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Dietary Patterns of Children on Three Indigenous Societies

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Abstract. Despite increasing research interest on Indigenous Peoples' food systems, the specificities of Indigenous children's diets remain largely unexplored. We analyze data on food consumption of children from three Indigenous societies with relatively little involvement in the market economy: the Tsimane' (Bolivian Amazon), the Baka (Congo Basin), and the Punan Tubu (Borneo), as such societies allow for the rare possibility to see relationships that become hard to spot once external influences become commonplace. We describe children's diets and measure dietary quality through two standard indicators: dietary diversity and dietary quality (proxied by fruits and vegetables and animal source food consumption). The diversity of Indigenous children's diets varied from one society to another but was high compared to previously reported data. Overall, children's diets were more diverse than adults' diets, without stark differences between the diets of boys and girls or between children of different ages. There was a tendency for more diverse diets amongst children who attend school compared to those who do not. Children in the sample rely on a complex mixture of locally-sourced foods (mainly fruits, vegetables, and animal source foods) and products from the market (mainly oils, sweets, spices, and beverages). Findings from this work suggest that Indigenous children remain highly dependent on forest resources and subsistence agriculture for their diets. In that sense, the implications of the ongoing environmental changes on Indigenous children's diets require more scholarly attention.

Keywords: dietary diversity, Indigenous food systems, local diets, nutrition transition, wild edibles.

Introduction

The study of Indigenous Peoples' diets and food systems is gaining attention in the context of global discourses around food sovereignty and cultural identity (Charlton 2016; Coté 2016; Kuhnlein et al. 2009; Nolan and Pieroni 2014). Works on Indigenous Peoples' food systems have provided a detailed understanding of the diversity and complexity of Indigenous diets (e.g., D'Ambrosio and Puri 2016; Knezevic et al. 2017; Zycherman 2015) and of the critical role local diets play in supporting Indigenous health (Kuhnlein 2014; Kuhnlein and Receveur 2007; Nesbitt and Moore 2016). But, while general information regarding Indigenous Peoples' diets is becoming increasingly available, the particularities and specificities of Indigenous children's diets remain largely unexplored (Dufour et al. 2016). Indeed, our knowledge of Indigenous children's diets mostly comes from works that focus 1) on adults' diets and present children's data as complementary (e.g., Kuhnlein and Receveur 2007; Roche et al. 2008, but see Chege et al. 2015 for an exception) or 2) on the health effects of diets among children (e.g., Egeland et al. 2010; El Hayek et al. 2010; Huet et al. 2012) and infants (e.g., Chege et al. 2015;

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Coimbra et al. 2013; Ickowitz et al. 2014; Keatinge et al. 2011).

Here we focus on Indigenous children's diets. Specifically, we use data collected among three Indigenous societies to examine questions that arise when considering the implication of three previous research findings on children's diets. First, recent research suggests that access to diverse landscapes shapes dietary quality because foods from the forest are important sources of energy and allow diet diversification (Peñafiel et al. 2011; Powell et al. 2013). As children from Indigenous societies typically live in close relationship with the environment but relate to it through daily activities that differ from adults' activities (Ruiz-Mallen et al. 2013; Gallois et al. 2015; Boyette 2010), the question is posed as to whether such difference is reflected in adults' and children's dietary patterns.

Second, research has extensively documented how Indigenous children's daily life varies according to their sex, age, and school attendance (Gallois et al. 2015; Lancy 2008; Ruiz-Mallen et al. 2013). Indigenous children are often involved in productive activities, such as foraging and agriculture, but involvement varies between boys and girls and among children of different group ages. For example, hunting is a main activity among Baka boys (from five to 16 years old), but Baka girls are more involved in household maintenance, fishing, and gathering activities. Similarly, Baka adolescents are more involved in income generating activities (i.e., agricultural wage labor or commercial hunting and gathering) than younger kids (Gallois et al. 2015). Is this variation in children's activities reflected in children's diets? Does the incorporation of new activities (i.e., schooling) affect children's diets? To date, no research has addressed this topic.

Finally, because of diet's long-term health effects, much research on Indigenous People's diets has focused on nutritional transitions (e.g., Kuhnlein et al. 2004; Port Lourenco et al. 2008; Valery et al. 2012). Nutritional transitions bring profound changes to the dietary choices of Indigenous Peoples, not only through the reduction in consumption of locally-produced foods, but also through the incorporation of highly processed products (Galvin et al. 2015; Iannotti and Lesorogol 2014). As most of this research has been conducted among adults, we lack a clear understanding of whether changes in dietary choices are also evident in the diets of Indigenous children.

Therefore, this article has three goals. Our first goal is to describe the dietary quality of children in three Indigenous societies as compared to adults in the same society. Our second goal is to assess differences in the composition of children's diets specifically looking at dietary differences 1) between boys and girls, 2) amongst children of different ages, and 3) between children who attend school and those who do not. Finally, our last goal is to examine food sources (i.e., wild, crops, and market) in children´s diets and across food groups.

