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Palm Communities in Western Ecuador

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Western Ecuador is, in spite of its modest area of ca. 80 000 km², one of the most heterogeneous regions of South America with respect to climate and vegetation types. It joins the Chocó wet forest region stretching from Panamá through western Colombia to northern Ecuador, the isolated Túmbez dry forest region of northwestern Peru–southwestern Ecuador, and the premontane moist and wet forest belt on the lower part of the western slopes of the Andes mountains. The region is characterized by strong climatic and altitudinal gradients, which result in the formation of several narrow vegetation zones, which tend to run in a northwest–southeast direction. Especially in the extreme north and south abrupt changes from wet evergreen forest to dry deciduous *Ceiba trichistandra* savanna may occur over very short distances. Fragmentation of the vegetation zones by local cloud forest formation in the Andean foothill region and in the Cordillera de la Costa, at elevations as low as 600–800 m, further adds to the biogeographic complexity. Plant species endemism is high throughout the region, especially in the moist and dry forest zones (Borchsenius 1997a). Unfortunately human pressure on the vegetation is also high, and the forests of western Ecuador are severely threatened (Dodson and Gentry 1991).

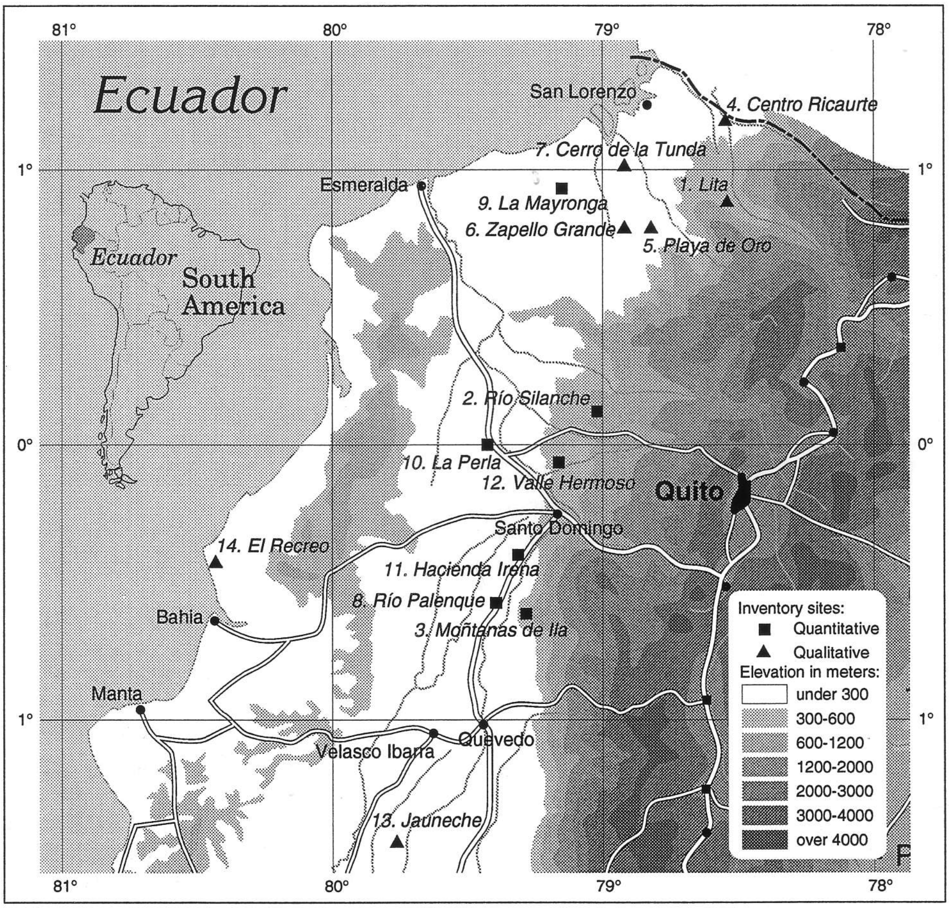
The present paper presents information on the palm communities at 14 localities in western Ecuador, with the aim of describing the qualitative and quantitative changes produced over small distances. In addition, the potential value of palms as indicator organisms for the overall climatic regime is discussed. Palms in the neotropics in general present several interesting features that make them promising indicator organisms: they are abundant in the vegetation; their species diversity is sufficiently high to allow both qualitative and quantitative differences in community structure to be detected; and their taxonomy is worked out sufficiently well to allow reliable identification of the taxa involved.

