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Understanding transmission of traditional knowledge across north-western South America: a cross-cultural study in palms (Arecaceae)

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The transmission of traditional knowledge (TK) depends largely on the ability of people to preserve and learn new knowledge. Different and opposing evidence about loss, persistence and generation of TK has been reported, but cross-cultural comparisons are notably missing. We interviewed 2050 informants at 25 localities in Colombia, Ecuador, Peru and Bolivia, across three ecoregions (Amazon, Andes, Chocó) and three cultural groups (Indigenous, Mestizos, African-Americans). Our main aims were to: (1) explore the transmission of palm use knowledge for 10 use categories across five age cohorts; and (2) identify the use categories in which knowledge is widely shared by all age cohorts or unique to one cohort. TK was heterogeneous between different age cohorts in the Amazon and the Chocó and increased with age. TK in the Andes was more evenly distributed between generations, with divergent tendencies in relation to age. TK about the categories *Human food* and *Construction* was widely distributed. TK in the categories *Medicinal and veterinary*, *Utensils and tools* and *Cultural* uses were more narrowly distributed. Our cross-cultural and multiple-scale study indirectly shows that the maintenance of TK relies on multiple variables, including ecological, social, cultural and economical factors. Our results provide a strong argument that conservation of TK should be embedded in local strategies that recognize all possible influences on knowledge transmission. © 2016 The Linnean Society of London, *Botanical Journal of the Linnean Society*, 2016, **182**, 480–504

ADDITIONAL KEYWORDS: cultural change – ecosystem services – ethnobotany – indigenous people – livelihood – loss of ecological knowledge – tropical rain forest.

INTRODUCTION

The transmission of traditional knowledge (TK) in many rural and indigenous communities has improved livelihoods in times of disturbance and change (e.g. Berkes, Colding & Folke, 2000; Colding, Elmqvist & Olsson, 2003; Pardo-de-Santayana & Macía, 2015). During the last decades various studies have reported conflicting evidence on changes occurring in TK (Begossi, Hanazaki & Tamashiro, 2002; Zarger & Stepp, 2004; Lozada, Ladio & Weigandt, 2006; Godoy *et al.*, 2009a; Zent & Maffi, 2010) and different hypotheses have been put forward to explain these opposite findings. The decrease in TK has been attributed to: (1) decrease in plant diversity due to land use change (Shanley & Rosa, 2004; Rocha & Cavalcante, 2006); (2) erosion of cultural practices and local languages (Benz *et al.*, 2000); (3) replacement of traditional education by formal schooling (Reyes-García *et al.*, 2010); and (4) economic factors that lead to migration, urbanization, new transportation routes and integration into market economies (Godoy *et al.*, 2005; Reyes-García *et al.*, 2005). The persistence of TK has been

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attributed to: (1) ecosystem characteristics such as low floristic diversity, which promotes rapid learning and more widely distributed knowledge (Lykke, Kristensen & Ganaba, 2004); (2) the maintenance of traditions and livelihood systems (Zarger & Stepp, 2004); (3) forest-based market activities, including commercialization of non-timber forest products (Godoy *et al.*, 1998); and (4) geographical isolation (Vandebroek *et al.*, 2004a; Byg, Vormisto & Balslev, 2007). Other authors have highlighted differences in the selection of methods to measure TK and the statistical techniques utilized that can also account for the contradictory findings (Heckler, 2002; Reyes-García *et al.*, 2003, 2007; Ladio & Lozada, 2004; Vandebroek *et al.*, 2004a).

Often, studies estimating cultural change have compared TK among different age cohorts and have inferred TK loss if older participants know more than younger ones (Phillips & Gentry, 1993; Figueiredo, Leitão-Filho & Begossi, 1997; Estomba, Ladio & Lozada, 2006). This approach may lead to an erroneous impression of cultural change of young vs. older participants, unless the participants' position in the life cycle is considered (Godoy *et al.*, 2009a). For example, knowledge of women after motherhood is higher than knowledge of women without children (Voeks, 2007). Other studies have, however, measured cultural change based on birth periods (i.e. age cohorts) and related it to changes in abundance of wildlife, education, livelihood shifts (e.g. wage work outside their community) and the development of transport and communication infrastructure (Godoy *et al.*, 2009a; Reyes-García *et al.*, 2013a). The observed trends have also been explained by the adaptive nature of TK in response to livelihood changes (Eakin, 2000; Ross, 2002; Reyes-García *et al.*, 2005, 2013b; Zent & Maffi, 2010). Resilience is, however, increasingly influenced and challenged by intensified globalization and economic development, which accelerates the exchange of knowledge and the introduction of foreign products and creates syncretic development and feedback loops (Cox, 2000; Leonti & Casu, 2013; Fernández-Llamazares *et al.*, 2015). The idea that TK systems are able to adapt to external and internal pressures has been a mainstay in applied ecology (Berkes *et al.*, 2000). Analysing cultural change only in terms of lost knowledge, however, tends to downplay the dynamic nature of TK and places little emphasis on understanding adaptive responses to new environmental, social and economic conditions (Gómez-Baggethun & Reyes-García, 2013; Hanazaki *et al.*, 2013; McCarter *et al.*, 2014). Consequently, our understanding of how these processes affect the transmission of TK systems and its ability to evolve and adapt is highly fragmentary.

The importance of understanding the processes of transmission of TK lies in the possibility of understanding the conservation, loss and dissemination of TK (Hewlett & Cavalli-Sforza, 1986). Transmission of TK occurs through three non-mutually exclusive models. First, transmission from parent to child (vertical) is highly conservative and assumes individual variations in which the TK is disseminated slowly within a society. Second, transmission between individuals of the same generation (horizontal) results in rapid diffusion of new knowledge, as long as contact between people remains constant. Third, oblique transmission (from older to younger generations) and horizontal transmission involve multiple transmitters and one receiver and generate a higher level of uniformity of knowledge within the social group, while allowing generational changes in TK (Reyes-García *et al.*, 2009; Reyes-García, 2010). It is important to note that not all TK domains are transmitted equally across generations: some domains are more vulnerable to TK loss, whereas in others new knowledge is generated as an adaptation to environmental change (Reyes-García *et al.*, 2013b). Because TK has contributed to the understanding of biodiversity and to the generation of strategies for conservation (Muller-Schwarze, 2006), identifying changes in its distribution could have an important role in resource management (Wyndham, 2002; Cristancho & Vining, 2009; Zent, 2009a, b).

Several studies have examined the causes of the loss or alteration of TK, but few have considered the intercultural context of these processes at larger scales, as pointed out in other studies (Eyssartier, Ladio & Lozada, 2006; McMillen, 2012; Hanazaki *et al.*, 2013; Reyes-García *et al.*, 2013a). To our knowledge, the study of Cámara-Leret *et al.* (2014a) is the only cross-cultural study that examined medicinal palm use patterns at multiple scales (ecoregions, countries, human groups, communities and individuals) in north-western South America. Most medicinal knowledge was not shared among most of the analysed scales, although minor knowledge components were widely shared, even across countries. In another large-scale study across north-western South America, Paniagua-Zambrana *et al.* (2014) described the influence of socioeconomic factors (e.g. gender, age or purchasing power) on TK. The above studies pointed to the complexity of TK patterns at different scales and to the importance of standard protocols to render results from local studies comparable at larger scales.

We used palms (Arecaceae) as a model group because of their importance for the livelihoods of indigenous and non-indigenous populations in tropical America (Phillips & Gentry, 1993; Galeano, 2000; Macía, 2004) and their abundance and wide distribution in rainforest habitats (Pintaud *et al.*, 2008; Balslev *et al.*, 2011) and because many palm species have uses that are shared among or are unique to different cultures and regions (Macía *et al.*, 2011; Cámara-Leret *et al.*, 2014a).

In this work, we study TK transmission over large scales, but focusing on all palms uses across three ecoregions (Amazon, Andes and Chocó), four countries (Colombia, Ecuador, Peru and Bolivia) and three human groups (Indigenous, Mestizos and African-Americans) in north-western South America using a standardized interview protocol. Specifically, we ask two questions. (1) Is TK uniformly distributed across age cohorts and use categories? and (2) Which use categories are mainly shared across age cohorts or are unique to a single age cohort?

METHODS

Study region

Our research was conducted in 25 localities in three ecoregions, the Amazon (n = 14 localities) and Andes (n = 7) of Colombia, Ecuador, Peru and Bolivia and the Chocó (n = 4) of Colombia and Ecuador (Fig. 1). We classified ecoregions following Macía *et al.* (2011), with the Amazon defined as the lowlands to the east of the Andes at < 1000 m elevation; the Andes as the humid montane forests on both slopes of the Andes > 1000 m, including the inter-Andean valleys of Bolivia with lower precipitation; and the Chocó as the humid forests along the Pacific coast of Colombia and northern Ecuador, < 1000 m. Localities were inhabited by Indigenous (n = 15 localities), African-American (n = 1), Mestizo (n = 8) and multi-ethnic indigenous groups (n = 1). Localities were selected in each ecoregion to have uniform ethnic composition and varying levels of education and health services, accessibility to markets and access to mature forests for harvesting palms. Localities included more than one community if the number of people interviewed in a single community was < 87 people (seven expert informants + 80 general informants), as defined in our research protocol (Paniagua-Zambrana, Macía & Cámara-Leret, 2010; Cámara-Leret, Paniagua-Zambrana & Macía, 2012) (Appendix 1).

Data collection

Ethnobotanical data were gathered through semi-structured interviews and socioeconomic data were assembled through structured interviews using a standardized research protocol (Paniagua-Zambrana *et al.*, 2010; Cámara-Leret *et al.*, 2012). Prior to starting interviews, we obtained the necessary permits and established informed consent with the communities and informants. From March 2010 to December 2011, we collected ethnobotanical information with two types of informants: experts, of whom we interviewed zero to seven in each community (n = 159), and general informants, of whom we interviewed ten to 89 in each community (n = 1891). Experts were selected by consensus of community members during a communal meeting. General informants were selected by researchers to achieve a balanced representation of gender and age cohorts within the localities. We divided informants into five age cohorts, starting at 18 years and using a range of 10 years for each age cohort (18–30, 31–40, 41–50, 51–60, and > 60 years old) to achieve an equal representation of all ages (Appendix 2). Within the age cohorts, *c*. 50% were women and 50% were men. We first interviewed expert informants through 'walks in the woods,' during which we documented all palm species that grew in the surroundings of the communities, collected vouchers, identified the species, documented their uses and recorded their vernacular names. These names were later used in the interviews with general informants. We conducted semi-structured interviews with expert informants during the 'walks in the woods' and with the general informants during household visits. Experts were asked the same questions as general informants. We asked all informants about each species found in the walks in the woods with experts and about widespread species found across our study area according to a bibliographic revision of palm use (Macía *et al.*, 2011). Additionally, we gathered personal information (gender, age, ethnicity, education level, languages spoken, migration status, time in residence) and household data (size of family, tenure of farm animals, farm size, tools, transports, house size, house construction materials) to determine the socioeconomic context of each informant. Interviews were conducted in Spanish or with local interpreters whenever informants did not speak Spanish. Palms were identified in the field wherever possible and vouchers were collected when our field identifications needed confirmation. Voucher specimens were deposited in the herbaria AAU, AMAZ, COL, LPB and QCA (herbarium acronyms follow Thiers, 2015).

