Indigenous Perceptions of Tree Species Abundance Across an Upper Amazonian Landscape

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INDIGENOUS PERCEPTIONS OF TREE SPECIES ABUNDANCE ACROSS AN UPPER AMAZONIAN LANDSCAPE

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Indigenous cultures know a great deal about the landscape they inhabit, and their knowledge can be a valuable tool for ecologists. In order to explore how residents' knowledge might help characterize a large and diverse forest type in southeastern Peru, we asked plant experts of the local Cashinahua culture to predict whether the tree species recorded in a single 1-ha plot in upland forest were common on the surrounding landscape. We then compared their answers with data collected in four other 1-ha plots scattered over an area of about 7,000 km². Cashinahua predictions matched tree plot data for 66% of the species examined. Species labeled as common by the Cashinahua included 9 of the top 11 most common species in the 5 plots and 39% of all trees in the plots. We discuss three obstacles to using local knowledge in large-scale vegetation studies: 1) the often-confusing relation between indigenous and Linnaean taxonomic nomenclature, 2) differing cultural conceptions of commonness and rarity, and 3) the limitations of describing tree species abundance via 1-ha tree plots. Where these limitations can be overcome, studies of large-scale vegetation patterns stand to benefit greatly from incorporating local knowledge of regionally abundant species.

Key words: *Amazon, Cashinahua, Matsigenka, Peru, Purus, tree species abundance, indigenous knowledge*

Las culturas indígenas poseen conocimientos detallados de los paisajes donde ellos residen y estos conocimientos pueden ser de gran utilidad para los ecólogos. Para investigar cómo los conocimientos tradicionales puedan ayudar a caracterizar un tipo de bosque diverso y extenso en el sudeste peruano, preguntamos a expertos de la cultura Cashinahua si las especies arbóreas en una parcela de 1 ha son comunes o raras a nivel de paisaje. Comparamos sus respuestas con datos obtenidos de otras cuatro parcelas de árboles establecidas en un área de cerca de 7,000 km². Las predicciones Cashinahua concordaron con los datos de parcelas para un 66% de las especies examinadas. Las especies indicadas como comunes por los Cashinahua incluyeron 9 de las 11 especies más comunes en las cinco parcelas de árboles y representaron un 39% de todos los árboles en la red de parcelas. Existen tres obstáculos al uso de conocimientos locales para los estudios de vegetación a grandes escalas: 1) la frecuente falta de concordancia entre la nomenclatura taxonómica indígena y la de Linnaeus, 2) concepciones diferentes de la abundancia y la rareza, y 3) las limitaciones en describir la abundancia de especies arbóreas con parcelas de árboles de 1 ha. Cuando estas limitaciones pueden ser superadas, los estudios de vegetación a escalas grandes pueden beneficiarse de los conocimientos locales sobre la abundancia regional de las especies.

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Introduction

Several studies have reported that indigenous cultures living in tropical forests use meticulous classification systems to distinguish between vegetation types on the landscape (Abraão et al. 2008; Fleck and Harder 2000; Gilmore and Young 2010; Hernandez-Stefanoni et al. 2006; Shepard et al. 2001; Torre-Cuadros and Ross 2003). For example, Shepard et al. (2004) reported that the Matsigenka of southeastern Peru distinguish at least 61 different vegetation types in the lowlands of Manu National Park. When these vegetation types are mapped onto satellite imagery, the results are similar to the vegetation maps that ecologists use to describe the distribution of vegetation types over large spatial scales. Given that indigenous plant experts are able to generate such maps without the intensive botanical inventories and multivariate statistical analyses required by ecologists, these studies make it clear that vegetation mapping in the tropics can benefit when indigenous experts provide ''ethnobotanical ground-truthing'' (Shepard et al. 2004).

