	Iñapari	Terra firme	300	437603	8782080
426	Tahuamanu	Iñapari	Terra firme	308	441081	8784023
427	Tahuamanu	Iñapari	Terra firme	303	438395	8778975
428	Tahuamanu	Iñapari	Terra firme	324	436938	8777494
429	Tahuamanu	Iñapari	Terra firme	309	438435	8771642
430	Tahuamanu	Iñapari	Terra firme	310	438634	8775123
431	Tahuamanu	Iñapari	Terra firme	308	439651	8766660
432	Tahuamanu	Iñapari	Terra firme	339	438197	8762006
433	Tahuamanu	Iñapari	Terra firme	322	439937	8756840
434	Tahuamanu	Iñapari	Terra firme	332	444088	8751590
435	Madre de Dios	Sector Fitzcarrald	Terra firme	238	463878	8601416
436	Madre de Dios	Las Mercedes	Terra firme	212	450245	8596366
437	Tambopata	San Juan	Terra firme	249	426200	8578113
438	Tambopata	Interoceanico sur nr 3	Terra firme	245	416608	8574894
439	Madre de Dios	Interoceanico sur nr 1	Terra firme	260	485400	8621821
440	Madre de Dios	Bello Horizonte	Terra firme	236	490741	8621281
441	Madre de Dios	Infierno	Terra firme	223	474833	8593635
442	Madre de Dios	Santa Rosa	Terra firme	440	355099	8570951
443	Madre de Dios	Santa Rosa	Terrace	300	357699	8574112
444	Madre de Dios	Santa Rosa	Terrace	282	359094	8576785
445	Madre de Dios	Santa Rosa	Terrace	281	360863	8578796
446	Madre de Dios	Santa Rosa	Premontane	342	362948	8568652
447	Madre de Dios	Santa Rosa	Terra firme	300	363269	8570698
448	Madre de Dios	Santa Rosa	Terra firme	297	361176	8572467
449	Madre de Dios	Santa Rosa	Premontane	385	359790	8569888
450	Madre de Dios	Santa Rosa	Terrace	273	371614	8574717
451	Madre de Dios	Santa Rosa	Terrace	267	370760	8580996
452	Madre de Dios	Santa Rosa	Terrace	343	353317	8559110
453	Madre de Dios	Santa Rosa	Premontane	448	355321	8558571
454	Madre de Dios	Reservar Ecologica Taricaya	Floodplain	187	503400	8615508
455	Madre de Dios	Reservar Ecologica Taricaya	Floodplain	230	502158	8615482
456	Madre de Dios	Reservar Ecologica Taricaya	Floodplain	172	503332	8615482
457	Madre de Dios	Reservar Ecologica Taricaya	Floodplain	211	500825	8614031
458	Madre de Dios	Reservar Ecologica Taricaya	Floodplain	186	502567	8615973
459	Madre de Dios	Reservar Ecologica Taricaya	Floodplain	191	501710	8616056

Table 3. Species registered in the Madre de Dios region by Henderson (1995, 2000). The twelve species not found in this study are highlighted in bold.

Chelyocarpus ulei	*Attalea butyracea*	*Bactris simplifrons*
Mauritia flexuosa	*Attalea maripa*	***Bactris sphaerocarpa***
Chamaedorea angustisecta	*Attalea phalerata*	*Astrocaryum murumuru murumuru (gratum/ulei)*
Chamaedorea pauciflora	***Attalea tessmannii***	*Astrocaryum huaimi (gratum/ulei)*
Chamaedorea pinnatifrons	*Aiphanes aculeata (A. horrida)*	*Astrocaryum murumuru javarense (gratum/ulei)*
Wendlandiella gracilis	***Aiphanes weberbaueri***	***Pholidostachys synanthera***
Iriartea stenocarpa	*Bactris acanthocarpa*	*Geonoma brevispatha*
Iriartea deltoidea	***Bactris brongniartii***	*Geonoma brongniartii*
Socratea exorrhiza	*Bactris chaveziae*	*Geonoma camana*
Socratea salazarii	*Bactris concinna*	*Geonoma deversa*
Wettinia augusta	*Bactris gasipaes chichagui*	*Geonoma interrupta*
Euterpe precatoria	*Bactris hirta spruceana*	*Geonoma macrostachys acaulis*
Oenocarpus bataua	***Bactris macana***	***Geonoma macrostachys macrostachys***
Oenocarpus balickii	*Bactris maraja juruensis*	*Geonoma maxima chelidonura*
Oenocarpus mapora	*Bactris maraja maraja*	***Geonoma stricta piscicauda***
Hyospathe elegans	*Bactris maraja trichospatha*	*Geonoma stricta trailii*
Syagrus sancona	***Bactris martiana***	***Geonoma triglochin***
Desmoncus mitis	*Bactris riparia*	*Phytelephas macrocarpa*
Desmoncus polyacanthos		

The Madre de Dios forests had densities of 1709 – 3245 (average 2755) palms/hectare which overlaps with densities recorded in Ucayali (1460 – 6756 palms/hectare, average 3512; Balslev et al. 2010) and that are similar to values recorded in the Colombian Amazon (2900 – 3737 individuals/hectare, average 3301; Balslev unpublished data).