Data analysis

Data were analyzed at the species level, with the exception of *Bactris gasipaes* Kunth, for which we differentiated the wild var. *chichagui* (H.Karst.) A.J.Hend. from the cultivated var. *gasipaes* Kunth. All palm uses and useful species reported in the interviews were classified in ten use categories following the Economic Botany Data Collection

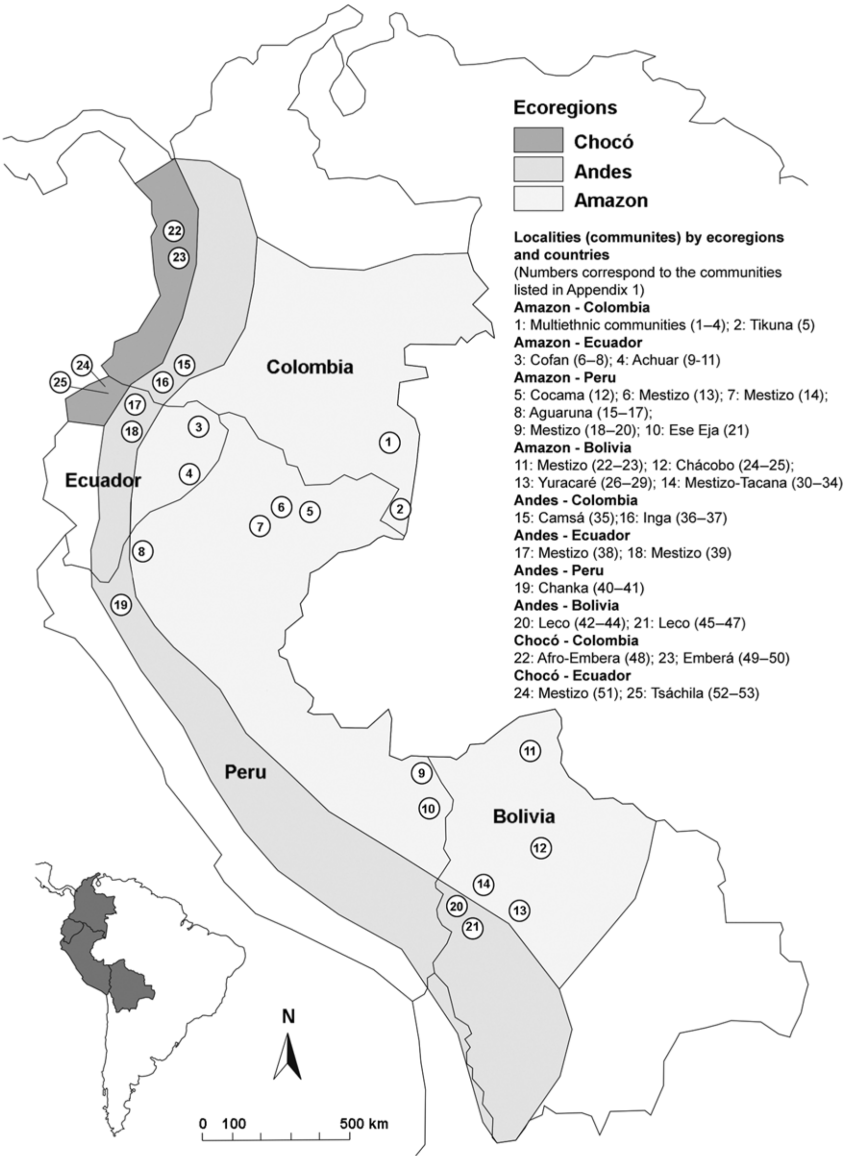


Figure 1. Map of the study area in north-western South America showing ecoregions (Amazon, Andes, Chocó), countries (Colombia, Ecuador, Peru, Bolivia) and localities (n = 25) where palm ethnobotanical data were gathered. See Appendix 1 for details on localities.

Standard (Cook, 1995) with the modifications proposed by Macía *et al.* (2011). Use categories included *Animal food, Construction, Cultural, Environmental, Fuel, Human food, Medicinal and veterinary, Toxic, Utensils and tools* and *Other uses* (including indirect uses, especially the use of beetle larvae that develop in rotting trunks). We calculated two different indicators of TK: (1) number of useful palm species and (2) number of palm uses, modified from Macía *et al.* (2011) and defined as a specific use of a palm part from a given species associated to a use category, a use sub-category and considering a different palm use for each product, food or artefact made using the same part of the plant. We performed a Kruskal–Wallis test and its corresponding *post hoc* Tukey test to test for significant differences in the total number of useful palm species and palm uses cited by different age cohorts in each of the 25 localities. We applied the same analysis to test for significant differences in TK in the ten use categories across age cohorts. As the indicators of TK were strongly correlated ($r \geq 0.6$; $P < 0.05$), we used only one indicator, i.e. palm uses, in the subsequent analyses. In each locality and for each use category, we identified how many palm uses were widely shared by all age cohorts (hereafter ‘common’ uses) or just by one age cohort (hereafter 'unique' uses). Using a Kruskal–Wallis test and its corresponding *post hoc* Tukey test, we evaluated if the proportion of informants that reported common uses differed from the proportion of informants that reported unique uses. All analyses were performed using R 3.0.1 programming language (R Development Core Team 2014).

RESULTS

In total, 3354 palm uses corresponding to 139 different palm species were reported in 2050 interviews across north-western South America (Table 1). TK peaked in the Amazon, with informants in northern Amazonia, especially in Colombia, citing the highest number of palm uses and useful palm species, followed by informants in localities in the southern Amazon of Peru and in the Chocó of Colombia.

Transmission of traditional knowledge (TK) across age cohorts

We found significant differences in the distribution of TK across age cohorts in 14 of the 25 localities, which represent all human groups and ecoregions (Fig. 2). Age cohorts showed significant differences in 75% of localities in the northern Amazon (Fig. 2A–C) and in 50% of the southern Amazon (Fig. 2D–H), although without a clear pattern across human groups. In the Andes, only two Mestizo localities in Ecuador showed significant differences (Fig. 2I–J), whereas in the Chocó all localities showed significant differences in relation to age cohorts (Fig. 2K–N).

In the localities with statistically significant differences, younger respondents (18–40 years) knew fewer palm uses than older respondents (>41 years old), except for the Chocó Emberá locality where the opposite pattern was found (Fig. 2L). Only in two indigenous localities in the northern Amazon did TK gradually increase with age (Fig. 2A–B).

Transmission of traditional knowledge (TK) across use categories

The five use categories with the highest use values for all human groups in the lowlands were *Utensils and tools, Construction, Human food, Cultural*, and *Other uses* in the Amazon and *Medicinal and veterinary* instead of *Other uses* for the last use category in the Chocó (Table 1). In the Andes, *Construction, Utensils and tools, Human food, Cultural* and *Environmental* were the most important use categories for all human groups in Colombia and Ecuador. The same occurred in Peru and Bolivia, but *Environmental* was replaced by *Medicinal and veterinary* uses.

In 19 of the 25 localities, informant's age significantly explained differences in TK for one to five of the ten use categories (Table 2). In three of four localities of the northern Amazon, *Construction, Human food, Medicinal and veterinary* and *Utensils and tools* showed significant differences related to age cohorts. Younger respondents (18–30 years) knew fewer palm uses than older respondents (> 31). TK of *Construction* use clearly increased with age, except among the Achuar. *Human food* was more concentrated among informants >51 years old, except among the Tikuna where TK was more evenly distributed. *Medicinal and veterinary* uses, *Utensils and tools, Other uses* and *Cultural use* were more homogeneous among informants >31 years old.

In southern Amazonia, 70% of localities (four indigenous and three Mestizo) showed differences of TK related to age in different use categories (Table 2). *Utensils and tools* was the only category showing significant differences in > 50% of localities, especially in indigenous communities. *Construction* and *Cultural uses* showed significant differences in three localities, two Mestizo in the first category and two indigenous in the second one. *Human food, Medicinal and veterinary* and *Other uses* showed differences in two localities, the first only in Mestizo areas. Younger respondents (18–30 years) knew fewer palm uses than older respondents (>31 years), except for *Cultural use* among the Ese Eja, where participants > 60 years had less knowledge. Knowledge about *Human food, Medicinal and veterinary, Utensils and tools*, and *Other uses* was concentrated in participants > 41 years old.

In the Andes, 71% of localities (three indigenous and two Mestizo) showed significant differences related to age cohorts (Table 2). *Construction, Human food* and *Utensils and tools* had significant differences in only two localities and in the first case both were Mestizo. In 50% of these localities, the younger respondents (18–30 years) knew fewer palm uses than older respondents (> 31 years), except for: (1) *Human food* among the mestizos of locality 18 and among the Leco; (2) *Utensils and tools* among the mestizos of locality 17 and (3) *Cultural use* among the Inga. The knowledge of *Construction* and *Other uses* was higher among older informants (> 41 years). For *Cultural uses*, TK was highest for participants 31–60 years old, and for *Utensils and tools* in informants > 31 years. *Human food* showed two opposite maxima, one among the younger informants and another among those > 51 years old.

In the Chocó, between two and four use categories showed significant differences related to age cohorts

Table 1. Total number of useful palm species, palm uses, and palm uses per use category reported in the 25 localities in north-western South America (Colombia, Ecuador, Peru and Bolivia). See Appendix 1 for details on localities

Ecoregion Ethnicity-Locality no.	Useful species	Palm uses	Palm uses per use category: Animal food	Construction	Cultural	Environmental	Fuel	Human food	Medicinal and veterinary	Toxic	Utensils and tools	Other uses
Northern Amazon												
Multiethnic indigenous-1	55	687	27	119	110	2	17	120	50	–	213	29
Tikuna-2	50	550	8	88	116	16	–	61	51	–	154	56
Cofan-3	41	277	–	55	48	2	3	44	6	–	93	27
Achuar-4	32	261	5	62	22	–	–	53	10	–	69	40
Southern Amazon												
Cocama-5	39	290	4	81	30	8	2	53	20	–	73	19
Mestizo-6	37	335	11	89	32	2	–	61	42	–	58	40
Mestizo-7	35	223	4	65	21	2	–	51	20	–	45	15
Aguaruna-8	30	288	1	78	16	–	2	63	23	–	86	19
Mestizo-Amakaeri-9	23	218	3	60	31	4	1	43	9	–	31	36
Ese Eja-10	25	304	1	50	45	–	–	53	25	–	76	54
Mestizo-11	26	243	4	45	33	3	–	38	41	–	61	18
Chácobo-12	24	222	1	29	33	–	–	34	29	–	63	33
Yuracaré-13	18	144	1	22	15	–	2	35	23	–	35	11
Mestizo-Tacana-14	20	134	–	39	17	–	–	38	9	–	28	3
Northern Andes												
Camsá-15	15	108	–	29	28	4	1	12	–	–	34	–
Inga-16	20	131	–	39	27	2	3	17	7	–	36	–
Mestizo-17	16	102	–	32	13	11	–	25	2	–	16	3
Mestizo-18	15	108	1	34	21	3	–	23	5	–	13	8
Southern Andes												
Chanka-19	28	319	1	88	36	1	14	60	22	–	69	28
Leco-20	16	169	3	33	19	–	2	23	39	–	36	14
Leco-21	15	130	1	29	16	–	1	21	24	–	29	9
Chocó												
African-American-22	30	366	5	105	39	20	1	56	26	2	109	3
Emberá-23	38	391	9	96	46	5	8	95	24	–	100	8
Mestizo-24	17	117	1	33	17	8	1	28	5	–	13	11
Tsa'chila-25	21	292	2	50	50	4	3	45	26	–	56	56
Total	139	3354	61	571	575	63	48	346	398	2	1036	254