In this paper we ask whether indigenous experts can also help ecologists detect the strong but sometimes well-disguised homogeneous elements present in Amazonian tree communities. In a previous publication, we reported that upland (*terra firme*) forests of eastern Ecuador and southeastern Peru were dominated by a suite of tree species that were both locally common and frequently encountered across about 10,000 km² of forest (Pitman et al. 2001). Until that study, the prevailing notion in the ecological literature was that the abundance of tropical tree species fluctuated across the landscape (e.g., Gentry 1988; Hubbell and Foster 1986a). The data from Ecuador and Peru suggested a very different scenario, in which upland forests were dominated by a small suite of ubiquitous taxa representing 63–73% of all trees (Pitman et al. 2001). Similar oligarchies have since been documented for tree and liana communities in other areas of western Amazonia (Burnham 2002, 2004; Macía and Svenning 2005; Vormisto et al. 2004).

In this paper we ask whether indigenous plant experts also recognize these large-scale oligarchies. Our question is not whether indigenous residents recognize that some tree species dominate forest types over large scales –the answer to that broad question is clearly yes (e.g., see Shepard et al. 2004)– but rather whether they recognize them in *upland* forests of western Amazonia. The distinction between upland and other forest types is important because the dominant tree species in Amazonian uplands are rarely common in an absolute sense. Unlike *Mauritia* L. f. palm swamps, where the single most common species can account for 100% of all trees in a hectare, the single most common tree species in a hectare of upland forest in western Amazonia can account for as few as 3% of all trees (Vriesendorp et al. 2004). In order to detect upland oligarchies, ecologists typically need to establish multiple vegetation inventories at intervals across the landscape– an undertaking requiring weeks of work.

Thus it is a valid question whether indigenous plant experts recognize upland tree oligarchies. For example, the Matsigenka are reported to characterize upland forests primarily via indicator species that are not trees– e.g., as places where certain bird species sing, certain kinds of fern, moss, and epiphytes grow,

or certain understory palms are frequent (Shepard et al. 2001, 2004). Indeed, Shepard et al. (2001:Table 2) report that the Matsigenka only associate a few large-tree taxa with upland forests, and they use those species to indicate atypical conditions there (e.g., *Mauritia*, *Oenocarpus*, *Socratea* and *Euterpe* in swampy areas, *Cecropia* and *Erythrina* spp. in disturbed areas). As a result, the largest upland forest type in Shepard et al. 's (2004:Figure 6) map of Matsigenka-defined habitats around the village of Tayakome in Manu National Park is defined in that study by an understory palm species (*Socratea salazarii*), which gives almost no information about the tree community in that forest type.

Since upland forests are typically the largest and most diverse habitat patches on Amazonian landscapes –typically with more than 1,000 species of large trees that account for most of the regional biomass (Pitman et al. 2001)– describing them via non-arboreal organisms effectively leaves large areas of the vegetation map as terra incognita. We suspected that this result reflected the design of previous studies rather than the capabilities of indigenous plant experts, and speculated that a more precise characterization of upland tree communities would make ethnobotanical ground-truthing even more useful for ecologists. We tested the proposition in southeastern Peru by first asking indigenous plant experts at a single upland site to predict the landscape-scale abundance of several dozen tree species, and then testing their predictions with data from five upland tree inventories established across that landscape.

Study Site and Indigenous Residents

Study Site

The study was carried out in the headwaters of the Purús River, a landscape of low hills and valleys in Peru's Ucayali and Madre de Dios departments (Figure 1; both the river and the region are referred to hereafter by their Peruvian name, Alto Purús). This is lowland Amazonian forest between 250 and 350 masl. Mean temperature is about 25°C and annual rainfall averages around 2000 mm, 80% of which falls during the October-to-April rainy season (Pitman 2003). Rivers in the Alto Purús watershed are flanked by a very narrow band of floodplain forest types, which together account for just about 5% of the landscape. Thus around 95% of the landscape is hilly or terraced uplands, which are covered by closed-canopy forest and extensive bamboo thickets (Pitman, Graham et al. 2003). There are no roads in this region.

