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Environments of Learning: Rarámuri Children's Plant Knowledge and Experience of Schooling, Family, and Landscapes in the Sierra Tarahumara, Mexico

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Abstract This paper investigates social-environmental factors contributing to differential ethnobotanical expertise among children in Rarámuri (Tarahumara) communities in Chihuahua, Mexico, to explore processes of indigenous ecological education and epistemologies of research. One hundred and four children from two schools (one with a Ráramuri knowledge curriculum and one without) were interviewed about their knowledge of 40 useful plants. Overall, children showed less ethnobotanical expertise than expected and a great deal of variability by age, though most shared knowledge of a core set of culturally and ecologically salient plants. No significant difference was found between girls' and boys' knowledge. The overall use-knowledge scores were almost twice as high as naming scores (mean of 40% vs. 24.4%). This supports the conclusion that use-context is more culturally relevant, salient or easier for children to remember than names. The social–environmental factors significant in predicting levels of plant knowledge among children were whether a child attended a Rarámuri or Spanish-instruction school, and, to a lesser extent, age. However, these effects were not strong, and individual variability in expertise is best interpreted using ethnographic knowledge of each child's family and personal history, leading to a model of ethnobotanical education that foregrounds experiential learning and personal and family interest in useful plants. Though overall plant knowledge may be lower among children today compared to previous generations, a community knowledge structure seems to be reproduced in which a few individuals in each age cohort show great proficiency, and children make the same kinds of mistakes and share specialized names for plants.

Keywords Rarámuri · Northern Mexico · Ethnobotany · Children's local knowledge · Cultural transmission · Experiential knowledge

Introduction

Silvino was eight years old, the older brother of my goddaughter in a Rarámuri community in the highlands of the Sierra Tarahumara, Northern Mexico. He walked quickly through the pine and oak forest in the cliff-lined valley ahead of me on our way to a hot spring a few kilometers upstream. As we walked I asked him in Spanish about the plants and animals whose paths we crossed. He told me how to eat certain plants, the best way to prepare others, in which season to harvest honey from a wild hive. He spoke casually and with interest about which plants are good medicine. I was impressed. In fact, I was so impressed that for months afterwards my thoughts returned over and over to ponder the sense of curiosity, relaxation and vitality I observed in Silvino's interactions with his home landscape, and then I returned in person to try to understand Rarámuri environments of ethnobotanical learning.

Children's learning about the world around them—their social, cultural and biophysical environments—is essential to human ecological processes in all societies. The young are the "living messages we send to a time we will not see" (Postman 1994:xi), agents of long-term resilience as well as influential ecological actors in their own right in their own time. To understand human ecological process in any one place over time, we examine children's psychological,

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familial, community and social growth, in interaction with their non-human environments. These form the broad-brush patterns of human ecological adaptation, accommodation and innovation over time. In northern Mexico, Rarámuri children grow up in communities that are undergoing socioeconomic, cultural and environmental changes on a scale to rival that at European contact. As their political-economic geography expands and young people negotiate new pressures, identities, schooling and survival strategies in their communities, the ecological learning that was once incorporated as a matter of course in daily life may be shifting too (Benz *et al*. 2000; Zent 2001). As part of a larger ethnographic project on Rarámuri childhood and informal ethnobotanical education (Wyndham 2004a, b), this study documents plant knowledge variation among children in a small rural highland community in Chihuahua and identifies socio-environmental factors that may play a role in this variation. To what extent are children learning an adult repertoire of local plant knowledge? What social, familial and experiential factors might account for differential acquisition of knowledge among children? From ethnographic work, I highlight the importance of knowledge-sharing among family members, time spent in contact with living landscapes, schooling that values local language and knowledge, and strong peer networks to learn the traditional ecologies of Rarámuri landscapes. Through the research process I was educated to Rarámuri notions of the centrality of experiential and performative knowledge—knowing through relationships with plants—which challenges the particulate and disembodied models implicit in many studies of the transmission of ecological knowledge, including this one.

I designed this study with several underlying assumptions. A fundamental ontological assumption is that knowledge is measurable and comparable, and in some way ‘particulate’—that is, knowledge (here, knowledge about plants) can be treated as ‘chunks’ of information that can be ‘acquired’ (cf. Marchand 2003 on ‘informational atomism’). The implicit model is one that regards culture as information that is “received or created, stored, retrieved, transmitted, utilized, and even lost” (Roberts 1964:438); by extension, that information is differentially distributed in patterns that correspond to experience and action throughout the lifespan of individuals. These discernable patterns allow us to infer how learning takes place (Boster 1991:203), while provoking an inquiry into how traditional knowledge is heterogeneous and constantly changing, as has been increasingly recognized in ethnographic and ethnobotanical studies over the past two decades (Boster 1987; Brunel 1974; Garro 1986; Godoy *et al*. 2005; Simpson 1994). The paradigm that posits local plant knowledge as cross-culturally commensurate (measured, for example, with naming and use expertise) has been critiqued by Agrawal (1999) as ‘scientizing’ local knowledge, a translation process that not only strips local knowledge of its meaning but also can further tip the balance of unequal power relations in local communities. There are important aspects of local knowledge that are embedded in local cultural values and epistemologies; as researchers we move between different constructions of what knowledge *is*, and are faced with the conundrum of how to translate and interpret knowledge across cultures (Heckler 2006).

Rarámuri Knowledge in Global Contexts

As the world becomes more and more interconnected by way of interactions and exchanges of information and goods, economic development of the Sierra Tarahumara has accelerated through the extraction of natural resources and selling natural and cultural attractions to tourism, in addition to a thriving traffic in narcotics. These benefit indigenous Rarámuri subsistence farmers only peripherally in the short term, and impose additional pressures in the long term due to erosion of arable land and decrease in rainfall because of deforestation, as well as increasing competition for land. In the communities discussed here, approximately one-third of the men under 35 years old have to leave the Sierra or even the state of Chihuahua to find seasonal work to maintain their families at home. As the means of livelihood and healthcare options change, so does the knowledge and know-how sought after and taught to youngsters; as one healer told me, “Only the poorest of the poor need to know about edible wild plants anymore.” Nevertheless, my observations over about ten years point to the continuing importance of ethnobotanical knowledge in this area—knowledge that is embodied in everyday relations, used and practiced in the social contexts of food procurement, artisanship, and traditional familial health care (Bye *et al*. 1975; Bye 1985; Cardenal 1993; Miller 2002; Miller and Valencia 1999; Pennington 1963).