Studied Societies

This study took place amongst three Indigenous, small-scale, subsistence-based societies: the Tsimane' (Bolivian Amazon), the Baka (Congo Basin), and the Punan Tubu (Borneo). To date, all three societies have relatively little (albeit increasing and uneven) involvement in market economies, school-based education, and modern healthcare systems. In addition, the three societies resemble one another in that they depend on the consumption of local natural resources through a combination of foraging and farming in an environment where they have historical continuity of resource use. We selected these three societies because relatively isolated Indigenous societies allow for the rare possibility to see relations that become hard to spot once external influences become commonplace. For instance, gendered involvement in children's productive activities might change as the school system generalizes. While we

selected societies where we had the logistical infrastructure to work, other relatively self-sufficient Indigenous societies might have been equally valid to explore the ideas presented here. Below we provide some background information for each of the societies, with a special focus on childhood. As children in the three societies are understudied, we complement information from previous literature with our own ethnographic observations.

The Tsimane' are a contemporary horticultural and foraging society living in the rainforests of the southwestern department of Beni, in the Bolivian Amazon. The Tsimane' number approximately 14,000 people living in some 125 villages, mostly concentrated along riverbanks and logging roads (Reyes-García et al. 2014). Nowadays, despite increasing integration into the market economy, the Tsimane' continue to be highly self-sufficient (Godoy et al. 2010).

Tsimane' children forage both by joining adults' expeditions and in mixed-age children's groups. According to Aiello (2013), gathering edible plants in nearby forests is common for both boys and girls over five years of age, with Tsimane' children between seven and 12 years of age spending about 20% of their time undertaking various subsistence activities, including gathering fruits, hunting, fishing, and gardening. Plant foraging by most Tsimane' children occurs within village limits or in the immediate surroundings (Aiello 2013), with boys being allowed to wander further away from their houses than girls. Fruit gathered by children is often consumed on the spot and only a small fraction is taken back home. As they grow older, children are allowed to go further in the forest and, by the age of 12, parents typically send children to the forest and fallow fields to gather fruit. Tsimane' children also hunt birds and small mammals with slingshots and fish with hooks. Small game hunting is almost exclusively an opportunistic activity for boys, who only join adult hunting expeditions after reaching adolescence. Both girls and boys undertake their own fishing trips and join collective fishing expeditions (Díaz-Reviriego et al. 2017). Although children's hunting and fishing is essentially considered "play" (Martinez-Rodriguez 2009), recent work suggests that Tsimane' children's involvement in productive activities has a positive impact on their health and wellbeing (Aiello 2013).

The Baka are one of the foraging societies living in the tropical forest from the Congo Basin, with an estimated population between 30,000 and 70,000 in Cameroon (Leclerc 2012). Like the Tsimane', the Baka maintain a highly autarkic livelihood, despite increasing integration into the market economy (Leclerc 2012).

Baka children are highly involved in subsistence activities (i.e., hunting, gathering, fishing, and agriculture) both by joining adults but also in children-only groups (Gallois et al. 2015). From an early age, children gather a variety of foods for their own consumption in nearby forests, including wild edibles, sub-spontaneous crops (e.g., domesticated plants that also grow out of the plots spontaneously, such as yams), mushrooms, and caterpillars. Pre-adolescents and adolescents tend to go further into the forest to collect a broader range of wild edibles, often to be sold. Baka children, especially boys, also hunt, although adults do not consider children's preys as proper foods (Gallois et al. 2017). Children mostly hunt small mammals (i.e., squirrels and rodents) and birds, which they immediately cook and consume. Small groups of children hunt using bows and arrows and snares made of plants. As they age, children use more complex hunting techniques (i.e., spears and shotguns) and target bigger prey. Adolescents accompany adults in hunting trips. Baka children also fish, although fishing is not a predominant Baka subsistence activity. Young children participate in fishing trips with women, where they gather small fish and shellfish on the riverbanks. Before adolescence, girls and boys generally go

fishing in groups, whereas adolescent boys generally fish alone (Gallois and Duda 2016).

The third society where we worked, the Punan, is a previously nomadic group of around 10,000 people living in the interior highland of North Kalimantan in Indonesian Borneo (Levang et al. 2007). The Punan are composed of diverse groups, amongst which the Punan Tubu consist of about 800 people living in seven small and difficult to access villages in the upper watershed of the Tubu river. Contemporary Punan Tubu practice upland rice swidden cultivation, but they are still seasonally mobile within a forested territory, where they engage in wild boar hunting and the gathering of wild edible and other forest products (Kaskija 2012; Levang et al. 2007).