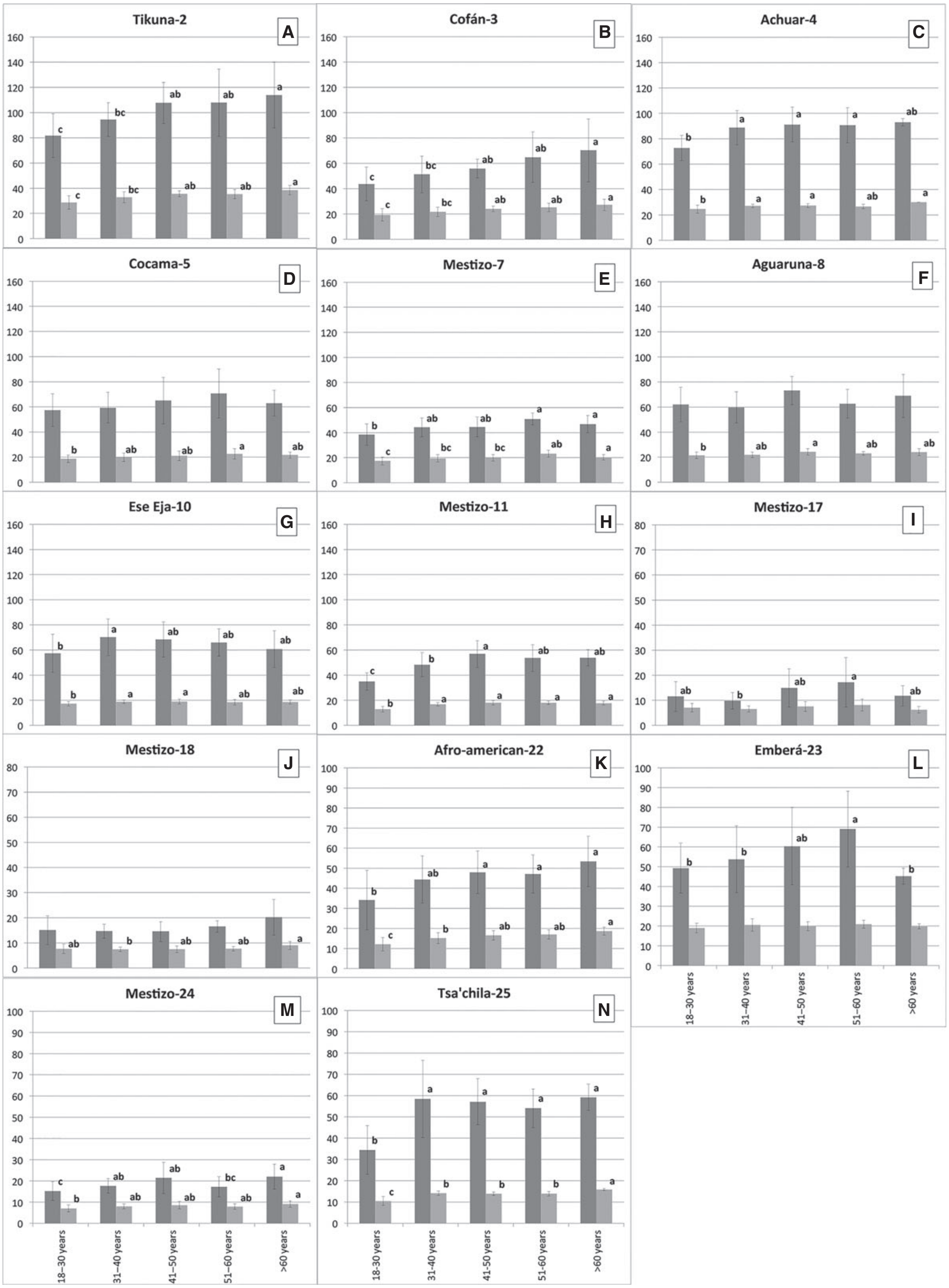


Figure 2. Number of palm uses (dark grey bars) and useful species (light grey bars) cited by five age cohorts in the 14 localities in north-western South America were significant differences in at least one use category are shown. Letters (e.g. a, b, c) indicate significantly different means based on a Kruskal–Wallis test and its corresponding *post hoc* Tukey test ($P < 0.05$), with the levels indicated by different letters showing significant differences. See Appendix 1 for details on localities.

Table 2. Mean number of palm uses (±SD) cited by five different age cohorts for the six most important use categories in north-western South America (Colombia, Ecuador, Peru and Bolivia)

Ecoregion - Ethnicity-Locality no.	Age cohort (years)	Construction	Cultural	Human food	Medicinal and veterinary	Utensils and tools	Other uses
Northern Amazon Tikuna-2	18–30	**14.3 ± 4.4 c**	18.6 ± 5.8	**22.8 ± 3.0 b**	**3.9 ± 1.2 b**	**11.9 ± 5.0 b**	**8.6 ± 3.5 b**
	31–40	**17.5 ± 3.2 bc**	20.0 ± 4.6	**25.5 ± 2.0 a**	**4.5 ± 1.6 ab**	**13.7 ± 4.8 ab**	**12.0 ± 2.9 ab**
	41–50	**19.2 ± 4.5 ab**	22.8 ± 4.8	**25.7 ± 2.3 a**	**5.4 ± 1.9 ab**	**19.6 ± 6.1 a**	**12.8 ± 4.0 a**
	51–60	**20.1 ± 6.6 ab**	22.9 ± 5.9	**26.4 ± 3.2 a**	**5.7 ± 2.6 a**	**16.5 ± 10.3 ab**	**14.1 ± 4.8 a**
	> 60	**22.6 ± 5.9 a**	22.6 ± 5.2	**27.5 ± 4.1 a**	**5.1 ± 1.8 ab**	**19.5 ± 9.3 a**	**13.8 ± 4.6 a**
Northern Amazon Cofan-3	18–30	**7.2 ± 2.7 c**	**7.4 ± 2.8 b**	**15.8 ± 4.0 bc**	**0.7 ± 0.6 b**	**7.7 ± 4.7 b**	4.3 ± 3.7
	31–40	**9.6 ± 5.0 bc**	**9.5 ± 2.1 ab**	**15.4 ± 2.7 c**	**0.7 ± 0.7 b**	**11.1 ± 5.4 ab**	4.5 ± 4.4
	41–50	**11.6 ± 2.3 abc**	**9.5 ± 3.5 ab**	**16.8 ± 2.2 bc**	**0.9 ± 0.4 ab**	**10.1 ± 3.9 ab**	6.9 ± 3.7
	51–60	**13.6 ± 7.2 ab**	**11.5 ± 3.5 a**	**19.0 ± 1.3 ab**	**0.8 ± 1.0 ab**	**11.6 ± 5.5 ab**	8.1 ± 5.7
	> 60	**16.0 ± 7.9 a**	**9.9 ± 3.3 ab**	**20.1 ± 2.7 a**	**1.5 ± 1.0 a**	**14.2 ± 7.3 a**	7.9 ± 7.9
Northern Amazon Achuar-4	18–30	**14.7 ± 2.7 b**	6.1 ± 2.3	**24.0 ± 2.6 b**	**0.9 ± 1.0 b**	**8.4 ± 4.1 b**	**18.3 ± 3.6 b**
	31–40	**16.9 ± 3.1 ab**	7.6 ± 2.4	**26.6 ± 2.1 a**	**1.8 ± 1.1 a**	**13.1 ± 4.3 a**	**22.6 ± 4.7 ab**
	41–50	**18.6 ± 3.2 a**	7.7 ± 1.8	**25.8 ± 3.0 ab**	**2.0 ± 1.3 a**	**13.5 ± 4.9 ab**	**23.2 ± 4.9 a**
	51–60	**16.9 ± 3.0 ab**	7.7 ± 3.2	**28.4 ± 2.9 a**	**1.9 ± 0.9 ab**	**11.3 ± 4.2 ab**	**24.4 ± 4.5 ab**
	> 60	**17.5 ± 0.7 ab**	4.0 ± 0.0	**30.0 ± 0.0 a**	**1.0 ± 0.0 ab**	**15.5 ± 2.1 ab**	**25.0 ± 1.4 ab**
Southern Amazon Mestizo-6	18–30	16.2 ± 3.8	2.0 ± 2.1	18.3 ± 2.7	1.9 ± 1.2	5.5 ± 3.7	**3.2 ± 2.6 b**
	31–40	18.2 ± 4.5	2.4 ± 1.7	18.5 ± 2.6	2.1 ± 1.6	7.0 ± 3.4	**3.5 ± 3.2 b**
	41–50	18.5 ± 4.1	2.0 ± 1.9	20.4 ± 3.7	2.3 ± 1.6	6.7 ± 4.5	**7.1 ± 4.8 a**
	51–60	17.2 ± 4.2	2.2 ± 1.7	19.9 ± 4.3	1.3 ± 1.2	7.2 ± 3.7	**4.1 ± 2.6 ab**
	> 60	17.4 ± 4.9	2.0 ± 1.9	21.3 ± 4.2	1.3 ± 1.0	7.0 ± 3.2	**3.4 ± 2.6 ab**
Southern Amazon Mestizo-7	18–30	**11.6 ± 4.2 b**	2.5 ± 1.3	**15.4 ± 2.5 b**	**1.0 ± 0.8 b**	5.9 ± 2.1	2.0 ± 1.3
	31–40	**14.3 ± 3.6 ab**	2.3 ± 1.2	**17.1 ± 3.1 ab**	**1.4 ± 0.9 ab**	6.8 ± 1.7	2.1 ± 1.1
	41–50	**14 ± 3.3 ab**	1.7 ± 1.3	**17.3 ± 2.3 ab**	**1.8 ± 1.0 a**	7.3 ± 2.3	2.1 ± 1.0
	51–60	**17.5 ± 2.2 a**	1.8 ± 1.0	**19.2 ± 2.5 a**	**2.0 ± 0.9 a**	7.9 ± 1.6	2.1 ± 0.9
	> 60	**13.9 ± 3.4 ab**	1.8 ± 1.3	**19.5 ± 2.7 a**	**1.9 ± 0.8 a**	7.5 ± 2.6	1.8 ± 1.4
Southern Amazon Aguaruna-8	18–30	20.2 ± 6.3	2.0 ± 1.9	23.9 ± 5.4	1.4 ± 1.4	**6.5 ± 3.9 b**	8.1 ± 1.5
	31–40	20.2 ± 5.8	1.4 ± 1.7	23.7 ± 3.4	1.3 ± 2.2	**5.1 ± 3.7 b**	7.8 ± 1.7
	41–50	22.4 ± 3.5	2.3 ± 2.3	28.3 ± 4.3	1.5 ± 1.4	**11.4 ± 4.0 a**	7.2 ± 2.6
	51–60	23.5 ± 4.8	1.2 ± 1.2	24.2 ± 4.4	0.6 ± 0.7	**6.3 ± 5.4 b**	6.9 ± 1.9
	> 60	23.1 ± 6.0	2.3 ± 2.6	25.8 ± 6.0	1.1 ± 1.5	**8.3 ± 4.7 ab**	8.5 ± 1.2
Southern Amazon Ese Eja-10	18–30	9.7 ± 3.4	**11.3 ± 4.0 ab**	17.8 ± 3.1	**1.1 ± 0.9 b**	**9.1 ± 4.3 b**	**8.5 ± 4.3 b**
	31–40	11.5 ± 2.8	**13.8 ± 3.9 a**	19.6 ± 4.7	**1.3 ± 0.7 b**	**12.1 ± 4.6 ab**	**12.0 ± 4.0 a**
	41–50	10.5 ± 2.0	**14.4 ± 4.0 a**	18.7 ± 2.4	**1.5 ± 1.0 ab**	**13.9 ± 5.5 a**	**9.4 ± 4.2 ab**
	51–60	10.2 ± 1.6	**11.0 ± 4.6 ab**	20.8 ± 4.6	**2.5 ± 1.4 a**	**10.3 ± 3.6 ab**	**11.2 ± 4.7 ab**
	> 60	12.3 ± 3.5	**7.8 ± 5.1 b**	18.3 ± 3.0	**1.7 ± 1.5 ab**	**12.4 ± 5.3 ab**	**8.2 ± 5.2 ab**