The role of childhood environments in cognitive development has been well researched (Lerner *et al*. 1995; Valsiner 1988; Valsiner and Voss 1996) and a growing body of research has focused specifically on the acquisition of biological or ecological knowledge in children’s development. It has been suggested that childhood processes of learning to forage in local environments improves individual cognitive ability to describe and predict levels of biodiversity (Chipenuik 1995). Nabhan and others have also stressed the important role that interactive knowledge of one's biotic environment plays in children’s social, psychological, intellectual and spiritual development (Nabhan and Trimble 1994). Dougherty’s (1978) research on urban US children’s biological classification suggests that the relatively low importance of botanical interaction for urban children led to attrition in naming abilities as well as a shift from generic names (Berlin 1992, Stross 1973) to life form names in classification (for example, from "oak" or "pine" to "tree"). In contrast to urban cultures, rural Rarámuri communities provide rich contexts for child–plant interaction and we expect correspondingly high levels of naming ability, as has been seen in other such environments such as with the Tzeltal Maya of Highland Chiapas (Stross 1973; Zarger and Stepp 2004) and Zapotec children in Oaxaca (Hunn 2008). The greater Sierra Madre Occidental is a center of species diversity for pines, oaks, junipers, succulents and perennial herbs, and home to about 2,000–4,000 plant species (Bye 1994:20). Within the Sierra Tarahumara, which is a subset of the Sierra Madre Occidental, Bye estimates that 400 plant species are used as medicine and about 300 species are included in local diets (1994:22). At least another 100–200 are of material value for building, weaving, dying and other uses. Bye compared registers of useful plants collected in the region by Edward Palmer in the late 1800s with lists of plants used today and estimated that about 37% of ethnobotanical knowledge may have lost currency over the past century (1994:22).

In this study I explore the role of children's environmental interactions in learning about the everyday useful plants of Rarámuri landscapes, with particular attention to methodological issues central to the study of acquisition and transmission of knowledge. 'Environments' are here understood as both human and non-human contexts, including daily life experience such as schooling choice, participation in traditional occupations (especially herding and foraging, commonly children's activities), and family knowledge/interest in plants, all posited as influential in how children learn about their biological worlds. Schooling is one of the most powerful agents of social change and epistemological shifts at the interface of indigenous contact with colonial systems. Rarámuri children's scores on naming and plant use interviews are evaluated in light of their different schooling experience, both in terms of time spent in school and the kind of school they attended. The two primary schools available to Rarámuri children in the area—one state-run and the other privately run by Jesuits—use different curricula and provide different social environments to their students. At the time of this study, the Basíhuare school is primarily Mexican or Mestizo and instruction is primarily in Spanish, whereas Rarámuri teachers and parents are more involved in guiding operations at the Rejogochi school and most of the instruction is bilingual Rarámuri and Spanish. I expected that children attending the Spanish-language state school in Basíhuare would have lower plant naming and use-knowledge for their ages; children attending the primarily Rarámuri-language non-government school would have higher expertise; and children who attend little or no school at all would have the highest expertise at the earliest ages. From my observations and informal discussions, I know that children from families that include a plant knowledge specialist such as an herbalist or artisan generally know more about the specialized group of plants related to their parents' craft.

I tested for significant variation in knowledge scores associated with age, gender, school choice and bilingual ability, evaluating children's plant competency in comparison to adult knowledge scores. Based on results among other indigenous communities that rely largely upon their immediate landscapes for subsistence (Hunn 2008; Zarger 2002) I expected to see that children achieve average adult-level competency by about age 12 and that overall, patterns of expertise would parallel Rarámuri ideas of human cognitive development. Rarámuri conceptualize the ontogeny of environmental knowledge among children as gradually increasing in expertise and relationship-maintenance that continues through adulthood as individuals practice 'thinking better' and 'living well'.

Research Techniques and Analysis

I investigated children's knowledge of three categories of non-cultivated plants: medicinal, edible, and of material importance. This leaves out at least two important categories of Rarámuri plant knowledge—the spiritually powerful plants, and domesticated/semi-domesticated plants, each of which merits its own study. Because I was interviewing children, it was not appropriate to talk about spiritually powerful plants due to the dangers surrounding these relationships (Wyndham, in press). I chose to work with 'wild' useful plants because this is the 'knowledge environment' most affected by recent transitions to increased schooling, and presumably more 'endangered' than knowledge of cultivated plants grown near the households. During the summer and fall of 2001, and the spring of 2002, I made ethnobotanical collections of about 60 species for this study, primarily with the guidance of my *compadre* Moreno Vatista, a local knowledge holder. Our collections were made around the settled valleys of Rejogochi and Basíhuare on foot, setting out in a different direction each time to access the diverse ecologies of this area including meadows, pine forests, oak groves, natural springs oases, swidden burn areas, garbage-flora skirting rock-shelter homes, ruderal plants around living areas, canyons and mountaintops. Collections were made of all plants deemed culturally significant enough to warrant inclusion in the knowledge elicitation tests and not necessarily dependent on the abundance of the species—either my consultant brought a notable plant to my attention and explained its use, preparation and significance, or I inquired about novel or salient plants[1]. A final selection of 41 specimens (40 species[2], Table 1) were laminated in plastic on 42×29 cm cardstock, creating a 'traveling herbarium' (Berlin *et al.* 1990) for interviewing. A roughly equal number of medicinal, edible and manufacture-use plants were included, ranging from what I expected to be very easy identifications to medium and difficult identifications. The specimen elicitation sequence was ordered so as to ask about several widely known plants in the beginning so children would understand the task and warm up; kinds of plants and kinds of uses were mixed throughout the set.

After six months of ethnographic participant–observation during which time I interacted with many if not all of the children in the area, interviewees for this study were recruited in a convenience sample, with an attempt to contact each child in the research communities and invite them to participate. I maintained a rough balance between girls and boys, age groups, and attendees at different schools. Though the sample was not randomly selected, I am confident that it is generally representative, with one caveat: there is a potential bias due to the fact that children who attend school were willing to engage in the interview process more readily than children who had never attended school, spoke no Spanish and had little experience interacting with outsiders (there were two such children who preferred not to participate). However, it is relatively rare in the research area for children to have absolutely no experience in school—thus I recorded the number of years each child had attended overall, rather than their grade level.