During fieldwork, we observed that groups of Punan Tubu children forage together. For example, groups of young boys often travel to the closest river to catch small fish or softshell turtles that they immediately cook and consume. Children as young as four years of age gather small fruit for their own consumption. Groups of children also harvest cassava or the fruits from cultivated trees around the village and eat these foods by themselves or share them with other children. As they grow up, children also accompany women to collect wild fruit deep into the forest. Older boys also go net fishing in deep river waters near the village. Pre-adolescent girls participate in planting, harvesting, and processing crops, particularly cassava, while pre-adolescent boys start practicing adult hunting with spears and dogs.

Methods

We conducted 18 months of fieldwork (from May 2012 to October 2013). Six researchers collected data in two communities in each of the three societies. Each researcher teamed up with local research assistants who helped in data collection and translations. We used a mixed method approach, combining both qualitative (i.e., participant observation and semi-structured interviews) and quantitative data collection methods (i.e., 24-hour dietary recalls and a census; see Reyes-García et al. [2016] for a full methodological description). All the protocols were pilot-tested in neighboring villages. This research adheres to the Code of Ethics of the International Society of Ethnobiology (ISE 2006) and has received the approval of the Ethics Committee of the Universitat Autònoma de Barcelona (CEEAH-04102010). We obtained Free Prior and Informed Consent (FPIC; sensu FAO 2016) from each village and individual participating in this study, as well as agreement from the relevant political organization representing the Indigenous groups where we worked. As we interviewed children, we also followed the Code of Ethical Research Practice of the Centre for Children and Young People (CCYP 2005), which provides specific guidance on the standard ethical procedures to conduct research with children in international contexts. This included obtaining both parental and child consent and explaining to children their right to withdraw from the research at any point.

Sampling

In each society, we worked in villages with different levels of distance to the closest market town. In each village, we worked with all adults and children willing to participate. We defined children as individuals between three and 16 years of age. We selected three years of age as our low-end because, by this age, most infants in the societies where we worked are weaned. We selected 16 years as our up-end as, by this age, adolescents start forming their own households and are considered adults. Our final sample includes 405 children (142 Tsimane', 162 Baka, and 101 Punan Tubu) and 483 adults (132 Tsimane', 233 Baka, and 118 Punan Tubu). To have a complete portrait of local diets, we interviewed each participant several times, resulting in an average of 4.9 interviews per participant.

Qualitative Data Collection Methods

We integrated qualitative data collection methods through our fieldwork, but particularly used them during the first six months. Through semi-structured interviews with local experts (Davis and Wagner 2003), we collected contextual information on local livelihoods (i.e., techniques, division of labor, seasonality, and assets associated to subsistence activities) and diets and dietary changes. For example, we asked about locally available food items and food availability (such as seasonality and new market foods). We also asked about ingredients used in local dishes, local meal customs, as well as children's food habits and ways of procuring food. For example, we gathered information on daily number of meals, eating habits (such as eating out of one pot, on separate plates, or buying meals), cultural values around food, local recipes, seasonality, changes in food preparation, social norms regarding food preparation and consumption, and gender dimensions of food procurement.

Quantitative Data Collection Methods

During the second stage of fieldwork, we used two systematic protocols for data collection, census and dietary recall. In each village, we conducted a census to collect each household's demographic information (e.g., age, sex, kinship relations). As most people could not recall their date of birth, we used kinship information to estimate children's age and then refined the estimation by crosschecking with information from children from other households. The census also included information on whether children attended school.

We collected data on diet using a standard protocol adapted from the Food and Agricultural Organization (FAO)/Nutrition and Consumer Protection Division (FAO 2016). Specifically, we classified locally consumed products according to the FAO food-groups protocol (Supplemental Table 1). Then, twice a quarter, we visited each household and asked participants to list all the foods and drinks consumed inside and outside the house during the previous 24 hours. We administered the questionnaire avoiding celebrations and fasting periods, when food consumption might not reflect the usual diet.

We collected information on children´s diets by asking a proxy respondent (e.g., the mother). For children six years of age or older, we complemented this information with information obtained by directly asking the child, but only in the instances that the child was willing to answer questions. We did so to improve data accuracy, as previous research has found that parents sometimes do not know what children eat outside the household and that children's recall is not always accurate and/or reliable (Baxter 2009).

The interview started as a free recall of items eaten (meals and snacks). As respondents listed foods, researchers marked the items in the corresponding food group. After the participant stopped listing, we probed for foods potentially consumed outside the house, such as food consumed in the forest, in agricultural fields, or when visiting other households. We also probed for spices and food items used in cooking, such as sugar, salt, and oil. Once the participant ended the recall, we probed for food groups for which the participant had not listed any food. To assess the sources of food, for each food item mentioned, we asked participants whether the item was cultivated, obtained from the wild, or bought.