Table 2. *Continued*

Ecoregion - Ethnicity-Locality no.	Age cohort (years)	Construction	Cultural	Human food	Medicinal and veterinary	Utensils and tools	Other uses
Southern Amazon Mestizo-11	18–30	**7.5 ± 2.5 b**	**3.8 ± 1.3 c**	**12.4 ± 2.4 c**	4.1 ± 1.5	**3.5 ± 1.3 b**	3.3 ± 1.0
	31–40	**12.9 ± 3.3 a**	**4.6 ± 1.7 bc**	**14.9 ± 2.1 bc**	5.3 ± 2.5	**6.3 ± 2.5 ab**	4.1 ± 2.4
	41–50	**14.2 ± 3.1 a**	**6.1 ± 2.3 ab**	**17.2 ± 2.2 a**	6.1 ± 1.1	**9.1 ± 4.4 a**	3.9 ± 1.5
	51–60	**13.6 ± 2.5 a**	**6.6 ± 2.5 ab**	**15.8 ± 2.9 ab**	5.4 ± 2.0	**8.3 ± 4.1 a**	3.8 ± 1.5
	> 60	**13.4 ± 1.5 a**	**6.7 ± 2.3 a**	**15.9 ± 2.1 ab**	5.4 ± 2.1	**8.6 ± 2.8 a**	3.4 ± 1.3
Southern Amazon Chácobo-12	18–30	**7.1 ± 3.0 b**	3.2 ± 2.7	13.9 ± 2.8	2.7 ± 1.7	**7.3 ± 3.3 b**	5.0 ± 3.4
	31–40	**8.1 ± 2.1 ab**	3.4 ± 3.3	14.1 ± 2.3	2.5 ± 1.4	**8.2 ± 2.6 ab**	5.0 ± 2.9
	41–50	**10.5 ± 2.4 a**	3.0 ± 2.9	15.4 ± 2.3	4.1 ± 2.3	**10.4 ± 4.1 a**	5.9 ± 3.0
	51–60	**7.5 ± 2.1 ab**	1.2 ± 1.0	15.5 ± 1.9	2.3 ± 1.6	**7.3 ± 3.6 ab**	4.2 ± 2.3
	> 60	**9.0 ± 0.0 ab**	2.7 ± 0.6	15.0 ± 3.0	2.3 ± 1.5	**10.0 ± 5.0 ab**	2.7 ± 1.5
Southern Amazon Yuracaré-13	18–30	10.2 ± 1.2	**3.9 ± 1.6 b**	10.8 ± 2.6	1.1 ± 0.9	**11.3 ± 3.1 b**	1.6 ± 1.9
	31–40	10.1 ± 2.6	**5.3 ± 2.0 ab**	13.4 ± 4.4	1.2 ± 1.6	**14.9 ± 3.7 a**	2.5 ± 3.1
	41–50	10.1 ± 1.6	**5.6 ± 1.9 a**	13.9 ± 3.1	1.4 ± 1.6	**15.0 ± 4.1 a**	1.8 ± 2.6
	51–60	9.3 ± 1.0	**5.5 ± 1.0 ab**	10.8 ± 1.0	0.8 ± 1.0	**9.8 ± 1.9 ab**	0.8 ± 1.5
	> 60	9.9 ± 1.9	**5.8 ± 1.0 ab**	14.3 ± 3.1	0.9 ± 1.1	**12.4 ± 3.1 ab**	1.0 ± 1.6
Northern Andes Camsá-15	18–30	2.6 ± 1.5	2.9 ± 1.3	3.2 ± 0.6	–	**2.4 ± 1.6 b**	–
	31–40	2.8 ± 1.2	3.0 ± 0.9	3.6 ± 0.8	–	**3.0 ± 1.3 ab**	–
	41–50	2.3 ± 0.7	2.8 ± 0.9	3.7 ± 0.7	–	**3.4 ± 1.1 ab**	–
	51–60	2.7 ± 0.8	3.2 ± 1.6	3.7 ± 1.6	–	**3.7 ± 0.8 ab**	–
	> 60	3.1 ± 1.1	3.5 ± 1.1	3.5 ± 0.7	–	**3.8 ± 2.0 a**	–
Northern Andes Inga-16	18–30	3.2 ± 3.4	**2.8 ± 1.0 b**	5.2 ± 1.6	–	3.0 ± 2.7	–
	31–40	2.9 ± 2.2	**4.9 ± 1.9 a**	5.2 ± 0.9	–	4.0 ± 2.3	–
	41–50	3.1 ± 3.6	**3.8 ± 1.7 ab**	5.0 ± 0.9	0.3 ± 0.9	4.2 ± 3.0	–
	51–60	3.7 ± 3.8	**5.1 ± 2.1 a**	5.5 ± 0.9	0.1 ± 0.4	5.2 ± 3.3	–
	> 60	3.8 ± 2.4	**3.5 ± 1.0 b**	5.3 ± 1.6	0.2 ± 0.5	4.0 ± 2.2	–
Northern Andes Mestizo-17	18–30	**2.2 ± 2.4 b**	2.4 ± 0.9	6.1 ± 2.4	0 ± 0.2	**0.3 ± 0.8 b**	**0.1 ± 0.2 b**
	31–40	**1.5 ± 1.3 b**	2.2 ± 0.5	5.7 ± 1.7	–	**0.3 ± 0.8 b**	**0.1 ± 0.2 b**
	41–50	**3.5 ± 2.7 ab**	2.8 ± 1.1	7.2 ± 2.9	–	**0.9 ± 1.7 ab**	**0.2 ± 0.4 ab**
	51–60	**4.7 ± 3.3 a**	2.8 ± 1.6	7.1 ± 2.9	–	**1.7 ± 2.3 a**	**0.1 ± 0.3 ab**
	> 60	**3.1 ± 2.0 ab**	2.5 ± 0.9	5.3 ± 1.7	0.1 ± 0.3	**0.1 ± 0.3 b**	**0.3 ± 0.5 a**
Northern Andes Mestizo-18	18–30	**3.7 ± 2.5 b**	2.9 ± 0.9	**7.1 ± 2.0 ab**	0.2 ± 0.4	0.8 ± 1.1	0.3 ± 0.6
	31–40	**4.2 ± 1.5 ab**	2.8 ± 0.8	**6.5 ± 1.2 b**	0.1 ± 0.2	0.7 ± 1.0	0.3 ± 0.5
	41–50	**4.1 ± 2.0 ab**	3.1 ± 1.3	**6.1 ± 1.4 b**	0.2 ± 0.4	0.5 ± 0.7	0.2 ± 0.4
	51–60	**4.8 ± 2.1 ab**	3.6 ± 1.3	**6.9 ± 1.2 ab**	0.1 ± 0.3	0.6 ± 0.5	0.2 ± 0.4
	> 60	**6.1 ± 2.0 a**	2.7 ± 1.2	**8.2 ± 2.2 a**	0.3 ± 0.8	1.5 ± 1.5	1.1 ± 1.5

Table 2. *Continued*

Ecoregion - Ethnicity-Locality no.	Age cohort (years)	Construction	Cultural	Human food	Medicinal and veterinary	Utensils and tools	Other uses
Southern Andes	18–30	5.9 ± 2.7	3.0 ± 1.6	**9.7 ± 2.3 ab**	3.7 ± 3.3	5.5 ± 3.1	4.0 ± 1.6
Leco-20	31–40	6.7 ± 1.8	2.7 ± 1.4	**10.3 ± 2.4 a**	3.2 ± 3.1	6.0 ± 3.4	3.7 ± 1.6
	41–50	6.8 ± 1.8	3.0 ± 1.6	**10.0 ± 3.7 ab**	4.0 ± 2.8	6.1 ± 3.9	3.5 ± 1.4
	51–60	5.9 ± 1.7	2.7 ± 1.4	**9.6 ± 2.4 ab**	5.3 ± 3.5	5.7 ± 4.0	4.3 ± 0.5
	> 60	4.9 ± 1.8	2.1 ± 1.2	**7.3 ± 2.5 b**	3.7 ± 2.8	3.4 ± 1.8	3.1 ± 1.1
Chocó	18–30	**6.4 ± 6.7 c**	3.6 ± 1.5	16.4 ± 3.7	1.3 ± 0.8	**5.2 ± 4.3 b**	0.1 ± 0.2
African-American-22	31–40	**11.2 ± 4.8 bc**	3.6 ± 2.7	17.6 ± 4.4	1.5 ± 0.9	**8.8 ± 4.7 ab**	0.1 ± 0.5
	41–50	**14.7 ± 5.3 ab**	3.3 ± 1.6	17.2 ± 3.0	2.0 ± 0.9	**8.3 ± 3.7 ab**	0.1 ± 0.3
	51–60	**14.4 ± 3.9 ab**	2.5 ± 1.6	16.2 ± 2.3	1.4 ± 0.6	**10.3 ± 3.6 a**	-
	> 60	**17.2 ± 5.2 a**	2.7 ± 1.4	17.3 ± 3.0	1.8 ± 0.9	**11.3 ± 4.7 a**	0.1 ± 0.2
Chocó	18–30	**15.9 ± 4.0 b**	4.8 ± 3.5	**19.0 ± 3.8 b**	**0.5 ± 1.0 ab**	**7.2 ± 3.5 b**	0.5 ± 0.8
Emberá-23	31–40	**17.6 ± 3.9 ab**	5.4 ± 4.5	**19.2 ± 4.6 b**	**0.9 ± 1.2 ab**	**8.8 ± 4.8 ab**	0.2 ± 0.5
	41–50	**17.1 ± 5.0 ab**	7.3 ± 3.9	**20.9 ± 5.4 ab**	**1.0 ± 1.3 a**	**10.6 ± 5.3 ab**	0.9 ± 1.5
	51–60	**19.6 ± 4.3 a**	7.1 ± 5.0	**24.1 ± 5.9 a**	**1.7 ± 1.4 a**	**12.8 ± 5.4 a**	1.1 ± 1.5
	> 60	**16.8 ± 2.3 ab**	4.8 ± 2.6	**16.6 ± 3.1 b**	**0.2 ± 0.5 b**	**6.4 ± 1.8 ab**	–
Chocó	18–30	**4.1 ± 1.8 b**	2.1 ± 1.0	**7.3 ± 1.9 b**	0.5 ± 0.6	0.7 ± 0.9	–
Mestizo-24	31–40	**4.9 ± 1.5 b**	2.5 ± 1.1	**8.3 ± 2.0 ab**	0.2 ± 0.4	1.1 ± 0.9	–
	41–50	**8.6 ± 3.7 a**	2.4 ± 1.4	**8.4 ± 2.1 ab**	0.4 ± 0.5	0.3 ± 0.5	1.0 ± 1.3
	51–60	**5.9 ± 2.3 ab**	2.0 ± 1.4	**7.7 ± 1.2 b**	0.3 ± 0.6	0.7 ± 0.8	0.2 ± 0.8
	> 60	**7.0 ± 2.3 a**	1.6 ± 0.8	**9.9 ± 1.9 a**	0.2 ± 0.4	0.8 ± 1.0	2.0 ± 2.0
Chocó	18–30	**6.1 ± 3.1 b**	5.8 ± 2.4	**13.5 ± 4.6 b**	0.2 ± 0.4	3.6 ± 1.6	5.0 ± 2.1
Tsa'chila-25	31–40	**11.7 ± 3.2 a**	10.0 ± 5.8	**15.9 ± 2.7 ab**	1.8 ± 3.5	7.1 ± 5.4	11.0 ± 6.9
	41–50	**12.2 ± 2.6 a**	10.0 ± 3.1	**17.6 ± 1.9 ab**	1.6 ± 1.8	5.4 ± 2.2	9.5 ± 7.0
	51–60	**11.5 ± 2.8 a**	9.1 ± 1.0	**18.8 ± 3.8 a**	0.4 ± 0.5	4.5 ± 1.2	9.5 ± 3.5
	> 60	**14.3 ± 2.1 a**	9.4 ± 3.4	**18.6 ± 3.1 a**	1.2 ± 0.8	5.1 ± 0.9	9.9 ± 2.7