The interviews, almost always conducted in the Rarámuri language, lasted from 30–60 min. Most interviews were conducted at my house in the community, seated at a table. If the plant was aromatic, the interviewee was offered a smell as well as visual prompt, and I asked interviewees to name and identify uses for each of the plants. I took notes on how participants presented their knowledge, their affect, commentary and engagement with the task. I employed four research assistants (two young men and two young women) to help with interviewing, and in some cases, to do the interviews on their own. The interviews were conducted over a ten-month period, through several seasons, which may have affected children's answers, discussed below.

To check for interviewee consistency and/or guessing, two plant specimens in the interview were the same species (*Bidens ferulifolia*, a well-known weed). Eight respondents gave different names for this species the first and second times they encountered it, suggesting that they were guessing or not paying a great deal of attention to the interview process; these interviews were removed from the sample. This result suggests reliability for the remaining interviews overall.

The results of the ethnobotanical elicitation interviews were analyzed using a cultural consensus technique and the analysis software ANTHROPAC 4.0 (Borgatti 1992). Consensus analysis provides an estimate of the 'knowledge competence score' for each interviewee, in which knowledge is defined as shared information (Romney *et al.* 1986; Weller and Romney 1988). These competence scores, or more correctly, agreement scores, proved not to be useful for assessing competence from an adult perspective, because many children 'agreed' on the 'wrong' answers; in other words, they made the same mistakes. Thus, those children who were conservative and only answered the few plants that everyone knows, had higher scores than the adult experts, who cited names that few children knew, so the consensus analysis does not assess 'knowledge competence' from an adult perspective.

Nonetheless, this analysis is useful because it does tell us that there is a somewhat coherent "culture" of shared knowledge among children, even if this knowledge includes misnomers for plants and identifications at inflated taxonomic levels. In other words, the ways the mistakes are made *are shared*, and this is relevant to understanding ontogenetic processes of knowledge acquisition. This is most evident by looking at the structure of the factors, which in this case includes an all-positive single factor, with a first eigenvalue of 68.62 and a second of 8.67. The second (last) factor accounts for the adult interviewees and the first factor accounts for the Rarámuri children. That the first factor (estimate of competence/agreement) is about eight times as large as the second factor indicates a strong cultural agreement on the domain of plant knowledge, or that this factor "accounts for all of the structure in the matrix other than sampling variability" (Romney *et al.* 1986:323). Thus we may proceed knowing that the child interviewees are indeed navigating a shared conceptual domain.

One hundred and four Rarámuri children's interviews were analyzed in the final sample: 46 girls and 58 boys from 5 to 18 years old (see Fig. 1 for age distribution). This represents approximately 68% of the total population in this age range and about 29% of residents of any age (from greater Rejogochi and Umirá, the primary source communities for students at Basíhuare and Rejogochi schools and this research project). Each interview was scored using an answer key created from the plant names and uses given by

[1] Voucher specimens were deposited at the herbarium of the Instituto Politécnico Nacional in Durango, Mexico (CIIDIR), where identifications were made.

[2] Two were the same species, in order to check for consistency in interview answers.

Table 1 List of plants used in this study by use-category (medicinal, edible, material)

Medicinals[a]

Chorónare (*Galium mexicanum* Rubiaceae; “sticky”)

Júpisi (Agastache micrantha Labiatae; “smelly”)

Mahtó (*Buddleia cordata* Loganiaciae; Spanish: *tepozán*)

Masérachi (*Ratibida* sp. Compositae)

Matarí (*Psacalium decompositum* Compositae)

Metakúchare (*Echeveria* sp. Crassulaceae; Spanish: *siempre vivo*; “small child of agave”)

Mochoáka (*Cheilanthes angustifolia* Polypodiaceae; “brain-like”)

Napilúti (*Euphorbia* cf. *sphaerorhiza* Euphorbiaceae; “ringed/ridges or linked/in sequence”)

Pasóchi (*Chenopodium ambrosioides* Chenopodiaceae; Spanish: *epazote*)

Sebanél (*Tagetes subulata* Compositae; “goat’s bell”)

Sowíware (*Eryngium* cf. *heterophyllum* Umbelliferae; Spanish: *yerba del sapo*; “spiny”)

Warisí (*Cucurbita foetidissima* Cucurbitaceae)

Wasía (*Ligusticum porteri* Umbelliferae; Spanish: *chuchupate*)

Edibles

Amári (*Dahlia sherffii* Compositae; Spanish: *camote*)—prized for its tasty tubers, eaten raw after scraping off the skin and dipping in salt, or roasted in hot ashes

Baniwá(ka) (*Desmodium* sp. Leguminosae; “covers everything”)—the leaves are famine-food additives to corn for esquiate (gruel)

Kasará sitákame (*Juncus* sp*?* Juncaceae*;* “red grass”)—this plant is used as a *tesgüino* beer additive, to increase fermentation and strength. It is ground with *basiáware* (*Bromus* sp.) and poured into the *tesgüino* after it is strained and cooled

Kihúbare (*Cosmos bipinnatus;* Compositae)—a popular potherb when young and tender (leaves and stems)

Rorogóchi/rorokóchari (*Plantago australis;* Plantaginaceae)—leaves are eaten by people as greens, preferably sautéed and with beans

Sipé (*Bidens odorata* Compositae)—an important pot-herb when young and tender

Sibarín (*Tagetes lucida* Compositae*;* Spanish: *yerba anís*)—popular beverage tea made by steeping the whole plant or leaves in hot water; it is also boiled with salt and drunk as a treatment for diarrhea

Mazána (*Vaccinium confertum* Ericaceae; Spanish: *manzanita*)—edible fruit, and a beverage made from the leaves

Urúpisi (*Arbutus xalapensis* Ericaceae; Spanish: *madroño*; name may be derived from *ku*, “wood,” that burns fiercely)—edible fruit. The wood is highly prized for carving large spoons, *batéa*s (dough-mixing troughs), and violin “ears” (heads)