Data Analysis

We used the information from the dietary recall to construct a measure of *dietary diversity*, defined as the average number of cited food groups in the person's diet of the previous 24 hours (Kennedy et al. 2011). As we classified food items in 16 groups, our measure of dietary diversity ranges from 0 to 16. We then created two additional indicators of dietary quality recommended in the aforementioned guidelines: fruits and vegetables consump-

tion (including vitamin-A rich fruits, other fruit, vitamin-A rich tubers and vegetables, dark green leafy vegetables, and other vegetables) and animal source foods consumption (including flesh meat, organ meat, fish, eggs, milk, and milk products). These two indices are constructed as the percentage of diets including either fruits and vegetables or animal source foods.

To assess differences in the composition of children's diets, we provide descriptive statistics comparing the consumption of the different food groups. Specifically, we compare: 1) children and adults, 2) boys and girls, 3) children of different ages, and 4) children who attend and do not attend school. To assess differences amongst children of different ages, we differentiate amongst: 1) early childhood (≥ 3 to < 6 years old); 2) middle childhood (≥ 6 to < 9 years old); 3) pre-adolescence (≥ 9 to < 12 years old); and 4) adolescence (≥ 12 to ≤ 16 years old). To assess differences between children who attend and do not attend school, we used only the sample of children above six years of age, when school attendance is—in theory—mandatory. We assess whether differences among these groups were statistically significant using a Pearson Chi-square test.

To examine the sources of food in children's diets, we generated three variables: crop, wild, and market. These variables took the value of 1 if at least one of the food items in the group came from 1) the agricultural fields, 2) the forest, and 3) a monetary exchange, respectively. To describe the sources of food, we calculated the percentage of diets containing at least one crop, wild, and market food item. Since each food group can have items from more than one source, the sum of the percentages of the three groups does not necessarily add up to 100%.

Results

We present the composition of children's diets in Table 1 (see also Supplemental Table 1 for more detail on dietary composition). The dietary diversity score of Tsimane' children was about 2 points higher than that of Baka and Punan Tubu children (6.4, 4.5, and 4.7, respectively). Moreover, while 100% of Tsimane' children's diets contained at least one fruit or vegetable, this was only the case for 78.9% and 85.7% of Baka and Punan Tubu children's diets, respectively. Similarly, while 86.7% of Tsimane' children's diets contained at least one animal source food, this was only the case for 51.3% and 57.9% of Baka and Punan Tubu children's diets, the difference lying in the high levels of fish consumption amongst the Tsimane'.

The composition of children's diet resembled the composition of diets of adults in the same group, with some remarkable differences (Table 1). Thus, Tsimane' children consumed more fruits and eggs, but less flesh meat than Tsimane' adults. Baka children consumed more tubers, green leafy vegetables, other fruits, organ and flesh meat, legumes, sweets, and spices than Baka adults, who in turn consumed more vitamin-A rich fruits than children. Finally, Punan Tubu children consumed more vitamin-A rich fruits and fish, but fewer vegetables than Punan Tubu adults (Table 1). Overall, in the three groups, dietary diversity was higher amongst children than amongst adults, although the difference was not statistically significant for the Tsimane'. Similarly, the percentage of diets including fruits and vegetables was higher amongst children than amongst adults, whereas the percentage of children's diets including animal source foods was only higher than the percentage of adult's diets including animal source foods amongst the Baka (51.3% vs 38.0%).

Amongst our participants, the composition of boys' diets resembled the composition of girls' diets for Baka and Punan Tubu children, but the percentage of diets including items from all food groups was lower among Tsimane' girls than among Tsimane' boys (Table 2). Tsimane' girls also had a lower dietary diversity

Table 1. Percentage of adults and children's diets including food items in the selected foods groups, by society.

	Tsimane'		Baka		Punan	
Food groups	Children	Adults	Children	Adults	Children	Adults
Cereals	84.69	82.17	9.28	10.53	81.69	82.12
Vitamin-A rich tubers and vegetables	12.78	14.12	0.00	0.00	0.00	0.33
White roots and tubers	33.29	34.62	97.04***	92.87	43.66	39.24
Green leafy vegetables	0.00	0.00	73.97*	70.10	72.23	67.88
Other vegetables	12.38	12.04	0.26*	1.01	6.84*	9.60
Vitamin-A rich fruits	98.93*	97.77	14.95*	17.82	12.88**	9.11
Other fruits	69.51***	61.52	13.53***	6.20	31.99	27.81
Organ meat	14.51	16.20	17.40***	5.03	3.82	3.81
Flesh meat	44.07**	50.82	43.43***	29.67	46.68	50.17
Egg	6.79*	4.46	0.00	0.08	0.00	0.17
Fish	58.85	55.42	12.89	11.15	18.31***	12.58
Legumes, nuts, and seeds	2.40	3.12	43.94***	30.83	0.40	0.50
Milk and milk products	2.13	1.78	0.00	0.00	0.60	0.33
Oils and fats	49.80	49.03	41.37	41.44	20.72	24.50
Sweets	52.73	56.91	2.84**	1.47	36.02	36.75
Spices, condiments, and beverages	92.28	91.23	76.55*	72.66	96.98	97.52
Dietary quality						
Dietary diversity (0-16)	6.35 (± 2.1)	6.31 (± 2.1)	4.47 *** (± 1.5)	3.91 (± 1.5)	4.73* (± 1.2)	4.62 (± 1.3)
Fruits and vegetables consumption (%)	100**	99.25	78.90	77.76	85.71**	80.13
Animal derived food consumption (%)	86.68	88.71	51.29***	38.03	57.95	57.95
N	751	673	776	1291	497	604