Only the localities with significant differences in at least one use category are shown (bold). Letters (a, b, c) indicate significantly different means based on a Kruskal–Wallis test and its corresponding *post hoc* Tukey test ($P < 0.05$), with the levels indicated by different letters showing significant differences. See Appendix 1 for details on localities.

in all localities (Table 2). *Construction* was the only use category with significant differences in all localities and, in most cases, knowledge was higher among informants > 31 years. Knowledge of *Human food* uses showed significant differences in three localities, two of them indigenous, and was concentrated among people > 41 years. *Utensils and tools* showed significant differences in two indigenous localities and were concentrated among participants > 31 years. *Medicinal and veterinary* use showed significant differences only among the Embera, and was higher among those < 60 years.

Common traditional knowledge (TK)

Between 13–43% of all palm uses reported in each locality were common TK reported by all five age cohorts (Fig. 3). Common TK was greater in southern Amazonia and was not correlated with the number of uses in localities (Table 1). In general, the number of use categories with common uses and the proportion of common uses in relation to all palm uses in a given ethnobotanical category were higher in the Amazon (northern and southern) and the Chocó than in the Andes (Fig. 4).

In northern Amazonia, more common TK was reported for *Human food* (Fig. 4F1–4), *Other uses* (Fig. 4 I1–4) and *Construction* (Fig. 4B1–4). Informants > 41 years knew more common TK, except in the Achuar where it was concentrated among people > 60 years (Table 3). In southern Amazonia, more common TK was found in *Human food* (Fig. 4F5–14), *Construction* (Fig. 4B5–14) and *Other uses* (Fig. 4I5–14). High percentages of common TK for *Cultural uses* were found in the Yuracaré (Fig. 4C13), Cocama (Fig. 4C5) and Ese Eja (Fig. 4C10) and *Utensils and tools* among Yuracaré (Fig. 4H13), Mestizo-Tacana (Fig. 4H14) and Ese Eja (Fig. 4H10). Common TK was lowest for *Medicinal and veterinary* uses (Fig. 4G5–14). Only among the mestizos in locality 11 was common TK significantly higher among informants >41 years (Table 3).

In the Andes, common TK was highest for *Human food* (Fig. 4F15–21), followed by *Construction* (Fig. 4B15–21), *Cultural* (Fig. 4C15–21) and *Utensils and tools* (Fig. 4H15–21). We found no significant differences in the proportion of respondents who reported uses for the remaining use categories in all age cohorts (Table 3).

In the Chocó, common TK was highest for *Human food* (Fig. 4F22–25), *Construction* (Fig. 4B22–25) and *Cultural uses* (Fig. 4C22–25). Most of informants reporting this knowledge were >31 years old for African-Americans, between 41–50 years for Tsa'chila and 18–40 and > 51 years old among the mestizos of locality 24 (Table 3).

Unique traditional knowledge (TK)

Between 12–60% of the palm uses reported across localities were unique TK reported by a single age cohort (Fig. 3). Unique TK peaked in the Chocó (30–44%) and the northern Andes (30–60%), and was lowest in the Amazon (northern and southern localities). Overall, the number of use categories represented in unique uses was higher in the Amazon and Chocó (Fig. 4). In the northern and southern Amazon, *Medicinal and veterinary* was the use category with the highest percentage of unique TK (Fig. 4G1–14), followed by *Utensils and tools* (Fig. 4H1–14) and *Cultural uses* (Fig. 4C1–14). In most localities, *Fuel* (Fig. 4E1–14), *Environmental* (Fig. 4D1–14) and *Animal food* (Fig. 4A1–14) had the highest percentage of unique uses (100%), but these were also the use categories with the lowest total number of palm uses (Table 1). In the northern Amazon the proportion of respondents who reported unique uses was significantly higher in the > 30 age cohort for the multiethnic community and for the Tikuna > 60 age cohort (Table 3). In seven localities of the southern Amazon, five of them indigenous, the proportion of respondents who reported unique uses was statistically significant (Table 3).

In the northern Andes, unique TK was highest in *Construction* (Fig. 4B15–18), *Cultural* (Fig. 4C15–18) and *Utensils and tools* (Fig. 4H15–18). As in Amazonia, *Environmental* (Fig. 4D15–18) and *Fuel* (Fig. 4I15–18) showed the highest percentages of unique uses, but these use categories also had the lowest number of uses. Unique TK was peaked in the > 50 age cohort, except among the Camsá where it was also higher in the > 30 age cohorts (Table 3). In the southern Andes, unique TK was highest in *Other uses* (Fig. 4I19–21), *Utensils and tools* (Fig. 4H19–21) and the *Medicinal and veterinary* uses (Fig. 4G19–21).

In the Chocó, as in other ecoregions, unique TK peaked in the use categories with few uses: *Fuel* (Fig. 4E22–25), *Environmental* (Fig. 4D22–25) and *Animal food* (Fig. 4A22–25). High percentages of unique TK were also found in *Medicinal and veterinary* (Fig. 4G22–25), *Other uses* (Fig. 4I22–25) and *Utensils and tools* (Fig. 4H22–25). The Emberá (< 60 years) and Tsa'chila (> 50 and < 60 years) showed significant differences in the proportion of people who mentioned unique TK (Table 3).

DISCUSSION

Patterns of transmission of traditional knowledge (TK) across different scales

Our study shows that transmission of TK about palms has distinct patterns at all analysed scales

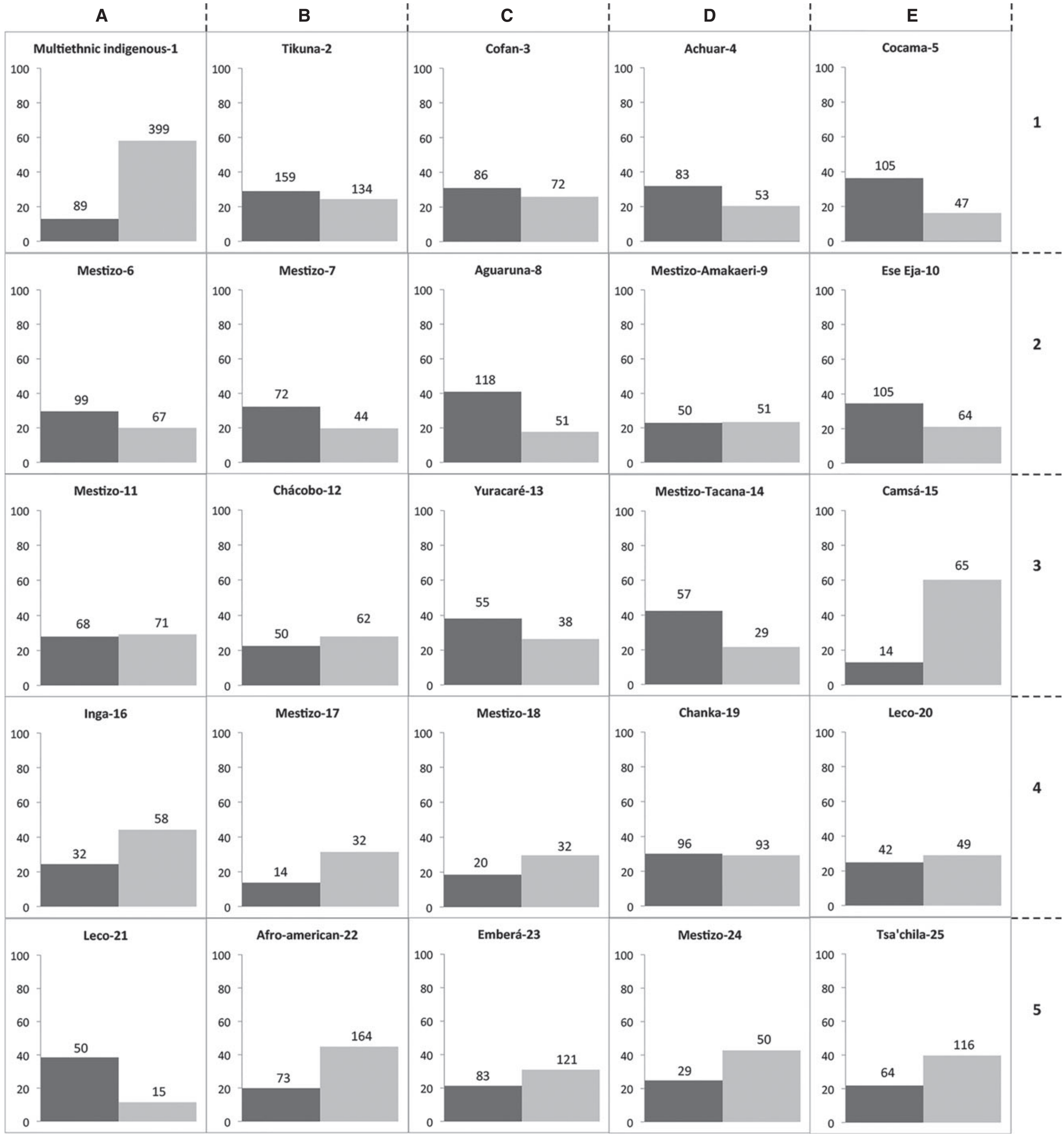
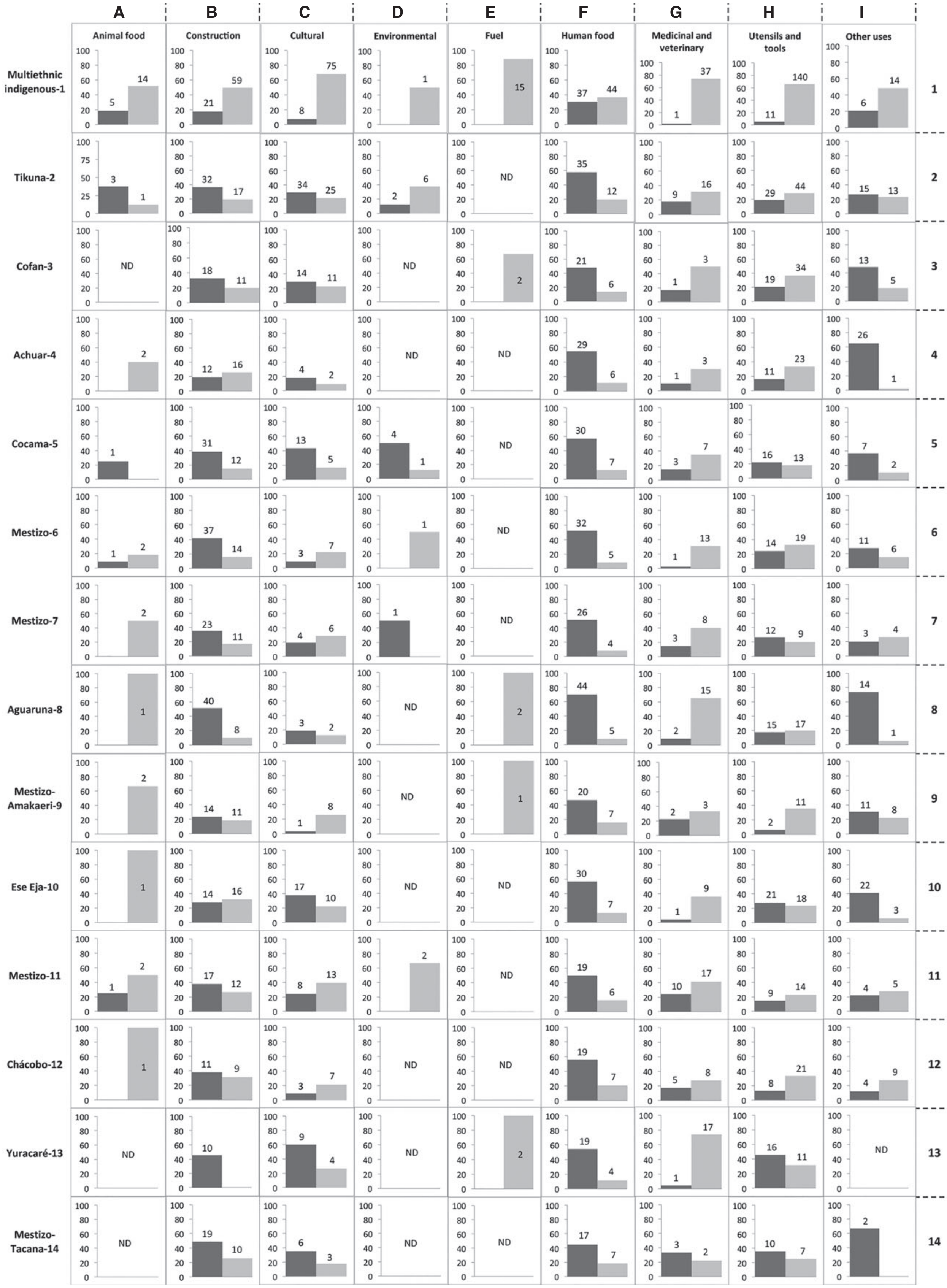