Víviri (*Zornia thymifolia* Leguminosae; Spanish: *yerba de la víbora*)—makes a popular and pleasant tea beverage from the whole upper plant

Wasorí (*Amaranthus hybridus* Amaranthaceae; Spanish: *aguas*; “going around (visiting)”)—prized as greens (*kiribá*, probably a Rarámurization of the Spanish/Nahuatl *quelite*), the leaf is boiled and eaten mixed with beans

Wíchare (*Arctostaphylos pungens* Ericaceae; Spanish: *manzanilla*; “branchy”)—the flowers and fruits of this shrub are prized by children as snacks. The leaf can make a tea beverage, and is also taken to treat cough

Material and manufacture use/other

Basúl (*Bidens* aff. *ferulifolia* Compositae; possibly means “goes walking” or from the Spanish for “blue” (*azul*))—a yellow dye can be made from the flowers of this plant, boiling with scant water and sheep’s wool

Ikí (*Bletia aff. macristhmochila* Orchidaceae; Spanish: *resistol del monte*; “Bites”)—a strong glue is made from the bulb of this ground orchid and is used in the construction of violins, guitars and rattles

Moóchare (*Machaeranthera stenoloba* Compositae; “big-headed/dread-headed”)—the flowers are boiled with wool as a yellow dye

Okó’sare (*Pinus engelmannii* Pinaceae; “long-leaf pine”)—used in construction and as firewood, especially fatwood. Its needles are used in adobe brick manufacture

Rité bo’wára (*Usnea/ Teloschistes* Usneaceae; “rocks’ wool”)—this common lichen is used as a wool dye (colors: yellow, orange, peach)

Sawá (*Pinus lumholtzii* Pinaceae; Spanish: *pino triste*; “leaf”)—this ubiquitous pine is used to construct log houses, corrals, and for firewood. The needles are used in adobe brick manufacture

Siwá (*Milla biflora* Liliaceae)—*Siwá* simply means “flower,” so this plant may have other Rarámuri names. The dried bulb of this small wild lily was used by children in the past as toy buttons (for clothing) and flying tops

Siwáchare (Tillandsia recurvata Bromeliaceae; “flower”)— used as decoration during Easter week on pine bough arches

Sopépare (*Senecio hartwegii* Compositae; “similar to palm”)—a strong piscicide; the mashed root is dumped into a river or stream (preferably dammed) to stun or kill fish. The mashed root is also applied to livestock to kill external parasites such as fleas and ticks

Torí wasíra (*Dryopteris cinnamomea* Polypodiaceae; “chicken tail”)—also identified as *mocho’á*. This fern helps produce especially good *tesgüino.* The leaves are laid down as a bed on which to sprout soaked corn kernels for beer, with oak branches layered on top

Wa’á (*Cupressus lusitanica* Cupressaceae; Spanish: *táscate*; my consultant translated this name as referring to *wé na’awá*, “very angry,” when burning. It pops and crackles loudly). This wood is commonly used to make violins. Juniper branches are used in *morúbama* (sweat and smoke bath curings) and in infusions or alcohol tinctures to be rubbed on the legs while running races. It is prized as excellent firewood.

We simé ómáware (*Phytolacca icosandra* Phytolaccaceae; "brings menstruation fast")—should not be touched, especially by boys, otherwise "when they grow up they will have to buy lots of bars of soap to wash clothes since their wives will have continuous menstruation"

Wichátare (*Comarostaphylis polifolia* Ericaceae; "many-branched/hard to get through")—a plant that women should not touch, or they will menstruate all the time; if men touch it they too will begin to menstruate

Wiwaráka (*Nicotiana tabacum* Solanaceae)—a popular strong smoking herb

Wiyó [*Pinus strobiformis* Pinaceae; Spanish: *pino blanco* (Brambila 1983:609)]—this pine is used to carve yokes and violins

[a] Details of Rarámuri medicinal knowledge of these plants are not published here to respect possible future concerns about bioprospecting in the Sierra Tarahumara. See Cardenal (1993) for treatment of Rarámuri medicinal plants

the adult interviewees[3]. The response data were regularized; for example the answers "*ke machí*" (I don't know), "*se me perdió el nombre*" (I lost the name) and "*ke tabírí*" or "*ke namúti*" (nothing/none), "*ke chiborá*" (of no use) were all processed as no-answer data. While recognizing that 'correctness' of a plant name is perhaps a false concept in relative terms, it was used in this study to indicate the word agreed upon by adult Rarámuri to describe a botanical "discontinuity in nature" (Berlin 1992), whether at the species, generic or life-form taxonomic level.

The reported uses for each plant were scored in a similar way to the reported names, except that, because each child was asked to give all the uses they knew, some received more than one "point" per plant, and in many cases there were several possible "correct" answers. Most answers could be put in one of three use-categories: medicinal, edible or of material value. Other uses outside of those categories include plants used as *tesgüino* (corn beer) additives, fish poisons, animal foods, 'cures' for fields, plants that keep spirits and ghosts out of the *tesgüino* jars, plants as indicators of fertile soil, and plants used in steam baths (Table 1). Both naming and use-knowledge scores were analyzed using analysis of variance tests to explore the relative influence of children's individual life characteristics (age, years of school attendance, which school they chose to attend, and bilingual ability) on their individual botanical proficiency.

Results

The results for plant naming and plant use knowledge will be presented separately first, followed by a discussion of how they relate to each other. Overall the response levels (how many answers children gave) were lower than I expected, and the expertise (how many correct answers children gave, from an adult perspective) were lower than I expected. The social characteristics investigated showed little influence on the distribution of scores.

How Well Do Children Identify Plants by Name?

Figure 1 plots the children's naming scores by age, showing a steady increase in proficiency by age, though note the two outliers, a girl and boy who scored much higher than predicted by the distribution of scores. Though boys scored a little higher overall, there was no significant difference between girls' and boys' mean naming ability scores (22.8% and 26.0% respectively; ANOVA SS=41.27; MS=41.27; F=2.95; $p<0.0888$, ns)[4], so their results will be undifferentiated in this discussion. When each plant was analyzed to see if there were individual plants that boys or girls knew more consistently, only one emerged as being (significantly; $p<0.0383$) more often identified by boys. This was *Cucurbita foetidissima*, the dried gourd of which is used by boys as a substitute for the wooden *rarajipa* ball they use in traditional races.