Indigenous Residents

The Cashinahua are a self-identifying indigenous group of the Panoan cultural/linguistic family who live along the upper Juruá and Purús watersheds in Brazil and adjacent Peru. Following permanent contact with non-indigenous settlers in the 1950's, the Peruvian Cashinahua suffered a series of epidemics of introduced disease that wiped out as much as 80% of the population (Kensinger 1995). Since that time, in large part due to outside intervention in the form of vaccines and other Western medical attention, the group has recovered from the demographic collapse to a current population of 2,000–3,000 in Peru and 1,000–2,000 in Brazil.
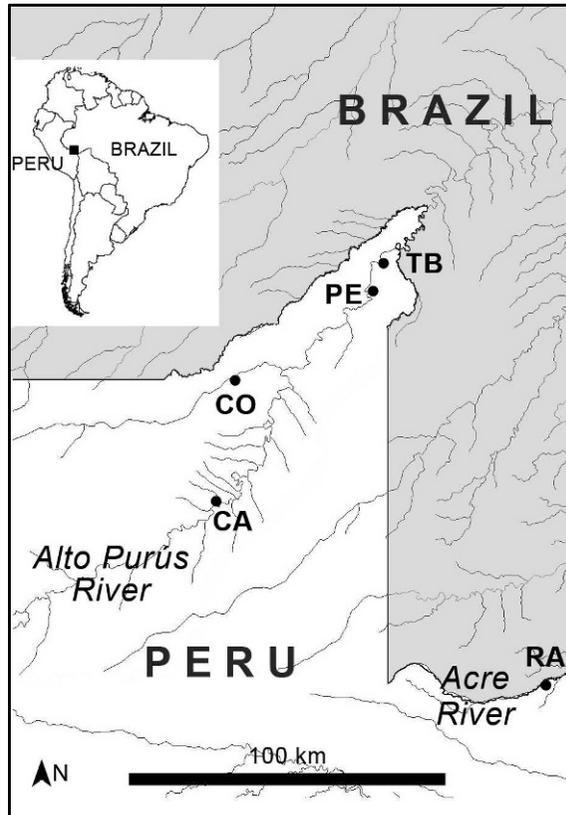
Figure 1. A map of the study region in southeastern Peru showing the location of the tree plots mentioned in the text. See Table 1 for the names of the plots.

The Cashinahua live in autonomous villages, each under the leadership of a headman, with traditional kinship relationships based on intermarriage within a two-clan (moiety) system. Villagers practice slash-and-burn agriculture in the surrounding forests, planting subsistence crops of manioc, maize, bananas and peanuts, and supplement their diet with fish and game.

Traditional gender separation of subsistence activities provides virtually all Cashinahua males with an intimate knowledge of trees. Because hunting requires a detailed knowledge of plants, especially those whose fruits attract game, men learn to identify trees from their fathers and older kinsmen at a young age. This day-to-day familiarity with upland tree communities is bolstered every few years by months-long dry season campaigns to clear tracts of upland forest for new garden plots.

Indigenous Informants

Our data comes from two Cashinahua plant experts. MPC was around 60 years old at the time of the Puerto Esperanza fieldwork and his oldest son, MPP, was 30. Both have traveled extensively in the Alto Purús region and have worked in jobs (skin collector, rubber tapper) that exposed them to upland forests

Table 1. Characteristics of the five 1-ha tree plots mentioned in the text. The two-letter codes are used for the plot locations in Figure 1.