Note: *, **, and *** Pr $<$ 0.1, $<$ 0.05, and $<$ 0.01 in a Pearson Chi-square test.

score and animal derived food consumption score than Tsimane' boys. Punan Tubu boys' diets also included more often green leafy vegetables than girl's diets, a difference that was also reflected in the score of overall fruits and vegetables consumption.

Overall, we did not find differences in the food groups included in the diets of children in different age categories (Table 3). The only statistically significant difference found relates to Tsimane' children's consumption of white roots and tuber consumption, a food group whose consumption increased with age. However, this trend seems to be an exception.

We also compared the diet composition for children attending and not attending school (Table 4). Amongst the Tsimane', children not attending school consumed fewer white roots and tubers, other vegetables, and oils and fats than children attending school. They also had a lower dietary diversity score and a lower overall consumption of animal derived foods than children attending school. In the case of the Punan Tubu, children not attending school

Table 2. Percentage of boys' and girls' diets including food items in the selected foods groups and categories, by society.

	Tsimane'		Baka		Punan	
Food groups	Girls	Boys	Girls	Boys	Girls	Boys
Cereals	82.86	86.28	9.49	9.07	84.39	80.25
Vitamin-A rich tubers and vegetables	11.43	13.97	0.00	0.00	0.00	0.00
White roots and tubers	29.43**	36.66	97.18	96.89	41.04	45.06
Green leafy vegetables	0.00	0.00	74.62	73.32	67.63*	74.69
Other vegetables	10.57	13.97	0.00	0.52	8.67	5.86
Vitamin-A rich fruits	98.57	99.25	15.64	14.25	9.83	14.51
Other fruits	69.71	69.33	14.87	12.18	28.32	33.95
Organ meat	10.57***	17.96	16.67	18.13	4.05	3.70
Flesh meat	43.43	44.64	42.82	44.04	50.87	44.44
Egg	6.86	6.73	0.00	0.00	0.00	0.00
Fish	55.71*	61.60	13.33	12.44	16.19	19.44
Legumes, nuts, and seeds	1.14**	3.49	42.82	45.08	0.00	0.62
Milk and milk products	2.00	2.24	0.00	0.00	0.58	0.62
Oils and fat	46.57*	52.62	40.77	41.97	23.12	19.44
Sweets	48.86**	56.11	2.31	3.37	35.26	36.42
Spices, condiments, and beverages	90.86	93.52	77.44	75.65	97.69	96.60
Dietary quality						
Dietary diversity (0-16)	6.09***	6.58	4.48	4.47	4.68	4.76
	(± 2.0)	(± 2.1)	(± 1.4)	(± 1.5)	(± 1.1)	(± 1.2)
Fruits and vegetables consumption (%)	100	100	81.02	78.75	79.19***	89.20
Animal derived food consumption (%)	82.86***	90.02	51.03	51.55	61.27	56.17
N	350	401	390	386	173	324

Note: *, **, and ***Pr $<$ 0.1, $<$ 0.05, and $<$ 0.01 in a Pearson Chi-square test.

consumed fewer white roots, tubers, and fish, but more items in the category of "other vegetables" than children attending school. As with Tsimane' children, Punan Tubu children not attending school presented an overall lower dietary diversity score and a lower overall consumption of animal derived foods than their peers attending school. We did not find any difference in the dietary composition of Baka children attending and not attending school.

Sources of food in children's diets varied from one society to another (Table 5). Tsimane' obtained from their agricultural plots food items in the categories of cereals, vitamin-A rich tubers and vegetables, whiter roots and tubers, vitamin-A rich fruits, eggs, and legumes. Food items in the categories of other fruits came from plots as well as from the wild. Tsimane' largely obtained organ meat, flesh meat, and fish from the wild. The market was the main source of other vegetables, milk products, oils and fats, sweets, and spices and beverages. The Baka obtained most vitamin-A rich fruits, other fruits, and oils and fats from agricultural plots. White roots and tubers and other vegetables were equally

Table 3. Percentage of children's diets including food items in the selected foods groups and categories, by age category and society.