The correct identification scores ranged from about 10% to 61%, with a mean of 24.4%. These scores were lower than I expected; possible reasons for this will be outlined in the discussion section below. To determine the relative influence of several social characteristics on the variation observed, separate analyses of variance (ANOVA) tests were done on the children's scores and their (1) ages, (2) years of formal schooling experience, (3) school attendance, and (4) bilingual ability. Then a general linear model procedure was run on all four characteristics to elucidate the relative influence of each when all the others were taken into account at the same time. I report the results for each variable, then summarize the results of the general linear model in Table 2.

An ANOVA analysis was performed on children's plant naming scores (raw correct identifications) and their age, to

[3] The adult responses were not uniform; in cases of disagreement I inquired with others and referenced published sources and my own ethnobotanical observations.

[4] Assumptions for ANOVA test include, 1) a random sample; 2) independence of variates; 3) normal data. The data presented here conform to assumptions 2 and 3, and, though the sample was not collected randomly, it constitutes a large percentage of the population and can be considered representative (see earlier discussion).

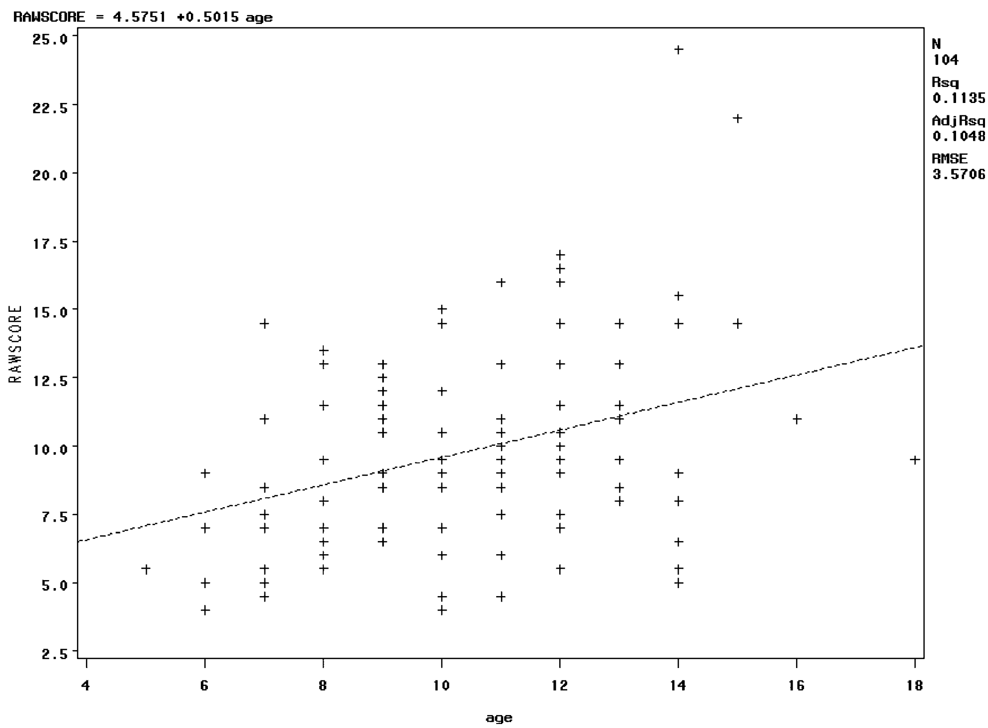

Fig. 1 Scatter plot of children's plant naming scores (out of 40 possible correct) by age

determine how much of the variability may be explained by the age of the participant. Participants were divided into four age classes of roughly the same N. The coefficient of determination (R^2) is 0.109, indicating a relatively weak positive relationship between age and naming competence for the set of plants in the study. In other words, age explains only approximately 11% of the variance (df=3, 100; F=4.10; p< 0.0087).

Interviewees in this study either attended the Rejogochi school, the Basíhuare school or no school at all. Those children who attended the Rejogochi primary school were slightly more likely to correctly name plants than those attending the Mexican state primary school or secondary school in Basíhuare. When the total years of schooling a child had experienced was adjusted to take into account other confounding factors such as age, this characteristic is significant (see General Linear Model (GLM) analysis results below). Interviewees' self-reporting of being a monolingual Rarámuri speaker or bilingual Rarámuri-Spanish speaker had no significant effect on plant naming scores (df=1,102; F=0.08; p< 0.7754).

How Well Do Children Know the Uses for Plants?

Use-knowledge refers to answers to the question, "What is this used for?" which was asked for each plant after the interviewee replied to the query about the plant name. One point (up to three total) were given for each 'correct' answer for each plant specimen, which should be taken into account when assessing the following scores (they are reported as total uses known for the 40 plants rather than as percentage scores). The use-knowledge scores ranged from

Table 2 Summary of results of general linear model procedure for plant naming and use scores

Source of variance	df	Sums of squares (SS)	Mean squares (MS)	F	P value
Plant naming scores					
Age*	3	253.7	84.6	7.47	<0.0002*
School choice*	1	46.29	46.29	4.09	<0.0461*
Years of schooling*	1	72.19	72.19	6.37	<0.0133*
Bilingual ability	1	1.69	1.69	0.15	0.70
Plant use scores					
Age*	3	96.8	32.3	0.65	0.59
School choice*	1	1001.2	1001.2	20.1	<0.0001*
Years of schooling*	1	0.81	0.81	0.02	0.90
Bilingual ability	1	63.9	63.9	1.28	0.26