The range extension of 40 – 320 kilometers for seven species testifies to the patchy nature of the present state of knowledge of Amazon palms. In a study in the upper Ucayali river valley one third of all the palms encountered were found 150 – 400 kilometers beyond their previously known ranges (Balslev et al. 2010).

We identified four forest habitats in our study area: *terra firme,* floodplain, terrace and premontane hills. This is similar to the study in Ucayali (Balslev et al. 2010) where the same four habitats were encountered, where the only difference was that premontane hills were called Andean hills. Thus, for the present study, we tried to standardize the classification in order to make comparisons possible.

The *terra firme* forest in our study recorded the second highest density of palms, and the greatest species richness. In contrast, Balslev et al. (2010) mention the *terra firme* forest in the Ucayali study as a forest with low density and diversity of palms, which may be due to the difference in sampling intensity carried out between the two studies since the Ucayali study included only a single transect in *terra firme*.

In general, floodplain forests have been shown to be not as diverse as the other habitats (Balslev et al. 2011). If the sampling effort in terrace and premontane forest had been a little higher we might have seen a few more species on the list.

Geonoma deversa and *G. occidentalis* were recorded as the two most abundant species. This differs greatly from other palm community studies in Peru (Kahn & Mejia 1990, Balslev et al. 2010, Kahn & Moussa 1994). *Geonoma occidentalis* (previously known as *G. brevispatha*) is not present in any of these studies. The distribution maps in Henderson (2011) show that its distribution is limited to the southern part of the Madre de Dios region in Peru and large parts of Bolivia and Brazil. A study in Bolivia showed high density of *Geonoma occidentalis* as well (Balslev et al. 2012), so it would seem that *Geonoma occidentalis* dominates these forests. *Geonoma deversa* is widespread throughout the Amazon basin (Henderson 1995), but seems to be particularly abundant in the Madre de Dios region compared to other regions (Balslev et al. 2010, Kahn & Mejia 1990). We also found species like *Euterpe precatoria, Attalea phalerata, Iriartea deltoidea, Astrocaryum gratum* and *Astrocaryum ulei* among the abundant species. The abundance of these large palm species is not because they totally dominate the habitats in which they are found. It seem that they have a high environmental adaptability, being able to grow in all habitats with small variations in density. It has also been demonstrated, that widespread palms tend to be tall and habitat generalists (Roukolainen & Vormisto 2000). Height maybe be associated with better dispersal of seeds, which contributes to a wider range. This agrees with the results in our study, where 14 species are found in all habitats and half of those are tall palm species.

As was to be expected for a high diversity area, we found a long tail of rare species (Zimmerman et al. 2008). Our study helps to clarify the conservation status of palms in the Madre de Dios region. A species like *Geonoma camana* is listed by Kahn and Moussa (1994) as insufficiently known *in situ* for the conservation status to be defined. In our study it would be listed

as rare, since it was found in low densities in all habitats except floodplain. Another palm whose conservation status could be changed (from rare to not threatened) is *Astrocaryum huicungo,* which is now called *A. ulei* or *A. gratum* in our region (Kahn & Millán 2009, Kahn & Millan 2013). *Astrocaryum ulei* and *A. gratum* were both abundant species, but interestingly enough they never occurred together. *Astrocaryum ulei* was found north of the Madre de Dios river while *A. gratum* was recorded to the south of it. It appears that the river functions as an effective dispersal barrier (Kahn et al. 2011).

Of the 42 species found, approximately 50% were solitary, 45% cespitose and 5% were colonial. Balslev and collaborators (2011) collected data from a large number of palm community studies all over the Amazon and Central America and found an average of 33% solitary and 66% cespitose species. Compared to that, it seem that solitary species are better represented in the Madre de Dios region respectively.

Conclusion

We found 42 species of palms in the palm communities in Peru's Madre de Dios region. Higher local species richness has been found elsewhere, but the Madre de Dios region is definitely one of the world's "hot spots" for palm diversity. With 38 different species and 2968 individuals per hectare the *terra firme* forest had the richest palm flora. The same pattern has been shown in other locations where *terra firme* communities are known for their extremely high local species richness (Balslev et al. 2011, Kahn & de Granville 1992). The palm communities of floodplain, terrace and premontane hill had similar species richness, but terrace forest had much lower abundance of palms. This is opposite to what has been found in the upper Ucayali river valley (Balslev et al. 2010), where terrace forest had by far the highest abundance of palms. The different results of the two studies show how important it is to know an area before deciding how to manage it. For example when exploiting palm species in terrace forests, the lower density in Madre de Dios should be taken into account so that the pressure on the forest is lowered compared to Ucayali. Bernal et al. (2011) discussed the management for 96 species of palms in South America and showed the necessity for stopping the custom of destructive harvest and assessing production of exploited areas.

In our study area the palms occupied all strata of their habitats. Palms were not as species rich or as abundant in the understory as they were in the mid-canopy and in the top of the canopy. The seven most abundant species were all found in the mid- and top canopy.

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