Figure 3. Common palm uses reported by all age cohorts (dark grey bars) and unique uses only reported by one age cohort (light grey bars) in 25 localities in north-western South America. Bars represent the relative percentage of palm uses in a locality. Numbers above each bar indicate the number of different palm uses. Letters (above the figure columns) and numbers (to the right of the figure rows) are used as coordinates to facilitate to locate the respective figure in the text.

(ecoregions, countries, human groups) in north-western South America. Common and unique TK classes were different across age cohorts within each locality, demonstrating the dynamic nature of knowledge. The conservation of knowledge in certain use categories and the incorporation of new knowledge in others (e.g. knowledge reported only by the younger generations) represent important elements of TK that change with socioeconomic and environmental conditions.


A
B
C
D
E
F
G
H
I
Animal food
Construction
Cultural
Environmental
Fuel
Human food
Medicinal and veterinary
Utensils and tools
Other uses
Multiethnic indigenous-1
Tikuna-2
Cofan-3
Achuar-4
Cocama-5
Mestizo-6
Mestizo-7
Aguaruna-8
Mestizo-Amakaeri-9
Ese Eja-10
Mestizo-11
Chácobo-12
Yuracaré-13
Mestizo-Tacana-14
1
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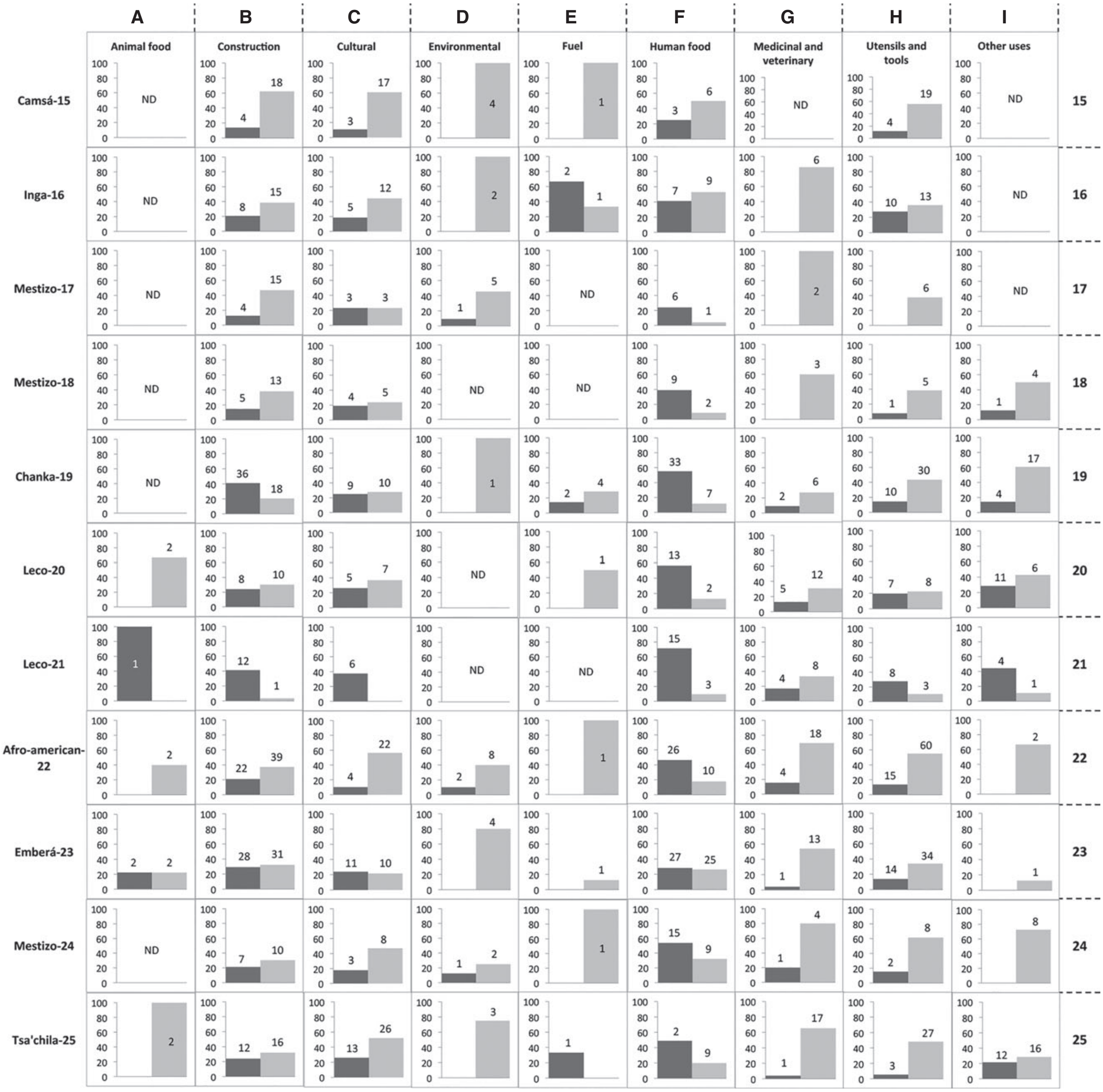

Figure 4. Common palm uses reported by all age cohorts (dark grey bars) and unique uses only reported by one age cohort (light grey bars) for nine use categories in 25 localities in north-western South America. Bars represent the relative percentage of uses in a locality. Numbers above each bar indicate the number of uses. ND: no data reported. Letters (above the figure columns) and numbers (to the right of the figure rows) are used as coordinates to facilitate to locate the respective figure in the text.

The patterns in the Amazon and the Chocó show more heterogeneity in TK of different age cohorts and a positive trend of age in relation to knowledge that can be explained by different factors complementarily. On the one hand, the high species diversity enables access to a wide range of potential resources (de la Torre *et al.*, 2009; Macía *et al.*, 2011; Cámara-Leret *et al.*, 2014b, c) where contact with nature still remains vital to the acquisition of knowledge (Atran, Medin & Ross, 2004; Lawrence *et al.*, 2005). On the other hand, the diversity of indigenous groups favours a highly distinctive ethnobotanical knowledge (Campos & Ehringhaus, 2003; Macía *et al.*, 2011; Cámara-Leret *et al.*, 2014a), especially as knowledge in these ecoregions about the use of palms is crucial for livelihoods

Table 3. Proportion of informants in each age cohort who report (A) common uses and (B) unique uses in north-western South America (Colombia, Ecuador, Peru and Bolivia)

	Age cohorts (years)				
Ethnicity–Locality	18–30	31–40	41–50	51–60	> 60
(A) Common uses					
Northern Amazon					
Multiethnic indigenous-1	44.15 ± 3.11 b	44.29 ± 3.11 b	49.87 ± 3.11 ab	57.12 ± 3.11 a	53.73 ± 3.11 ab
Tikuna-2	45.00 ± 2.53 b	52.80 ± 2.53 ab	55.79 ± 2.53 a	55.88 ± 2.53 a	55.74 ± 2.53 a
Cofan-3	44.50 ± 3.52 b	50.33 ± 3.52 ab	54.83 ± 3.52 ab	60.03 ± 3.52 a	59.63 ± 3.52 a
Achuar-4	66.11 ± 2.78 b	74.58 ± 2.78 b	74.10 ± 2.78 b	76.59 ± 2.78 b	96.99 ± 2.78 a
Southern Amazon					
Mestizo-11	47.94 ± 4.02 b	60.46 ± 4.02 ab	64.94 ± 4.02 a	63.45 ± 4.02 ab	64.05 ± 4.02 a
Chocó					
African-American-22	37.21 ± 3.59 b	48.33 ± 3.59 ab	49.17 ± 3.59 ab	50.34 ± 3.59 ab	54.51 ± 3.59 a
Mestizo-24	70.22 ± 5.93 a	61.13 ± 5.93 ab	38.97 ± 5.93 b	68.96 ± 5.93 a	77.58 ± 5.93 a
Tsa'chila-25	17.19 ± 2.39 c	42.09 ± 2.39 b	75.45 ± 2.39 a	36.50 ± 2.39 b	34.37 ± 2.39 b
(B) Unique uses					
Northern Amazon					
Multiethnic indigenous-1	1.01 ± 2.29 b	1.88 ± 3.23 a	1.64 ± 3.92 ab	2.30 ± 5.87 a	2.05 ± 3.96 a
Tikuna-2	1.01 ± 2.52 b	0.71 ± 2.31 b	1.97 ± 5.73 b	0.75 ± 2.11 b	4.15 ± 5.14 a
Southern Amazon					
Cocama-5	0.89 ± 1.99 b	0.79 ± 1.87 b	1.15 ± 2.24 ab	1.06 ± 4.29 b	2.87 ± 4.41 a
Aguaruna-8	2.52 ± 4.41 ab	3.11 ± 3.40 a	2.94 ± 6.19 a	0.53 ± 2.16 b	–
Mestizo-Amakaeri-9	0.53 ± 1.47 b	1.20 ± 3.01 b	1.34 ± 2.88 ab	1.25 ± 3.64 b	3.01 ± 3.84 a
Ese Eja-10	2.76 ± 3.59 a	1.77 ± 3.40 ab	1.08 ± 2.69 b	1.09 ± 3.61 ab	0.69 ± 3.98 b
Mestizo-11	–	1.95 ± 4.00 b	1.70 ± 3.70 b	1.01 ± 2.50 b	3.68 ± 5.78 a
Chácobo-12	1.46 ± 2.13 b	0.71 ± 1.70 b	4.16 ± 5.54 a	–	2.19 ± 8.31 ab
Yuracaré-13	0.73 ± 2.93 b	3.94 ± 4.21 a	2.44 ± 4.16 ab	–	0.99 ± 3.41 b
Northern Andes					
Camsá-15	2.48 ± 3.06 a	0.49 ± 1.53 b	–	2.82 ± 6.30 a	2.06 ± 3.71 ab
Mestizo-17	1.44 ± 3.49 ab	0.99 ± 2.08 ab	0.39 ± 2.21 b	3.44 ± 5.45 a	2.91 ± 5.07 ab
Mestizo-18	1.72 ± 0.74 ab	0.16 ± 0.74 b	0.72 ± 0.74 b	1.30 ± 0.74 ab	4.80 ± 0.74 a
Southern Andes					
Chanka-19	0.38 ± 1.62 c	0.40 ± 1.54 c	2.35 ± 3.36 ab	1.38 ± 2.87 bc	2.92 ± 4.81 a
Leco-20	1.73 ± 2.49 ab	0.92 ± 2.07 ab	2.04 ± 3.67 a	0.29 ± 2.04 b	1.48 ± 3.89 ab
Chocó					
Emberá-23	1.08 ± 1.96 ab	1.58 ± 2.69 ab	1.24 ± 2.71 ab	2.17 ± 4.16 a	0.66 ± 3.95 b
Tsa'chila-25	0.16 ± 1.18 b	4.70 ± 4.71 a	3.87 ± 6.56 ab	0.32 ± 1.99 b	2.41 ± 6.13 ab