Those marked with an "*" are considered statistically significant

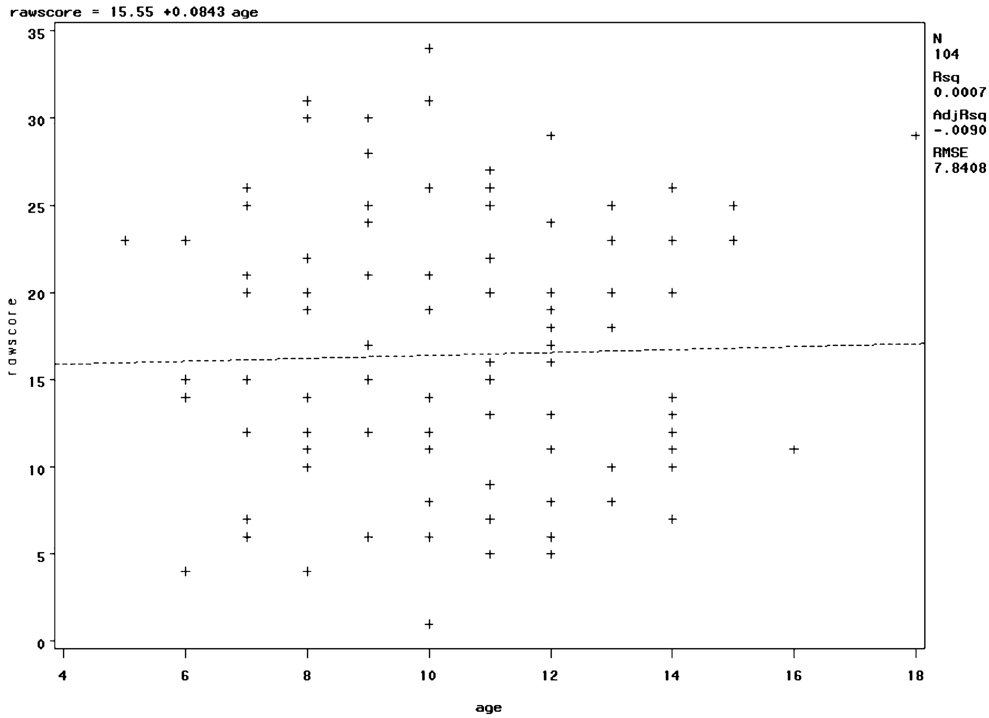

Fig. 2 Scatter plot of children's plant use-recognition scores by age

1 to 34 reported uses for the set of plants (Fig. 2). The mean use-knowledge scores for girls and boys were 12 and 17.4 respectively, a non-significant difference (df=1,102, F= 1.95; p< 0.1660, ns). Thus, girls' and boys' results will be discussed together.

In contrast to the plant-names analysis, age showed no significant influence on interviewee's use-knowledge scores (df=3,100; F=0.44; p< 0.7227). However, school attendance choice did account for 17% of the variance observed in use-knowledge (df=1,99; F=19.88; p< 0.0001; R^2= 0.167), again with the Rejogochi school attendees scoring higher than the Basíhuare school attendees (mean scores of 19.0 vs 12.6 correct uses out of 40). Though there was a slight negative correlation, years of schooling did not

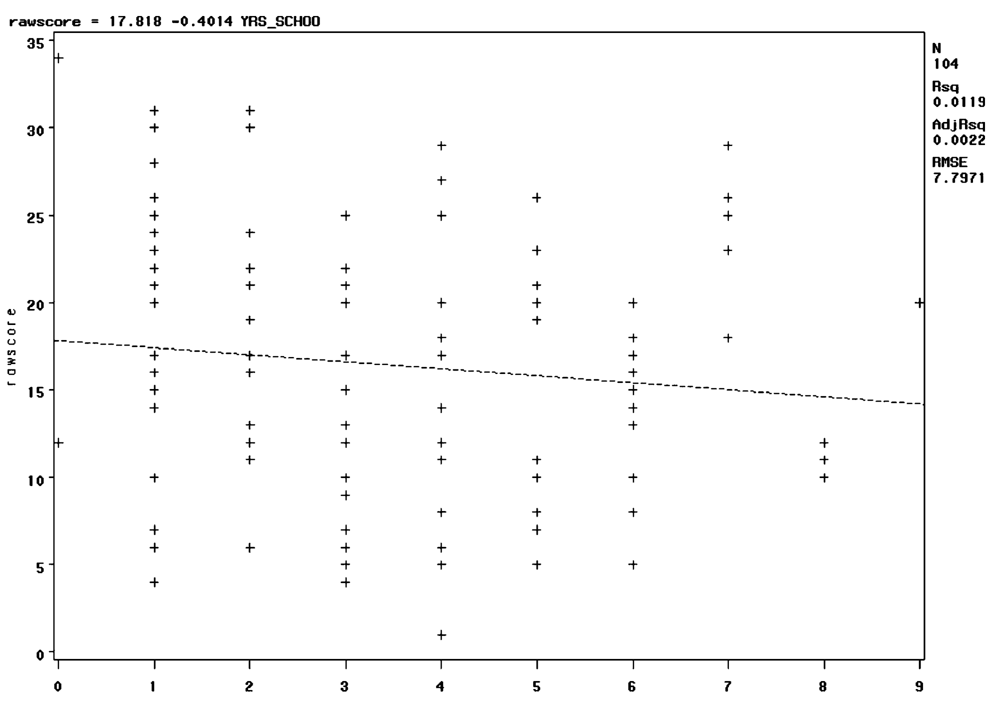

Fig. 3 Scatter plot of children's plant use scores (out of 40 possible correct) by years of schooling

significantly affect use-knowledge scores (df=1,102; F=1.22; $p<0.2713$). The scatterplot of these results (Fig. 3) shows that the highest scorer (a ten year old boy whose father had a keen interest in natural history) had no history of schooling at all. Self-reported monolingual or bilingual ability did not significantly affect use-knowledge scores (df=1,102; F=0.01; $p<0.9337$).

General Linear Model Analysis

Because these data were not collected in a completely balanced design, i.e., equal numbers in every category, a general linear model was used to assess each measured variable's relative influence as a source of variance, *taking into account* all the other variables and adjusting for them. For example, in this procedure, the effect of age on years of schooling is adjusted for. This procedure yielded similar results to the individual analyses, though slightly more extreme, lending additional weight to the previous results (Table 2).

Discussion

The consensus analysis procedure establishes that children share a 'culture' of plant knowledge that is different though related to that of adults. In other words, children agree in regular ways about which plants they name and how they are going to name them. This can also be expressed by saying that children make similar mistakes—in this case, patterns of misnomers for plants emerge as supra-taxonomic naming or using a name for a more common relative of the plant in question. These are probably due to both cognitive ontogenetic trajectories as children grow up as well as to the fact that much information is learned and taught among close networks of peers and relatives, such that a child's culture of plant-naming persists.