Materials and Methods

Qualitative inventories were compiled for 14 localities in western Ecuador (Fig. 1), representing six life zones in the sense of Holdridge et al. (1971). The inventories are based on revisions of herbarium collections kept in Aarhus University (AAU), the Departamento de Ciencias Biológicas of the Pontificia Universidad Católica del Ecuador (QCA), and Herbario Nacional del Ecuador (QCNE), together with visits to most of the sites during 1992–1994. A list of the localities, together with basic data on these, is provided in Table 1.

Quantitative inventories, based on transects of 0.1 ha placed in mature, undisturbed forest, were made for seven of the localities, mostly in the moist forest zone (Fig. 1). Each transect was 200 m long and 5 m wide, and divided into subfields 5 × 5 m square. All palm individuals present were identified, and referred to size class (>10 m tall, 3–10 m tall, 1–3 m tall, <1 m tall) and stage (adult, juvenile, seedling). Seedlings were only counted in every fourth subfield. In the final data table (Table 3) and in the computation of quantitative similarity indices, seedling numbers were left out, as it became obvious that seedling populations fluctuate greatly over the year, depending on fruit maturation and germination season for the dominant species. Seedlings are, however, included in tables concerning overall numbers of individuals and in comparisons with other studies. For three of the seven transects, the number of dicot trees in two size classes were also counted (diameter at breast height 5–10 cm, or > 10 cm) in order to provide a rough estimate of the structural importance of palms in the forests.

Naming of taxa follows Henderson et al. (1995), with the following exceptions: *Socratea hecatonandra* and *S. montana* are here included in *S. rostrata,* and *Geonoma irena* is separated from *G. cuneata* as a distinct species following Borchsenius (1997b). Herbarium vouchers of all taxa are deposited at the herbarium of Aarhus University



1. Map of western Ecuador showing the location of the 14 study sites listed in Table 1.

(AAU) and the herbarium of the Departamento de Ciencias Biológicas of the Pontificia Universidad Católica del Ecuador (QCA). A list of representative specimens collected at the different sites is available from the author upon request.

Similarity between sites was assessed by means of similarity indices calculated in the computer program r-Package (Legendre and Vaudor 1991). Cluster analyses based on similarity matrices were performed in the same program, using the unweighted arithmetic average algorithm (UPGMA). The similarity indices used were: the qualitative index of Sørensen, $IS_s = 2c/a + b$, where c is the number of species shared between two sites and a and b are the total numbers of species found at each of the two sites; and the quantitative index of Steinhaus, $IS_w = 2W/A + B$, where W is the total number of individuals belonging to species shared between the two sites, and A and B the numbers of individuals found at each site.

Results

The qualitative inventories for the 14 sites in this study contained a total of 45 species (Table 2), corresponding to 83% of all species (54) so far known to western Ecuador. The seven transected moist forest remnants contained a total of 28 species, of which 26 were recorded in the transects themselves. Alpha diversity for individual sites ranged from 3 to 6 at the two driest locations in the southwest (El Recreo and Jauneche), to 19 in the wet premontane forest at Lita in the north. The number of species recorded in each of the seven 0.1-ha transects ranged from 6 to 13, with the highest value recorded at the most rainy and humid site in the Montañas de Ila.

Table 1. Study sites. For each site geographical location, elevation in meters, annual precipitation in millimeters estimated from available climatic data, lifezone (Holdridge et al. 1971), and relevant references are given. Lifezone abbreviations. PPf: premontane pluvial forest. PWf: premontane wet forest. TWf: tropical wet forest. TMf: tropical moist forest. TDf: tropical dry forest. TVDf: tropical very dry forest.