Only localities with statistically significant differences are shown. Letters (a, b, c) indicate significantly different means based on a Kruskal–Wallis analysis and its corresponding *post hoc* Tukey test ($P < 0.05$), with the levels indicated by different letters showing significant differences. See Appendix 1 for details on localities.

(Macía, 2004; Pérez-Ojeda del Arco, La Torre-Cuadros & Reynel, 2011; Reyes-García *et al.*, 2013b). External factors, such as geographical isolation, lack of communication, limited access to markets (Byg *et al.*, 2007; Godoy *et al.*, 2009b) and limited services (e.g. health centres) (Benz *et al.*, 2000), foster greater dependence on local resources for subsistence. Additionally, the general trend that young people know less than older people, as previously been found (Begossi *et al.*, 2002; Byg & Balslev, 2004), may be the result of knowledge transmission and *in situ* learning (Phillips & Gentry, 1993; Zarger, 2002; Godoy *et al.*, 2009a). However, we also found the opposite pattern, in which middle-aged informants knew more in some localities than the other generations, possibly reflecting periods in which people had the opportunity to travel and learn more outside their communities.

In the Andes, the overall pattern that TK was evenly distributed between generations may be explained by its lower palm diversity that favours quick learning of non-specialist knowledge in the same way as seen elsewhere, e.g. in Africa (Lykke *et al.*, 2004). It may also be influenced by accelerated deforestation, with remaining palms often existing only in small and remote populations (de la Torre *et al.*, 2012). These changes may be accompanied by changes in the benchmarks for learning and in the abundance of resources like the disappearance of certain useful species, which would then not be known to the younger generation (Hanazaki *et al.*, 2013). Forest destruction, population growth and greater access to commercial centres in many cases force people to work outside their communities, thus exposing them to learning about species absent in their home ecoregion (Browder, 2002; Rudel, Bates & Machinguiashi, 2002; Reyes-García *et al.*, 2005). This situation is especially evident in the Ecuadorian Andes, where communities are more densely populated, have greater infrastructure development and are highly market-dependent. In this scenario, social changes, such as the construction of hospitals and schools (Zent, 2001; Byron, 2003; Reyes-García *et al.*, 2010), and economic changes, such as the incorporation into market economies (Godoy *et al.*, 2009b), have greatly affected traditional learning processes (Reyes-García *et al.*, 2008, 2013b).

Transmission of traditional knowledge (TK) across different use domains

Our findings indicate that although the most important domains of knowledge are commonly cited (e.g. *Utensils and tools, Construction, Human food, Cultural* and *Medicinal and veterinary*), they all show distinct tendencies at all scales (ecoregions, countries or localities), as previously reported at the intracultural level (Case, Pauli & Soejarto, 2005; Reyes-García *et al.*, 2013b). For example, *Construction* knowledge increased with age in the northern Amazon, northern Andes and the Chocó. This trend may be explained by the under exposure of young people to this knowledge because of the major use of external resources as building materials (Appendix 1). This might have led to a lack of interest in learning about local construction and thus to the absence or the loss of knowledge (Case *et al.*, 2005). In contrast, this knowledge was more homogeneously distributed among generations in the southern Amazon and southern Andes, probably because of the greater use of local materials in construction (Appendix 1) that lead to processes of knowledge transfer and active learning *in situ* (Phillips & Gentry, 1993; Zarger, 2002; Godoy *et al.*, 2009a).

In relation to *Human food*, TK was more homogeneously distributed among all age cohorts in the southern Amazon and the Andes and more heterogeneously distributed in the northern Amazon and Chocó, with higher knowledge among the oldest participants. This overall pattern could be associated with the different diversity of palms in these ecoregions since the larger palm diversity in the northern Amazon and Chocó might result in the retention of ethnobotanical knowledge by the older generation about rare species that are overlooked by the younger generation in the forest (e.g. understory species of *Bactris* Jacq. ex Scop. for *Human food*; Cámara-Leret *et al.*, 2014c). Additionally, these patterns may be due to a higher diversity of understory species in the northern Amazon and Chocó than in the southern Amazon and Andes (Balslev *et al.*, 2011). These ecoregion-scale differences in turn increase the likelihood that younger informants overlook these less salient palms in the northern Amazon and Chocó, but reduce between-group differences in knowledge in the southern Amazon and Andes. The influence of an increasing adoption of market economies, agricultural products and purchased food, including food items that were previously harvested from forests (Byron, 2003; Vadez *et al.*, 2008; Godoy *et al.*, 2009b; Zycherman, 2011; Gómez-Baggethun & Reyes-García, 2013; Reyes-García *et al.*, 2013b), could be generating a lack of interest of the younger generations to learn about local foods, because other options are readily available. We find a low percentage of uses reported only in one age cohort which could be explained because the contact and experience with food resources tend to be more evenly distributed within the population, even when one assumes knowledge to be patterned according to variables such as gender, social status, occupation and age (Byg & Balslev, 2004; Paniagua-Zambrana *et al.*, 2007, 2014; Quave & Pieroni, 2015). Extensive contact and dependence on food plants starts during childhood and people usually experiment with these more often than with other uses (Phillips & Gentry, 1993).

The greater knowledge about *Utensils and tools* mainly by the older generations (> 41 years), in particular in the Amazon and the Chocó, especially the high percentage of unique TK could be related to a growing exposure of the new generations to new technology (e.g. tools and alternative utensils available in commercial centres) and the perception that these are more effective (Godoy *et al.*, 2005; Reyes-García *et al.*, 2013b). This trend could also explain the homogeneity found in the knowledge of different age cohorts in the Andes, where knowledge in general was lower than in the lowlands. However, in certain cases, the ability to use this type of knowledge in subsistence activities (e.g. as tour guides or sale of handcrafts) could encourage people to learn more (Guest, 2002), as could be the case of the Achuar in Amazonian Ecuador.

The homogeneity of knowledge about *Cultural use* in most localities is probably due to the dominance of certain types of uses at each locality, many of them for commercial purposes (e.g. necklaces, hats or dyes). This result can be explained by the low percentage of common TK on *Cultural uses*. The high percentage of uses cited by only one age cohort, especially by the younger generation (< 41 years old), could be related to the increased exposure of these generations to activities related to tourism, and the possibility of generating income activities by using this type of knowledge (Guest, 2002). Although this local knowledge is acquired and taught 'by doing', which could relate a transmission process through families (vertical transmission) or from the oldest to the youngest, currently it is mainly transmitted horizontally, between members the same generation (Pérez-Ojeda del Arco *et al.*, 2011).

The trends found in relation to *Medicinal and veterinary* knowledge are in line with previous findings of high levels of unique TK across north-western South America (Cámara-Leret *et al.*, 2014a). This can be related to the nature of medicinal knowledge and the particular way it is acquired and transmitted among individuals, households, communities and ethnic groups (Potvin & Barrios, 2004; Vandebroek *et al.*, 2004a, b; Mathez-Stiefel & Vandebroek, 2012). Most of the medicinal knowledge is transmitted vertically in a family (Eyssartier *et al.*, 2006). The lower *Medicinal and veterinary* knowledge in the northern Amazon, especially among the younger generation (< 41 years old), and the low percentage of widely shared uses, may be related to the lack of interest (Almeida *et al.*, 2012), the predominant use and accessibility of alternative health services (e.g. health clinics, paramedics and hospitals) (Quinlan & Quinlan, 2007) and changes in the lifestyle and environment (Hanazaki *et al.*, 2013). The homogeneity found in most of the southern Amazon, the Andes and the Chocó and the low percentage of uses widely shared among all generations underline the dominance of a small number of uses that are possibly covering primary health needs (Paniagua-Zambrana, Cámara-Leret & Macía, 2015). It might also reflect the increasing influence of allopathic medicine, since most communities have health posts and, in the Andes, even hospitals, where the majority of illnesses are treated (Appendix 1). Researchers have highlighted the possibility that changes in local worldviews and the stigmatization of indigenous cultures might also play a role in explaining the loss of medicinal TK (Vandebroek *et al.*, 2004b; Case *et al.*, 2005).

Overall, the perception of knowledge loss among young people when comparing ethnobotanical domains among different age groups should be analysed with caution, because the current plant use practices rely on a complexity of factors (Paniagua-Zambrana *et al.*, 2014). Fluctuations in these factors can cause changes in the reference (baseline) of different generations and consequently account for differences in intergenerational knowledge (Hanazaki *et al.*, 2013). Our results, however, should be taken with caution because we lack longitudinal or diachronic observations to explain and better understand changes in TK. Furthermore, our analyses are based on palms, a major plant group for livelihood systems in the Neotropics (Macía *et al.*, 2011), but they do not necessarily reflect patterns in other groups of less conspicuous plants with more restricted distributions. Finally, some specific domains of TK could involve more complex transmission processes than others. Because the biocultural diversity in the tropics is high, more comparative studies at large spatial and temporal scales are needed to further advance our understanding about intergenerational patterns of TK.

CONCLUSIONS

Our cross-cultural and multiple-scale study shows strong variation in transmission of palm TK across use categories in north-western South America. Positive, null and negative trends of TK between generations of different localities confirm that knowledge transmission follows not one, but multiple pathways. Caution is needed when extrapolating local results because the different patterns among ecoregions, countries and cultural groups indirectly show that the mechanisms by which TK is maintained rely on multiple factors, including ecosystem properties, social factors such as cultural identity and economic factors such as access to services. Giving due consideration to all these factors and their interactions will be of paramount importance when designing strategies to preserve TK. Finally, our work underlines the fact that culture is dynamic, and that this dynamism guides the use of resources and conservation of TK. To preserve the variety of TK in a region, it will be crucial to design conservation practices that build on the intricate links between knowledge, practices and institutional context. This approach will require long-term intergenerational planning with the participation of institutions that are flexible and can adapt to change.