	Tsimane'				Baka				Punan			
Food group	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]	[1]	[2]	[3]	[4]
Cereals	86.81	86.01	83.48	83.75	8.24	8.76	7.14	12.55	77.50	81.33	82.54	84.09
Vitamin-A rich tubers & vegetables	11.81	10.49	13.39	14.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
White roots and tubers	43.06**	33.57	32.59	27.92	96.47	99.27	96.22	96.97	51.67	48.00	38.89	39.77
Green leafy vegetables	0.00	0.00	0.00	0.00	74.12	76.64	73.11	73.16	74.17	80.00	70.63	68.75
Other vegetables	13.89	9.79	13.84	11.67	0.00	0.00	0.42	0.43	5.00	2.67	7.94	9.09
Vitamin-A rich fruits	99.31	100	98.21	98.75	15.29	16.06	13.87	15.15	15.00	14.67	11.11	11.93
Other fruits	65.97	69.93	70.54	70.42	11.18	11.68	16.81	12.99	28.33	33.33	32.54	33.52
Organ meat	16.67	14.69	14.29	13.33	17.65	20.44	16.81	16.02	3.33	4.00	3.97	3.98
Flesh meat	40.28	46.85	41.96	46.67	42.94	43.80	43.28	43.72	44.17	42.67	50.00	47.73
Egg	5.56	8.39	6.70	6.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fish	56.94	60.14	62.50	55.83	12.35	15.33	12.18	12.55	23.33	22.67	16.67	14.20
Legumes, nuts, and seeds	4.17	1.40	2.68	1.67	41.18	48.18	45.38	41.99	0.83	1.33	0.00	0.00
Milk and milk products	1.39	1.40	2.68	2.50	0.00	0.00	0.00	0.00	0.00	1.33	0.79	0.57
Oils and fat	49.31	50.35	50.89	48.75	41.18	40.15	45.38	38.10	15.83	14.67	24.60	23.86
Sweets	50.00	51.75	54.46	53.33	2.94	2.92	3.36	2.16	34.17	37.33	37.30	35.80
Spices, condiments, and beverages	93.06	93.71	92.41	90.83	77.65	77.37	76.05	75.76	95.83	96.00	98.41	97.16
Dietary quality												
Dietary diversity (0-16)	6.38 (± 2.2)	6.38 (± 2.1)	6.41 (± 2.1)	6.26 (± 2.1)	4.41 (± 1.5)	4.61 (± 1.4)	4.5 (± 1.5)	4.42 (± 1.4)	4.69 (± 1.3)	4.8 (± 1.3)	4.75 (± 1.1)	4.70 (± 1.2)
Fruits and vegetable consumption (%)	100	100	100	100	80.58	83.21	79.41	77.92	82.5	90.67	86.5	85.23
Animal derived food consumption	86.11	88.81	87.50	85.00	51.18	51.82	49.57	52.81	58.33	57.33	60.32	56.25
N	144	143	224	240	170	137	238	231	120	75	126	176

Note: [1] Adolescence. [2] Pre-adolescence. [3] Middle childhood. [4] Early childhood.
*, **, and, *** Pr < 0.1, < 0.05, and < 0.01 in a Pearson Chi-square test.

Table 4. Percentage of children's diets including food items in the selected foods groups and categories for children attending and not attending school, by society.

	Tsimane'		Baka		Punan	
Food groups	No school	School	No school	School	No school	School
Cereals	88.12	84.39	5.95	8.89	78.26	80.59
Vitamin-A rich tubers and vegetables	88.12	84.39	5.95	8.89	78.26	80.59
White roots and tubers	19.80***	39.76	95.24	97.84	34.78**	47.99
Green leafy vegetables	0.00	0.00	75.60	73.32	82.61	72.53
Other vegetables	5.94*	14.39	0.00	0.27	10.87**	4.40
Vitamin-A rich fruits	100.00	98.78	16.07	14.29	4.35	15.02
Other fruits	65.35	70.00	12.50	14.56	39.13	29.67
Organ meat	11.88	15.85	18.45	17.52	2.17	4.03
Flesh meat	39.60	43.66	38.09	46.09	34.78	48.35
Egg	6.93	6.83	0.00	0.00	0.00	0.00
Fish	59.41	60.49	12.50	13.21	6.52***	23.08
Legumes, nuts, and seeds	3.96	2.44	45.24	43.94	2.17	0.37
Oils and fats	40.59*	52.68	41.67	43.40	17.39	19.05
Milk and milk products	2.97	1.71	0.00	0.00	2.17	0.37
Sweets	43.56	54.63	1.79	3.77	21.74	38.46
Spices, condiments, and beverages	91.09	93.41	79.17	76.01	95.65	97.07
Dietary quality						
Dietary diversity (0-16)	5.88*** (± 2.0)	6.52 (± 2.1)	4.42 (± 1.4)	4.53 (± 1.5)	4.33** (± 1.2)	4.81 (± 1.2)
Fruits and vegetables consumption (%)	100	100	82.74	79.51	89.13	85.53
Animal derived food consumption (%)	83.17*	88.54	45.23	53.37	43.47*	61.90
N	101	410	168	371	46	273