Tree plot	Coordinates	Elev. (masl)	No. trees	No. species	Basal area (m²)
Caobal 1 (CA)	10°23′30.8″S 71°13′04.3″W	340	609	157	35.2
Colombiana (CO)	10°04′20.7″S 71°05′47.2″W	330	542	132	41.1
Puerto Esperanza (PE)	9°46′37.9″S 70°4′54.2″W	280	518	158	29.6
Tres Bolas (TB)	9°41′12.6″S 70°38′42.3″W	250	532	150	24.7
Río Acre (RA)	11°00′11.7″S 70°06′26.6″W	~250	677	114	46.2
Total			2878	407	

at several different locales in our study area. While neither man is recognized in their community as a traditional Cashinahua herbalist –known as a ***bata dauya*** and trained in a complex system of plant classification (Graham 2001; Kensinger 1995)– this does not necessarily reflect a lack of expertise in identifying trees. Indeed, hunters may be as expert at tree identification as herbalists, since many of the plants employed in traditional Cashinahua medicine are shrubs and herbs (Graham 2001).

Methods

Tree Plot Data

Between 1997 and 2002, three of the authors who are Linnaean-trained botanists (PN, NP, and JT) established five 1-ha plots in upland forests in the Alto Purús watershed (Table 1). Three plots are on the Alto Purús River; one is on the Curanja and one is on the Acre. The two closest plots are separated by 38 km; the two most distant plots are 139 km apart. The minimum convex polygon containing all plots measures roughly 7,000 km².

In each 100 ×100 m plot, all free-standing trees ≥10 cm dbh were measured for diameter and identified to Linnaean species or morphospecies by NP, PN, and/or JT. Some trees that could not be identified in the field, based on those authors' prior experience carrying out tree inventories in southeastern Peru, were collected and voucher specimens compared to specialist-identified specimens in the Vargas Herbarium of the Universidad Nacional San Antonio Abad del Cusco (CUZ) and the Museo de Historia Natural de la Universidad Nacional Mayor de San Marcos (USM). Following the establishment of the plots, taxonomy within the five-plot dataset was standardized by NP, so that morphospecies A in one plot is equivalent to morphospecies A in all others. Photographs of all vouchers are available upon request from NP.

Cashinahua Abundance Predictions

At one plot, established in 2002 by NP just south of the town of Puerto Esperanza, two members of the Cashinahua indigenous group (MPC and MPP) also identified each tree ≥10 cm dbh using Cashinahua taxonomic nomenclature. The spelling of Cashinahua names was regularly checked during the fieldwork and later standardized by JG, a botanist familiar with the Cashinahua language. For each tree, the Cashinahua plant experts also answered the following

**Regional abundance
according to tree plot data**

	Common (oligarchs)	Not common (not oligarchs)
Common	21	18
Occasional	2	5
Rare	4	21

Cashinahua predictions (vertical axis label)

Figure 2. Correspondence between perceived and recorded abundance of 71 Amazonian tree species, based on Cashinahua predictions of regional abundance and tree plot data. The predictions were made in one of the five plots, while the data come from all five plots.

question: ''If you searched for this species in upland forests between here and the town of Colombiana (55 km to the southwest of Puerto Esperanza), would finding it be easy, hard, or somewhere in between?'' We converted the answers to this question to three qualitative measures of landscape abundance: ''common,'' ''rare,'' and ''occasional.'' The Cashinahua tree identifications and abundance predictions were a shared exercise; after a machete slash to the trunk, the two Cashinahua informants often engaged in a brief discussion with each other before offering an answer. Prior informed consent was given as part of a larger, long-running project involving these same informants (Graham 2001).

Comparison of Tree Plot Data and Cashinahua Predictions

Comparing the indigenous predictions to the tree plot data was complicated by the fact that the former were encoded in the Cashinahua plant classification system while the latter relied on Linnaean names. Correspondence between the two systems is imperfect, not just in our study but more generally (Graham, unpublished data); at the Puerto Esperanza tree plot, trees belonging to a single Cashinahua taxon were often recognized as multiple taxa by Linnaean botanists, and vice versa. We leave a fuller discussion of the complex relationships between the Linnaean and Cashinahua plant taxonomies to a future paper. Here we restrict the analysis to cases of perfect correspondence (i.e., names in one nomenclatural system that were used exclusively and consistently for a single name in the other nomenclatural system).