Before discussing the results of the naming and use scores in detail I would like to comment on some important aspects of the interview experience. The interviews were made over ten months; however, children have more exposure to names and uses of plants during wet summer growing seasons and thus may recall this information more easily during this time. Though most of the plants in the set were readily recognizable, for some of the species their decontextualization from the landscape or the season may have affected children's ability to recognize them. For example, many children mistook the orchid *ikí* (*Bletia macristhmochila*), which grows in high altitude oak forest, for the corn-sprout *pachí* (*Zea mays*), a mistake that would be unlikely in everyday life.

Age in years is not considered to be very important for Rarámuri, and so many of the children (and adults) reported guesses as to their ages, likely within 2–3 years accuracy. Age-related results should be interpreted with this in mind. Similarly, children's language ability as monolingual Rarámuri or bilingual Rarámuri/Spanish speakers was self-assessed and thus subject to varying standards; I found that girls were more likely to downplay their Spanish-speaking proficiency.

Perhaps most importantly, the underlying epistemological understanding of what 'plant knowledge' is was not necessarily shared by me as researcher and the interviewees as knowledge holders. Though some children adapted quickly to the tasks of naming the plants as objects and citing the uses they knew, others seemed bemused by the irrelevance of the task in that it was not related to any purposeful interaction with the plant itself. The formality of the structured interviews also transgressed several etiquette rules that may have affected children's responses, especially for those children who were less familiar with my household (cf. discussion of the influence of social context in Boster's ethnobotanical interviews, in Berlin 1992:226). The atmosphere of the interviewing was comfortable to the children in many respects, for example, most had visited me before, their friends were in the room or nearby, they shared tea and cookies as we prepared the tasks, and there was a playful sense of participating in something most of their friends were doing. However, asking questions directly and persistently—up to 80 direct questions in a row in this case—is not considered polite in Rarámuri society, though it would not be unexpected from a *chabóchi* (non-Rarámuri/White/Mexican) and is experienced to a lesser extent in schools. Additionally, boasting or even professing knowledge is frowned upon, especially in the presence of elders. At home Rarámuri children are expected to learn by observation and are rarely quizzed on what they know. Rather, their knowledge might be tested as life situations arise and judged by their actions and thoughtful speech. I believe that the artificial context, along with the procedure of interviewing children alone, may have had a dampening effect on children's responses, such that they professed to know less than might be observed in everyday social and ecological contexts.

Plant Naming and Use-Knowledge Proficiency

Children's overall scores for naming and use-knowledge of the experimental subset of 40 plants were lower than I expected. It is important to remember that the scores here are specific to a particular group of non-cultivated plants; we should be conservative in using these scores to represent each child's *general* plant knowledge; it is possible that it was overall a rather difficult sample of plants. Overall trends and relative rank are most relevant, though reasons for the overall low scores, especially the naming scores, may be explored productively.

One interpretation of the overall low scores is that past generations of Rejogochi children were 'more knowledgeable' and that competing interests of schooling, alternate livelihoods, and other social changes have made extensive knowledge of wild plants less intrinsic to Rarámuri life, and less available to children growing up today. I believe this is the case to some extent; however, it is only part of the story.

Another interpretation is that these results simply show the natural progression of knowledge acquisition: children have low scores because they have less experience and cognitive skills than adults, and they will attain adult levels of competence eventually. This is implausible, however, because even some of the teenagers had low knowledge scores, and evidence from comparable research elsewhere in indigenous America shows attainment of adult-level 'theoretical' plant knowledge by about age 12 (Hunn 2008; Zarger and Stepp 2004), which accords with Rarámuri social ontogeny. In this community, high competence is clearly attainable for children even at a young age, as can be seen in Figs. 1, 2 and 3. From my ethnographic work with the families of the children in this sample, I believe it is most likely that the overriding influence on children's plant learning is their immediate familial environment and access to extended time in local landscapes.

A third interpretation is that extensive knowledge of wild plant *names* are not particularly important for all Rarámuri, apart from a core group of culturally and biologically salient species that are used, traded and talked about regularly, and any plants used regularly in the practice of a craft. It was not uncommon that adults I asked did not know or remember names for medicinal plants they collected, traded and kept as household remedies (though this may in some cases have been due to unwillingness to profess expertise on their part). But they did know what they were used for, where to find them, or who to contact if they needed more. Though knowledge of wild foods and craft plants is widespread among adults, informal specialists who regularly collect and use a wide variety of medicinal plants are a minority in the community—perhaps one in ten or 15 adults. These people are usually not formal healers, but often play a consulting role for other community members, advising which plants to take for certain illnesses and where to find them. In this interpretation, the persistence of plant knowledge must be evaluated not only at the individual level (what each person knows) but also at the community level (do enough centrally connected people know the information such that it is available to individuals through their social networks when they need it?). Thus, 'community knowledge' is not a simple aggregate of all individuals' knowledge, but includes structural social communication networks as well. Rather than expecting to see an even distribution of scores by age, we might expect that each age cohort might have a few botanically gifted individuals, what Hunn (2008) calls 'precocious learners,' such as my young botanical guide Silvino.

Both children and adults showed a great deal of variation in how they pronounced plant names—for example, up to 20 versions of the same name were given for *Tagetes lucida*, an herb commonly used as a beverage and medicinal tea (Wyndham 2004a). Dialect and other information variation are well documented for Rarámuri communities and Rejogochi in particular (Merrill 1988), respected socially as an expression of individuality and personal preference as well as particular micro-histories. Whereas in urban North America a child might be ridiculed for saying "tomahto" and quickly learn to conform, among Rarámuri there is less corrective surveillance of others' experience or utterances, contributing to a relatively tolerant society that ideally respects individual choice over conformity. This type of informational diversity may be characteristic of non-literate societies and reflect emphases on higher-order agreement rather than conformity to details (Merrill 1988), pointing also to a pragmatic attitude with less focus on a regularized and codified Rarámuri botany. Thus, measuring plant knowledge by how well an individual conforms to an accepted norm may be fundamentally misleading, saying more about the epistemological disjunction between the expectations of university-trained researchers and children for whom learning the plant world is predominantly experiential, embodied and relational.