Note: *, **, and *** Pr $<$ 0.1, $<$ 0.05, and $<$ 0.01 in a Pearson Chi-square test.

obtained from agricultural plots and the market, probably reflecting exchanges with Bantu neighbors. The forest was the main source of green leafy vegetables, organ and flesh meat, fish, and legumes and nuts. Finally, Baka children obtained most cereals, sweets, and spices and beverages in the market. Punan Tubu children obtained most cereals (mostly rice), white roots and tubers, green leafy and other vegetables, and fruits from their agricultural plots, although some fruits and vegetables were also collected from the wild. As with Tsimane' and Baka children, Punan Tubu

children obtained most organ and flesh meat and fish from the wild. The market was the main source of legumes, milk products, oils and fats, sweets, and spices and beverages for the Punan Tubu.

Discussion

We derive four main findings from the work presented here. First, the diversity of Indigenous children's diets varies from one society to another, but it is generally high when compared to the dietary diversity scores reported in previous works. We acknowledge that such differences could be alternatively explained by cultural (i.e., different food systems), environmental (i.e., different food sources), or genetic differences (i.e., lactose intolerance in some of the groups; see Gerbault et al. 2009), as well as by a combination of these factors. However, establishing the potential role of each of these factors in shaping children's diets lies beyond the scope of this paper. We highlight, however, the higher dietary diversity found in comparison with other groups. For example, using a similar method with a representative sample of children from different ethnic groups in South Africa, Steyn et al. (2006) found a mean dietary diversity score of 3.6, one point lower than

Table 5. Sources of food in children's diets, by society.

	Tsimane' (n = 751)			Baka (n = 774)			Punan (n = 497)		
Food groups	**Crop**	**Wild**	**Market**	**Crop**	**Wild**	**Market**	**Crop**	**Wild**	Market
Cereals	90.3	0.6	14.6	0.0	0.0	100.0	98.5	0.0	8.6
Vitamin-A rich tubers and vegetables	94.8	0.0	5.9	.	.	.	.	.	.
White roots and tubers	97.2	0.0	0.8	45.9	2.3	57.6	100	0.0	0.0
Green leafy vegetables	.	.	.	40.2	61.5	8.4	98.6	6.0	0.0
Other vegetables	44.1	0.0	55.9	50.0	0.0	50.0	100	55.0	10.0
Vitamin-A rich fruits	98.9	2.4	0.3	76.3	0.0	23.7	95.3	4.8	0.0
Other fruits	50.0	57.3	0.2	96.2	3.8	0.0	76.5	58.4	0.0
Organ meat	15.6	87.2	0.0	0.0	100.0	1.5	0.0	100	0.0
Flesh meat	19.0	66.2	19.3	0.0	91.6	9.5	1.3	99.6	0.0
Egg	86.3	9.8	3.9	.	.	.	.	.	.
Fish	0.0	100	0.0	0.0	96.0	4.0	1.2	91.1	9.3
Legumes, nuts, and seeds	66.7	33.3	0.0	38.6	54.3	21.2	0.0	0.0	100
Milk and milk products	0.0	0.0	100	.	.	.	.	.	100
Oils and fat	35.3	4.0	60.7	69.2	25.5	6.9	0.0	73.8	70.7
Sweets	15.7	2.0	92.9	0.0	18.2	81.8	8.6	0.0	98.3
Spices, condiments, and beverages	1.0	0.9	98.4	73.6	5.9	97.0	17.8	0.3	99.8

the score found for Baka children (4.5), the group with the lowest score in our sample. Furthermore, in the Steyn et al. (2006) study, the items with the highest frequency of consumption were within the cereal and roots and tuber groups; in contrast, the other vegetables, vitamin-A rich and other fruit group were consumed by less than one third of the children. The levels of fruit and vegetable intake found are also higher than those reported in studies on Indigenous children's diets elsewhere (e.g., Novotny et al. 2012; Valery et al. 2012). While methodological differences could explain at least some of the variation, we argue that a plausible explanation for the high dietary diversity in our sample relates to the fact that children participating in this study live in close relationship with their environment. Recent research suggests that access to diverse landscapes shapes dietary diversity (Peñafiel et al. 2011; Powell et al. 2013), for which Indigenous children's contact with the natural environment might indeed be a pathway for achieving high diversity in diet.

The second important finding of our work is that Indigenous children's diets were more diverse than adult's diets. We can think of four non-mutually exclusive reasons to explain this difference. First, it is possible that adults recognize childhood as a vulnerable life stage requiring high food inputs to promote growth and maintain health, and thus derive certain foods to children. For instance, we observed that Baka adults regularly reserve meat for the children, even when they sell most of the animal hunted. Similarly, the Punan Tubu would feed to children fruit harvested from planted trees, particularly in the season when fruits are scarce. Second, children might have access to a more diversified diet than adults through cooperative breeding (Hrdy 2005b). Allomaternal care, or children's care by non-parental adults, might increase children's access to the wide range of foods consumed in several households. Indeed, such practice has been associated to the enhancement of infant survival (Hrdy 2005a; Kennedy 2005), so it might also relate to dietary diversity. Third, as has been reported in the case of the Orang Asli (Meyer-Rochow 2009), children participating in this study might have been exposed to different food taboos than those of adults, which could affect the types of foods that are allowed to be consumed or not.