To analyze how closely Cashinahua predictions of abundance and rarity corresponded to the data collected in the five tree plots, we used a 2×2 contingency table analysis based on Fisher's exact test. The 2×2 table was a modified version of Figure 2, in which the Cashinahua categories ''occasional'' and ''rare'' were collapsed into the single category ''not common.'' To compare the mean abundances of species in the three Cashinahua abundance categories, we used t-tests.

Table 2. Frequency and density data for 71 tree species in five 1-ha plots in the Alto Purús region, independently segregated into 3 abundance classes by Cashinahua plant experts.

Cashinahua prediction of regional abundance	Number of species	Mean number of 1-ha plots where recorded	Median density in the five 1-ha plots (trees/ha)
Common	39	3.1 ± 1.5	1.8
Occasional	7	2.3 ± 1.4	0.8
Rare	25	2.0 ± 1.0	0.5

Results

The five 1-ha plots in the Alto Purús watershed contained a total of 2,878 trees $\geq$10 cm dbh, sorted to 407 Linnaean species and morphospecies. The plots showed strong oligarchic elements, with the same suite of taxa dominating the community in most individual hectares. Fifty-one of the 407 species-level taxa were both frequent (recorded in most plots) and locally abundant (mean abundance $\geq$1 individual/ha). Representing 12.5% of all species, these 51 taxa accounted for 55% of all trees in the combined plots and 29–70% of trees in the individual hectares (and are hereafter referred to as oligarchic species, or oligarchs). Further details of the oligarchy in the Alto Purús tree plots, including a comparison with oligarchies in tree communities of the neighboring Madre de Dios watershed, are given in Pitman, Terborgh et al. (2003).

The Puerto Esperanza hectare contained 518 trees $\geq$10 cm dbh. The Linnaean botanist NP sorted these to 160 Linnaean species and morphospecies, with the exception of 6 trees that he was unable to identify. The Cashinahua plant experts sorted the same trees to 140 Cashinahua names, with the exception of 3 trees that they were unable to identify. In 71 cases, there appeared to be perfect correspondence between Linnaean and Cashinahua taxonomy. These 71 taxa represent 60% of all trees in the Puerto Esperanza plot.

Of the 71 species-level taxa for which Cashinahua and Linnaean names were consistent, 27 were oligarchs and 44 were not. Cashinahua experts called 78% of oligarchic species ''common'' and 59% of non-oligarchs ''rare'' or ''occasional'' (Figure 2). Cashinahua predictions of regional abundance corresponded with abundance patterns in the tree plot data for 47 of the 71 species tested (66%). There was a strong and statistically significant association between the Cashinahua abundance predictions and the abundances observed in the tree plots (contingency table with Fisher's exact test, p = 0.0032).

The 39 species that the Cashinahua plant experts labeled as regionally common include 9 of the top 11 most common species in the 5 tree plots, 9 of the 15 species present in all plots, and 39% of all trees in the plots. These 39 species had a higher mean abundance and higher median density than species considered occasional, and species considered occasional had a higher mean abundance and higher median density than species considered rare, although high variance means that the differences between mean abundances are not statistically significant (Table 2).

Discussion

Our results suggest that a botanist interested in describing the upland forests of the Alto Purús region could potentially account for about 40% of all trees in that forest type, across thousands of square kilometers, via a quick interview with an experienced Cashinahua hunter. It is important to note that this does not simply reflect the fact that upland forests in Alto Purús are dominated by three conspicuous and ubiquitous palm species. Even when those species are removed from the analysis, the remaining species considered common by the Cashinahua informants account for 25% of all trees in the Alto Purús tree plots.