Study sites	Abbr.	Geo. location	Elev.	Prec.	Lifezone	Ref.
1. Lita	Lit	78°33′W, 00°53′N	800	6 000	PPf	
2. Montañas de Ila	Sil	79°01′W, 00°07′N	700	3 700	PWf	(1)
3. Río Silanche	Ila	79°18′W, 00°38′S	600	3 000	PWf	
4. Centro Ricaurte	Ric	78°32′W, 01°10′N	200	5 900	TWf	(2)
5. Playa de Oro	Oro	78°50′W, 00°48′N	300	6 000	TWf	
6. Zapallo Grande	Zap	78°55′W, 00°48′N	100	5 200	TWf	
7. Cerro de la Tunda	Tun	78°55′W, 01°01′N	50	3 300	TMf	
8. Río Palenque	Pal	79°22′W, 00°35′S	200	2 900	TMf	(3)
9. La Mayronga	May	79°10′W, 00°55′N	100	3 100	TMf	
10. La Perla	Per	79°25′W, 00°01′S	250	3 300	TMf	
11. Hacienda Irena	Ire	79°18′W, 00°23′S	280	2 900	TMf	
12. Valle Hermoso	Her	79°10′W, 00°04′S	420	3 700	TMf	
13. Jauneche	Jau	79°45′W, 01°27′S	100	1 500	TDf	(4)
14. El Recreo	Rec	80°26′W, 00°26′S	50	600	TVDf	

1: Jørgensen and Ulloa (1989). 2: qualitative inventory based on collections in Herbario Nacional del Ecuador (QCNE). 3: Dodson and Gentry (1978). 4: Dodson et al. (1985).

The numbers of individuals in different size classes found at the seven transects are given in Table 4. Overall density of palms was highest at the premontane cloud forest site in the Montañas de Ila with 508 adult or juvenile individuals/0.1 ha plus 1 020 seedlings, and lowest at the La Mayronga site with 74 adult or juvenile individuals/ 0.1 ha plus 65 seedlings. The relative proportion of juvenile and adult palms varied considerably between lifeforms (Fig. 2). Solitary palms had a higher proportion of juvenile and seedling individuals than cespitose palms. Finally, comparison of the total number of palms and dicot trees in comparable size classes for three localities (Table 5) shows that palms make up a substantial component of the total tree stratum at these sites.

Cluster analysis based on a matrix of qualitative similarity for the 14 inventoried sites (Fig. 3) shows a division into four groups: (1) three premontane sites located at 600–900 m elevation (Lita, Río Silanche, and Montañas de Ila); (2) three northern lowland wet forest sites with 5 100–6 000 mm annual precipitation (Centro Ricaurte, Playa de Oro, and Zapallo Grande); (3) six lowland moist forest sites with 3 100–3 300 mm annual precipitation (Cerro de la Tunda, Río Palenque, La Mayronga, La Perla, Hcda. Irena, and Valle Hermoso); and (4) two dry forest sites with 600–1 500 mm annual precipitation (Jauneche and El Recreo). Characteristic species defining the groups were *Aiphanes erinacea, Socratea rostrata* (group 1), *Asterogyne martiana, Geonoma congesta* (group 2), *Desmoncus cirrhiferus* (group 1–2), *Geonoma irena* (group 3), *Astrocaryum standleyanum, Attalea colenda* (group 3–4), and *Syagrus sancona* (group 4). Species found in most of the region, except the two driest sites, included *Geonoma cuneata* and *Wettinia quinaria*, both with a preference for the wetter sites, together with *Iriartea deltoidea, Synechanthus warscewiczianus,* and *Wettinia aequalis*, all with a preference for lowland sites. Only *Bactris setulosa* and *Phytelephas aequatorialis* occurred at sites in all four groups, the latter with a preference for moist forest sites.

Qualitative similarities between the seven transected forest remnants resulted in a grouping pattern similar to that observed for all 14 sites with a basal grouping in the two premontane sites and the remaining five lowland moist forest sites (Fig. 4A). Quantitative comparisons, however, show a different pattern, where geographically close sites tend to have higher similarity values, e.g., Valle Hermoso/La Perla, and Río Palenque/Hcda. Irena (Fig. 4B). This comparison also stresses the dissimilarity between the most western site at La Mayronga, and the two eastern, premontane sites Montañas de Ila and Río Silanche. In addition, a marked dissimilarity is noted between the two latter sites, not evident in the qualitative comparison, due to dominance of *Wettinia quinaria* and *Iriartea deltoidea* in the first, vs. *Wettinia aequalis* and *Socratea rostrata* in the latter.