These three reasons, however, do not fully suffice to explain dietary differences between children's and adults' diets, as, in the societies included in this study, preadolescents are largely in charge of their own food provisioning. Therefore, the last potential pathway through which children might increase their dietary diversity is through the results of their own productive activities. Indigenous children's contributions to productive activities, such as foraging and agriculture, have been largely documented (Hawkes et al. 1995; Hewlett et al. 2011). For example, Hawkes et al. (1995) report that Hadza children living in the Eastern Rift forage for tubers, fruit, and berries, sometimes engaging in long excursions to gain access to remote foraging areas. Similarly, Meriam children, coastal-foragers in the Mer Island of Melanesia, are capable fishermen able to supplement adult fish provisioning (Bird and Bliege Bird 2002). Similar findings have been found amongst Mikea children in Madagascar (Tucker and Young 2005) and even Tsimane' (Aiello 2013) and Baka children (Gallois 2016). Indeed, previous studies have reported that children's food self-procurement can reach up to 50% of their caloric needs (Bird and Bliege Bird 2002; Tucker and Young 2005). And we argue that this form of food acquisition can also make children's diets relatively different from those of adults, potentially resulting in higher dietary diversity.

The third finding of this work refers to the lack of substantial differences between

boys' and girls' diets or amongst the diets of children of different ages. The finding goes against our intuition, as we had argued that different involvement in productive activities would be reflected in dietary differences. It is possible that the prevalence of food sharing levels up potential differences in food procurement which are not reflected in actual food consumption. Food sharing is a widespread, culturally-established practice in the three populations studied (Reyes-García et al. 2016), and has also been largely documented amongst children of different cultural traditions (e.g., Boyette 2013; Crittenden and Zes 2015; Tam et al. 2014). However, while the explanation is plausible, it requires further research to be tested. Moreover, this finding raises one additional question: given that children have greater dietary diversity than adults, but there are no differences among children of different ages, when and why do children lose this greater spread of food diversity?

We only found two remarkable exceptions to the patterns mentioned above. First, we found significant dietary differences between Tsimane' boys and girls. Some research amongst the Tsimane' suggests emerging inequalities in food distribution within households, with men eating more fresh fish and meat when they are away from home (see Godoy et al. 2007; Zycherman 2013). This pattern could be also occurring amongst children. Second, we found a tendency for more diverse diets amongst children attending school. We do not have a consistent explanation for why children attending school enjoy more diversified diets than children not attending, other than the potential impact of nutritional programs conveyed through public schools, which are present in Tsimane' and Punan Tubu but not in Baka schools.

Our final finding relates to food group sources. Children participating in this study rely on a complex combination of locally-sourced and market foods. While we lack baseline data on children's diets, our ethnographic understanding indicates that the consumption of market-foods could be on the rise. Moreover, at least one previous study in one of the studied areas also suggests so, as it reports that remote Punan Tubu communities have a more diversified diet and better nutritional status than communities closer to the market (Dounias et al. 2007). It is also worth noticing that most market-foods are items in the "oil and fat," "sweets and spices," and "beverages" food groups, food groups whose increased consumption has been directly associated with higher levels of diabetes and a growing epidemic of obesity amongst Indigenous children all over the world (Reading and Wien 2009; Valery et al. 2012). Thus, while our data suggest that the percentage of market foods consumed by children in the sample is lower than the percentages reported for other Indigenous Peoples (Kuhnlein et al. 2004), the trend could indeed be signaling emerging transformations in local diets.

Conclusion

Findings from this work suggest that Indigenous children remain highly dependent on forest resources and subsistence agriculture for their diets, with fruits and vegetables and animal sourced food largely coming from forests and agricultural plots. If access to diversified landscapes (including both forests and agricultural plots) contributes to increase the presence of diverse nutritious foods in the diet (i.e., fruits, vegetables, and animal source foods), then current drivers of landscape homogenization should be understood also in terms of food sovereignty. Most importantly, because childhood is a vulnerable life stage requiring higher food inputs to promote growth and maintain health, the implications of the ongoing environmental changes on Indigenous children's diets should be carefully evaluated. Policies addressing Indigenous Peoples' food security should consider the distinctive strategies and perspectives of children with regard to food

and diets. This study shows the specificities and particularities of Indigenous children's diets in three different groups across the tropics. The higher diversity in children's versus adults' diets calls for policy efforts to broaden the focus of food security policies and pay attention to the food procurement strategies of Indigenous children, as well as their tight relationships to their forests, thus adopting a biocultural approach.

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