The Cashinahua informants were likewise able to provide valuable information on which species were not common on the landscape. For example, although *Browneopsis ucayalina* Huber (Fabaceae) was abundant in the Puerto Esperanza tree plot, where it was the second most common species overall, the Cashinahua informants insisted that it was not generally common across the landscape. The tree plot data bore out their prediction; the species was not found in any of the other four hectares. Given that upland forests cover approximately 95% of the landscape in this region and a majority of the landscape in many other Amazonian regions (ONERN 1980), these results add to the abundant evidence that ethnobotanical ground-truthing is a useful tool for mapping large-scale vegetation patterns in Amazonian forests.

That conclusion comes with at least three caveats, however. First, the complicated correspondence between indigenous and Linnaean taxonomy means that before Cashinahua knowledge can be put to use in Linnaean-based plant ecology, a significant amount of work must be done to determine whether a particular Cashinahua taxonomic unit corresponds to part of one, one, or several Linnaean species. If we had used all of the Cashinahua predictions of regional abundance, rather than the subset of species for which the two taxonomic systems appear to agree, the result would have been chaos. It is also worth noting that our list of taxa for which the two nomenclatures appeared to agree, while conservative, is unlikely to be error-free; a considerable amount of further work is needed before we can reliably ''translate'' Linnaean species names to Cashinahua and vice versa (see Berlin 1992).

Second, Cashinahua plant experts were consistently more likely to label a given species ''common'' than they were to label it ''rare'' –a surprising contrast to scientific surveys of tropical vegetation, which typically report most tree species as rare (e.g., Hubbell and Foster 1986b; Pitman et al. 2001). For the subset of species for which Cashinahua and Linnaean names corresponded, Cashinahua labeled 55% as common. When all Linnaean species are considered, Cashinahua plant experts used the ''common'' designation nearly three times as often as the ''rare'' designation. Consequently, Cashinahua predictions in general were much more accurate for common Linnaean species than for rare ones, and it was more frequent for species that were rare in the tree plots to be ''wrongly'' labeled as common than for species that were common in the tree plots to be ''wrongly'' labeled as rare. For example, of the 17 rarest species in the Puerto Esperanza plot –species represented by a single tree there and never recorded in the other plots – 7 were considered common, 1 occasional, and 9 rare. That the Cashinahua regard

a larger proportion of taxa as common than the tree plot data suggest may simply reflect the fact that local residents are better at finding low-density tree species than randomly placed 1-ha plots.

Inevitably, it also reflects different ways of looking at rarity and abundance. The question we asked –''If you searched for this species in upland forests between Puerto Esperanza and the town of Colombiana, would finding it be easy, hard, or somewhere in between?''– could have been interpreted in a variety of ways. For example, Cashinahua plant experts might be more likely to call a species that occurs at low densities ''common'' if it possesses deeply ridged bark or some other feature that makes it conspicuous and easy to locate in the forest. Likewise, a species that grows at low densities but whose fruits are commonly harvested by the Cashinahua might be considered common simply because informants have a lifetime of experience finding it, or know several locations where individuals grow. Future studies might reduce this kind of misunderstanding by phrasing the question in a different way.

Finally, both of the datasets we have used to characterize the regional abundance of tree species on the Alto Purús landscape could be improved upon by future studies. The tree plot dataset is very small for such a large area and could be providing a biased view of regional abundance patterns. Likewise, our results might have been very different if another Cashinahua plant expert (or a larger number of experts) had identified trees and predicted regional abundances. While our sample size of 2 non-independent informants was too small to support rigorous generalizations, further tests of this kind can be easily carried out using the more than >900 1-ha tree plots established to date across the Amazon (H. ter Steege, pers. comm.).

In the end, given that indigenous residents of western Amazonia have used hundreds of plant species for food, medicine, and construction materials for generations, their ability to classify a given species as common or rare across the landscape they inhabit is fundamentally unsurprising– akin to developed world residents' ability to identify the names and logos of several hundred multinational corporations (Kahn and Kellert 2002). Ecologists seeking to understand large-scale patterns in tropical vegetation would be wise to make the most of such knowledge while it still exists.

Notes

Acknowledgements

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