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Appendix 1

Characteristics of the 25 localities in north-western South America (Colombia, Ecuador, Peru and Bolivia) where 2050 interviews about palm uses were gathered:

(a) The information about the nearest town and the time to reach it were obtained from interviews. The data represents the town and the time most frequently reported by the informants; (b) Availability of electricity: (1) no electricity, (2) free electricity, (3) paid electricity. Access to education: (1) no school, (2) primary school, (3) secondary school, (4) community college or university. Access to healthcare: (1) without health post (only traditional medicine), (2) health post/community nurse, (3) health post/physician (4) local hospital; (c) Percentage of house construction materials in relation to the total number of interviewees by locality; (d) Average ± SD in relation to the total number of interviewees by locality

Locality	Ecoregion – Country Community (population census approximately)	Ethnic group	Accessibility [(a)] Nearest town (distance in hours)	Type access	Social services available [(b)] Electricity	Education	Healthcare	House construction material [(c)] Local plant materials ≥ 50%	Mixed material ≥ 50%	Foreign commercial materials ≥ 50%	Average farm size (ha) ± SD[(d)]
Northern Amazon-Colombia											
1	Curare (130)	Multiethnic indigenous	La Pedrera (1.5)	Fluvial	1	2	1	16.9	4.6	78.5	1.2 ± 0.8
	Yucuna (160)	Multiethnic indigenous	La Pedrera (1)	Fluvial	1	2	1				
	Angostura (180)	Multiethnic indigenous	La Pedrera (0.75)	Fluvial	1	2	1				
	Camaritagua (60)	Multiethnic indigenous	La Pedrera (0.33)	Fluvial	1	1	1				
2	San Martín de Amacayacu (430)	Tikuna	Leticia (6)	Fluvial	1	2	1	48.9	6.8	44.3	0.5 ± 0.3
Northern Amazon-Ecuador											
3	Zábalo (170)	Cofan	Lago Agrio (6)	Fluvial	1	2	1	6.1	–	93.9	0.9 ± 0.8
	Pacuya (150)	Cofan	Lago Agrio (6)	Fluvial	1	1	1				
	Dureno (450)	Cofan	Lago Agrio (0.33)	Fluvial	1	2	1				
4	Wayusentsa (150)	Achuar	Kapawi (3)	Fluvial	1	2	1	96.9	–	3.1	0.3 ± 0.3
	Kapawi (220)	Achuar	Kapawi (0)	Fluvial	1	3	1				
	Kusutko (80)	Achuar	Kusutko (0)	Fluvial	1	2	1				
Southern Amazon-Peru											
5	San Martín (500)	Cocama	Nauta (18)	Fluvial	3	3	3	86.2	–	13.8	1.4 ± 0.8
6	El Chino (550)	Mestizo	Iquitos (10)	Fluvial	1	2	2	97.5	–	2.5	1.4 ± 1.3
7	Santa Ana (450)	Mestizo	Iquitos (5)	Fluvial	2	3	1	82.0	–	18.0	2.0 ± 2.2
8	Yamayakat (1000)	Aguaruna	Imacita (0.25)	Fluvial	3	2	3	71.0	2.9	26.1	0.9 ± 0.6
	Cusu Chico (150)	Aguaruna	Imacita (1)	Fluvial	3	2	3				
	Nueva Samaria (80)	Aguaruna	Imacita (0.75)	Fluvial	1	2	1				
9	Villa Santiago (120)	Mestizo-Amakaeri	Masuko (0.5)	Tarmac	1	2	3	28.2	14.1	57.7	2.3 ± 1.8
	Santa Rosa (500)	Mestizo	Masuko (1)	Tarmac	3	3	3				
	Unión Progreso (300)	Mestizo	Puerto Maldonado (1)	Tarmac	3	2	1				
10	Palma Real (300)	Ese Eja	Puerto Maldonado (4)	Fluvial	1	2	2	70.8	1.1	28.1	1.1 ± 0.9
Southern Amazon-Bolivia											
11	Santa María (250)	Mestizo	Riberalta (1)	Loose surface road	3	2	3	89.9	5.1	5.1	2.5 ± 1.5
	26 de Octubre (180)	Mestizo	Riberalta (1)	Road	1	2	2				

Table . *Continued*

Locality	Ecoregion – Country Community (population census approximately)	Ethnic group	Accessibility [(a)] Nearest town (distance in hours)	Accessibility [(a)] Type access	Social services available [(b)] Electricity	Social services available [(b)] Education	Social services available [(b)] Healthcare	House construction material [(c)] Local plant materials ≥ 50%	House construction material [(c)] Mixed material ≥ 50%	House construction material [(c)] Foreign commercial materials ≥ 50%	Average farm size (ha) ± SD[(d)]
12	Alto Ivón (500)	Chacobo	Riberalta (4)	Road	1	3	3	93.8	–	6.3	1.7 ± 0.8
	Motacuzal (30)	Chacobo	Riberalta (3.5)	Road	1	2	2				
13	San Benito (90)	Yuracaré	San Gabriel (1.66)	Fluvial/road	1	2	1	28.3	–	71.7	1.0 ± 0.1
	Sanandita (60)	Yuracaré	San Gabriel (1.5)	Fluvial/road	1	2	1				
	San Antonio (90)	Yuracaré	Ichoa (2)	Road	1	2	1				
	Secejsama (100)	Yuracaré	Isinuta (1.5)	Road	1	3	1				
14	25 de Mayo (100)	Mestizo-Tacana	San Buenaventura (1)	Road	1	2	3	94.9	–	5.1	1.8 ± 1.0
	Buena Vista (240)	Mestizo-Tacana	San Buenaventura (0.75)	Road	1	2	3				
	San Isidro (50)	Leco-Tacana	San Buenaventura (0.5)	Road	1	2	2				
	San Silvestre (100)	Tacana	San Buenaventura (1.5)	Road	1	2	2				
	Sta. Rosa de Maravilla (50)	Mestizo-Tacana	San Buenaventura (1.75)	Road	1	2	3				
Northern Andes-Colombia											
15	Sibundoy (13000)	Camsá	Sibundoy (0)	Tarmac	3	4	4	–	97.6	2.4	0.5 ± 0.6
16	Santiago (5800)	Inga	Santiago (0)	Tarmac	3	4	4	–	100	–	0.3 ± 0.4
	Juisanoy (2000)	Inga	Santiago (0.5)	Loose surface road	3	1	1				
Northern Andes-Ecuador											
17	Nanegalito (3200)	Mestizo	Quito (4)	Tarmac	3	4	4	-	81.4	18.6	0.8 ± 2.8
18	Mindo (1500)	Mestizo	Quito (3)	Tarmac	3	4	3	-	79.3	20.7	0.6 ± 2.7
Southern Andes-Peru											
19	Lamas Wayku (1200)	Chanka	Lamas (0.25)	Tarmac	3	2	3	2.2	5.6	92.2	1.8 ± 1.5
	Aviación (300)	Chanka	Lamas (2.5)	Loose surface road	2	2	3				
Southern Andes-Bolivia											
20	Irimo (350)	Leco	Apolo (3)	Loose surface road	2	2	2	42.7	2.2	55.1	2.2 ± 1.5
	Munaypata (80)	Leco	Apolo (1.5)	Loose surface road	2	3	2				
	Pucasucho (280)	Leco	Apolo (4)	Loose surface road	2	2	3				
21	Illipanayuyo (150)	Leco	Apolo (4)	Loose surface road	1	2	2	34.8	6.7	58.4	2.2 ± 2.3
	Santo Domingo (220)	Leco	Apolo (7)	Loose surface road	2	2	2				
	Correo (260)	Leco	Apolo (7)	Loose surface road	2	3	3				

Table . *Continued*

Locality	Ecoregion – Country Community (population census approximately)	Ethnic group	Accessibility [(a)] Nearest town (distance in hours)	Type access	Social services available [(b)] Electricity	Education	Healthcare	House construction material [(c)] Local plant materials ≥ 50%	Mixed material ≥ 50%	Foreign commercial materials ≥ 50%	Average farm size (ha) ± SD[(d)]
Chocó-Colombia											
22	Puerto Pervel (1500)	African-American	Quibdo (2)	Tarmac	3	2	3	1.2	91.9	7.0	0.4 ± 0.7
23	Aguacate (312)	Emberá	La Playa (24)	Fluvial	1	2	1	20.5	–	79.5	0.9 ± 1.0
	Villanueva (200)	Emberá	La Playa (24)	Fluvial	1	2	1				
Chocó-Ecuador											
24	Puerto Quito (1500)	Mestizo	Santo Domingo (0.5)	Tarmac	3	4	3	–	100	–	2.3 ± 8.7
25	Chigüilpe (130)	Tsa'chila	Santo Domingo (0.5)	Tarmac	3	2	3	12.0	86.0	2.0	4.8 ± 4.7
	Peripa (130)	Tsa'chila	Santo Domingo (0.5)	Tarmac	3	2	3				

Appendix 2

Distribution of informants by gender and age cohorts in 25 localities in north-western South America (Colombia, Ecuador, Peru and Bolivia) where traditional knowledge on palm use was gathered.

Ecoregion country	Human group	Ethnicity	Number of locality	Number of informants	Number of informants by gender: Men	Women	Number of informants by age cohort (years): 18–30	31–40	41–50	51–60	> 60
Northern Amazon											
Colombia	Indigenous	Multiethnic indigenous	1	65	42	23	17	17	13	6	12
		Tikuna	2	88	42	46	20	20	17	15	16
Ecuador	Indigenous	Cofan	3	82	38	44	26	21	13	8	14
		Achuar	4	65	31	34	23	21	12	7	2
Southern Amazon											
Peru	Indigenous	Cocama	5	87	44	43	19	17	24	10	17
	Mestizo	Mestizo	6	79	34	45	26	23	12	9	9
		Mestizo	7	89	39	50	22	21	19	11	16
	Indigenous	Aguaruna	8	69	35	34	21	17	12	11	8
	Mestizo	Mestizo-Amakaeri	9	78	45	33	22	14	16	11	15
	Indigenous	Ese Eja	10	89	38	51	35	22	13	10	9
Bolivia	Mestizo	Mestizo	11	79	39	40	10	18	19	14	18
	Indigenous	Chácobo	12	80	40	40	37	21	13	6	3
		Yuracaré	13	60	32	28	18	16	14	4	8
	Mestizo	Mestizo-Tacana	14	118	69	49	25	21	33	20	19

Table . *Continued*

					Number of informants by gender		Number of informants by age cohort (years)				
Ecoregion country	Human group	Ethnicity	Number of locality	Number of informants	Men	Women	18–30	31–40	41–50	51–60	> 60
Northern Andes											
Colombia	Indigenous	Camsá	15	82	30	52	31	19	11	6	15
	Indigenous	Inga	16	87	34	53	24	17	13	14	19
Ecuador	Mestizo	Mestizo	17	86	36	50	26	19	16	10	15
		Mestizo	18	87	48	39	29	20	13	12	13
Southern Andes											
Peru	Indigenous	Chanka	19	90	54	36	14	16	27	14	19
Bolivia	Indigenous	Leco	20	89	50	39	26	22	23	7	11
		Leco	21	89	45	44	18	25	23	15	8
Chocó											
Colombia	African-American	African-American	22	86	47	39	18	14	19	16	19
	Indigenous	Emberá	23	88	42	46	32	23	14	14	5
Ecuador	Mestizo	Mestizo	24	88	41	47	30	16	7	15	20
	Indigenous	Tsa'chila	25	50	22	28	11	11	10	8	10
				2050	1017	1033	580	2050	406	273	320