Table 2. Palm taxa recorded at 14 sites in western Ecuador (Table 1). Sites 1–3: premontane wet to pluvial forest. Sites 4–6: tropical wet forest. Sites 7–12: tropical moist forest. Sites 13–14: tropical dry to very dry forest.

Taxa	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Aiphanes hirsuta	x													
Aiphanes macroloba	x													
Bactris hondurensis	x													
Chamaedorea deneversiana	x													
Chamaedorea pinnatifrons	x													
Wettinia oxycarpa	x													
Geonoma tenuissima		x												
Hyospathe elegans		x												
Socratea rostrata	x	x												
Aiphanes erinacea	x	x	x											
Desmoncus cirrhiferus	x	x		x	x	x								
Geonoma cuneata var. *gracilis*	x	x			x									
Geonoma leptospadix	x			x										
Pholidostachys synanthera	x				x									
Geonoma cuneata var. *cuneata*	x	x	x		x	x	x	x	x					
Prestoea decurrens	x	x	x	x		x	x							
Aiphanes tricuspidata		x	x		x		x							
Geonoma cuneata var. *procumbens*	x	x	x	x								x		
Pholidostachys dactyloides	x	x	x	x		x	x	x			x			
Wettinia quinaria	x		x	x	x	x		x			x			
Iriartea deltoidea			x		x	x	x	x	x	x	x	x		
Oenocarpus bataua			x		x		x	x	x	x		x		
Synechanthus warscewiczianus		x		x	x	x	x	x	x	x	x	x		
Bactris setulosa		x	x		x	x	x	x	x	x	x	x	x	
Geonoma cuneata var. *sodiroi*	x	x									x			
Chamaedora linearis	x		x					x		x	x			
Wettinia aequalis		x	x					x			x	x		
Geonoma congesta				x										
Geonoma linearis						x								
Asterogyne martiana				x	x									
Geonoma deversa				x			x							
Oenocarpus mapora						x			x					
Euterpe precatoria				x	x	x	x							
Prestoea ensiformis							x	x						
Socratea exorrhiza				x	x	x	x	x	x	x				
Bactris coloradonis							x							
Geonoma interrupta										x	x			
Welfia regia										x		x		
Geonoma irena							x	x	x		x			
Phytelephas aequatorialis						x	x	x	x	x	x		x	
Astrocaryum standleyanum							x	x	x	x	x		x	
Attalea colenda							x	x	x	x			x	x
Bactris coloniata													x	
Syagrus sancona													x	x
Aiphanes eggersii														x
Total species	19	15	12	12	13	14	17	15	11	11	12	7	6	3

Discussion

Alpha diversity recorded at the various sites in this study is lower than that encountered in climatically comparable parts of the Amazon region. Kahn et al. (1988) and Kahn and Mejia (1991) reported values of 26–35 species of palms on areas of 0.5–0.72 ha of terra firme in the central and western part of the Amazon basin, which significantly outnumbers even the whole-area qualitative inventories for the most wet and species-rich

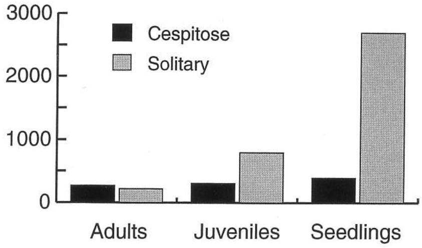
Table 3. Numbers of individuals (excl. seedlings) of 26 palm taxa in seven transects of 0.1 ha. (Table 1).

	Site						
Taxa	2 (Ila)	3 (Sil)	8 (Pal)	9 (May)	10 (Per)	11 (Ire)	12 (Her)
Geonoma tenuissima	17						
Hyospathe elegans	12						
Socratea rostrata	218						
Aiphanes erinacea	3						
Geonoma cuneata var. *gracilis*	136						
Geonoma cuneata var. *cuneata*	30	81	18	4			
Prestoea decurrens	1	12					
Aiphanes tricuspidata		1					
Geonoma cuneata var. *procumbens*	5						28
Pholidostachys dactyloides	8	64	12			1	
Wettinia quinaria		67				1	
Iriartea deltoidea		6		7	33	17	33
Oenocarpus bataua		1		18	1		7
Synechanthus warscewiczianus	12		80	10	19	16	12
Bactris setulosa	4	4	3		4	6	
Geonoma cuneata var. *sodiroi*	1					6	
Chamaedorea linearis		7	2		1	2	
Wettinia aequalis	61		41			108	50
Oenocarpus mapora				1			
Socratea exorrhiza				10	8		
Geonoma interrupta						3	
Welfia regia					111		74
Geonoma irena						45	
Phytelephas aequatorialis			7	7	1		
Astrocaryum standleyanum			2	6		1	
Attalea colenda				11			
Total							
Adults	180	69	75	7	28	86	37
Juveniles	328	174	90	67	150	120	167

localities in northwestern Ecuador. Similarly, Balslev (pers. comm.) found 22–27 species in five plots of 0.25 ha of terra firme forest in the Yasuní National Park in Amazonian Ecuador. In the eastern, more seasonal part of the Amazon at Río Tocantins, Kahn et al. (1988) reported 13 spp. on 3.84 ha, an alpha diversity of the same general level as that encountered in this study. Nevertheless, due to climatic heterogeneity and differences in species composition of the palm flora at different sites in western Ecuador, the region as such ends up with an overall diversity of 54 species, not much lower than that of eastern Ecuador (65 species).

Table 4. Numbers of palm individuals in five size classes in seven 0.1-ha transects.

	Size class					
Site	>10 m	3–10 m	1–3 m	0–1 m	Total	Seedl.
Montañas de Ila	35	48	87	338	508	1020
Hcda. Irena	11	44	13	138	206	400
Río Palenque	0	48	60	57	165	208
La Mayronga	5	8	20	41	74	65
Río Silanche	21	32	51	138	243	368
Valle Hermoso	19	38	65	82	204	744
La Perla	20	21	58	79	178	296
Total	111	239	354	873	1578	3101



2. Numbers of adult, juvenile, and seedling individuals of solitary (14 spp.) and caespitose (12 spp.) palms, summed for the seven 0.1-ha transects.

While alpha diversity is modest in the region, palm density is high, even compared to the more diverse moist Amazonian forests. The average value of 518 individuals (including seedlings) per 0.1 ha for the seven transects in this study falls within the range of 323–986 individuals per 0.1 ha reported for central and western Amazon terra firme sites by Kahn et al. (1988), and the highest value recorded here, of 508 adult and juvenile palms plus an estimated 1 020 seedlings on 0.1 ha at the Montañas de Ila site, marks a new record of palm abundance in the literature. Another remarkable difference between the findings of this study and those from the Amazon is the high density of large tree palms more than 10 m tall, up to 20–35 trees per 0.1 ha for the four most palm-rich sites, vs. 1–5 tall tree palms per 0.1 ha for terra firme, and 2–20 for swamp forest in northeastern Peru (Kahn et al. 1988, Kahn and Mejia 1990). The results emphasize the extraordinary structural and ecological importance of palms in the moist and wet forests of western Ecuador.

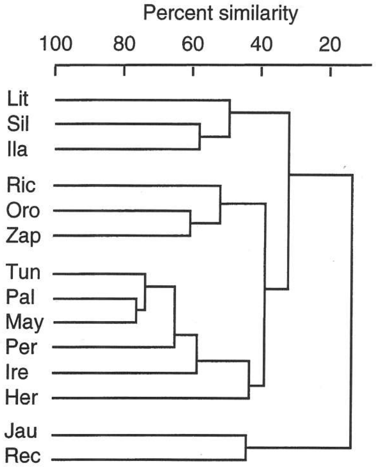
The quantitative inventories reveal striking changes in community composition over quite small geographic distances. In some cases this involves a substitution of dominant species, while the overall species lists remain fairly similar. A good example of this is provided by the two premontane localities Río Silanche and Montañas de Ila with dominance of *Wettinia quinaria* plus *Iriartea deltoidea*, and *Wettinia aequalis* plus *Socratea rostrata*, respectively. Another example comes from the *Welfia regia* dominated forest remnants at La Perla and Valle Hermoso. While the presence or absence of that species makes little difference in the qualitative similarity indices, the tremendous abundance of this palm in the forests is strongly reflected in the quantitative indices, whose values are very similar for the two sites and well separated from other lowland moist forest

Table 5. Numbers of palms and dicot trees in comparable size classes in three 0.1-ha transects.

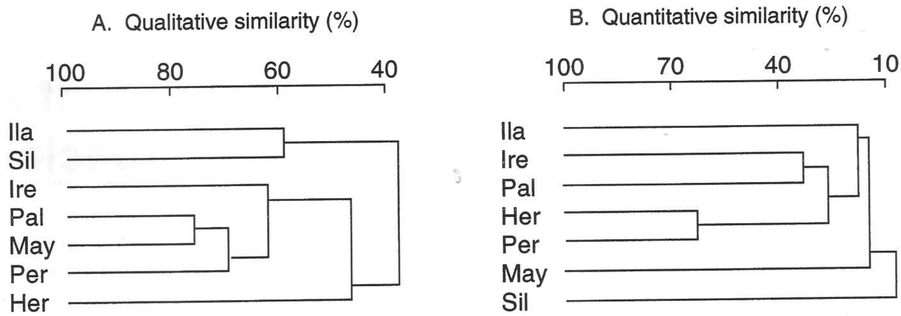
Size class	Río Silanche	Valle Hermoso	La Perla
Palms 3–10 m tall	32	38	21
Trees 5–10 cm dbh	45	27	35
Palms > 10 m tall	21	19	20
Trees > 10 cm dbh	50	33	27

sites, which they resemble qualitatively. A transect size of 0.1 ha is evidently not enough to get a detailed quantitative image of the palm community and the internal variation at a given locality. Nevertheless, it will provide an overall pattern of dominant or frequent species at a site, and due to the factors discussed above, several small transects will probably give a better impression of overall palm distribution and abundance than few, detailed studies involving larger areas. Besides, it actually proved difficult to locate just 0.1 ha of forest with intact canopy in several of the sites visited in this study, a fact that rather accurately illustrates the present conservation status of the west Ecuadorean moist forests.

In spite of the preliminary nature of this study, the results indicate that some palms do have distributions that seem to reflect climatic conditions rather accurately, at least if western Ecuador is regarded separately. Species restricted to one or a few lifezones include *Asterogyne martiana* and *Geonoma congesta* (tropical wet forest), *Aiphanes*



3. Dendrogram resulting from UPGMA cluster analysis of a qualitative similarity matrix for 14 sites in western Ecuador. Site abbreviations according to Table 1.



4. Dendrograms resulting from UPGMA cluster analysis of similarity matrices for seven sites in western Ecuador. (A) Qualitative similarity. (B) Quantitative similarity based on numbers of individuals (excl. seedlings) in one 0.1-ha transect per site.

erinacea (premontane wet forest), *Desmoncus cirrhiferus* (tropical and premontane wet forest), *Geonoma irena* (tropical moist forest), *Astrocaryum standleyanum, Attalea colenda* (tropical moist to dry forest), and *Syagrus sancona* (tropical dry forest). Other species of interest, particularly from a quantitative point of view, include *Wettinia quinaria* (dominant in wet forest types), *Synechanthus warscewiczianus* (dominant in moist forest types), and *Wettinia aequalis* (dominant in tropical moist forest close to the Andes and in some wet premontane forest types). The extreme dominance of *Socratea rostrata* at the Montañas de Ila site is apparently related to frequent cloud formation at that locality. The species appears suddenly at a certain altitude, and replaces *Iriartea deltoidea* as dominant in the forest canopy over an elevation interval of a few hundred meters. In the area of the Río Silanche locality the same phenomenon occurs at approximately 1100 m elevation.

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