When evaluated in light of my knowledge of the life histories of each child, the results show the importance of individual interest and pursuit of plant knowledge, starting from a young age and influenced by the availability of a mentor or family environment of botanical interaction. Of the two high-scoring outliers in the naming results, one was a boy who was currently attending school in Basíhuare, and the other a young teenage girl who had attended school in her youth for a few years. This girl's sister was the next-highest scorer; their family places a great deal of emphasis on incorporating natural history knowledge in daily life. The lowest scorer was a young boy who is extremely bright and observant, but who had only recently returned with his parents from living in his mother's natal community near Guachochi and working in Mexican towns. Thus, he was unfamiliar with the flora and even took a while to begin to speak in Rarámuri again.

No significant knowledge variation could be attributed to gender (except for the ability to name one plant, *Cucurbita foetidissima,* used in play by boys). This is not surprising as both girls and boys participate in outdoor work and botanical activities from a young age (Wyndham 2004b). The slightly higher scores by boys may be due to boys' somewhat wider range geographically and socially. The results of the naming proficiency patterns show only age, school choice and years of schooling as significant factors in determining how well children did (using the adjusted GLM results), but they are relatively weak correlations, age accounting for only 11% of the variation and school choice for 4%. Bilingualism, often used as a proxy for acculturation, was not significant overall, but in particular cases in which I knew the life experience of the child, such as the lowest scorer discussed above, proficiency in Spanish certainly was an indicator of lower local botanical knowledge if it meant that the child had spent significant time outside of the area.

The ages of participants ranged from five years old to 18 years old; that age was so uninfluential in knowledge scores requires explication. Though uncommon in studies of this kind, most of which show a marked positive correlation between scores and age, Hunn obtained a similar result in his study of children's plant knowledge in a Zapotec community in Oaxaca, Mexico (age accounting for only 8.4% of the variation; 2008:233). This is the kind of result one would expect in a community with differentiated groups with different environmental experiences; i.e., lack of learning occurring among certain portions of the population, such that we find some highly knowledgeable youngsters as well as some elders that cannot name many plants. Based on ethnographic experience, I interpret these results as indicating a learning environment in which certain children with the right relationships coupled with personal interest, become knowledgeable of a wide selection of plants at a young age, while other children learn only the basic, most biologically and culturally salient plants around them and increase their repertoire slowly. The observed community knowledge structure of a few highly competent individuals in each age cohort, then, may be similar for children and adults. Even if total knowledge of plants may be declining among younger generations, it seems likely that the overall knowledge structure is being reproduced.

The overall use-knowledge scores were almost twice as high as naming scores (mean of 16 uses cited for 40 plants, or 40%, though this is somewhat inflated by possible multiple uses per plant, vs. mean of 24.4% correct names). This supports the conclusion that use-context is more culturally relevant, salient or easier for children to remember than names. Surprisingly, the name and use-knowledge was not congruent for individual plants. Some plants were readily identifiable by name but not by use and *vice versa*. However, some of the more extreme discrepancies can be explained by considering the individual plants. *Cupressus lusitanica* was ranked fifth in use-recognition (firewood and medicinal) but 28th in naming recognition. This is certainly due to the common confusion of *wa'á* with *ahorí* (*Juniperus* sp.) by children as the two trees have similar characteristics. Similarly, the *Pinus* species were often confused with each other, which lowered the naming scores; since the pines all have similar, highly culturally and biologically salient uses, use-knowledge remained high.

Within the plant-use knowledge results, only school choice was significant in predicting how well children would score, though it accounted for only 17% of the variation observed. As with the plant names, this reflected better scores on the part of children who attend or had attended the Rejogochi primary school rather than the Basíhuare school. The Rejogochi school teaches primarily in Rarámuri language by Rarámuri teachers (for beginning grades); these students scored higher than students who went to the Spanish-instruction boarding school in Basíhuare. The Rejogochi school also has implemented curricula and activity programs to integrate traditional Rarámuri knowledge into classes, including field trips to collect and study wild useful plants, perhaps suggesting that programmatic changes in educational structure and format works to maintain active traditional knowledge bases for children. The results of this study may be attributable to this educational orientation, or to the fact that this school is in many ways more integrated in the local community in terms of teacher–parent participation. Also, it is easier for Rejogochi students to miss school without penalty to participate in traditional tasks and rituals. Another possible explanation is that Rejogochi students had more experience with the set of plants used in the study, which were mostly collected in the area. Basíhuare students come from a wider catchment area that includes differing botanical ecologies. Zent (1999) found a strong negative correlation between years of schooling and children's ability to recognize plants in Piaroa communities in Venezuela. My results echo this to a lesser extent, and are best interpreted by considering children's individual performances.

There have been relatively few studies in the Sierra Tarahumara that have utilized the kind of structured, formal interviewing and quantitative analysis that I used for this portion of my study. I believe there are particular challenges to doing this kind of research in Rarámuri communities, particularly with children, the effects of which must be acknowledged. In the present case, I surmise that the interviewing environment resulted in a 'dampening' of overall results; in other words, these results are a conservative representation of what children know about plants. The strengths of these data include their replicability, comparability, the inclusion of a large sample of informants, and value for triangulating towards understanding in conjunction with other kinds of evidence, such as ethnographic data. What could a researcher do differently to avoid some of the interviewing difficulties I describe here and yet maintain empirical rigor? I suggest that the highest-quality data for the domain of children's plant knowledge come from opportunistic observations and informal discussions during the course of everyday activities. Structured data-collection should mimic natural environments as much as possible, and forfeit some reliability if necessary to achieve this. For example, children might be more productively interviewed in groups, outdoors in the landscape of interest along plant trails as I and other researchers have done elsewhere, or children could be invited to organize specific research questions and data collection themselves.

Conclusion

Several years after he had first introduced me to the living treasures of the Sierra Madre—its wealth of biodiversity and ways of knowing the landscape—Silvino and his family migrated to an urban Rarámuri settlement outside Chihuahua City—a polluted, crowded, makeshift cement-scape in the desert, where instead of going to school he went to work making bricks. When he was twelve or thirteen I asked him how he felt about leaving his life in the mountains, expecting some measure of nostalgia or regret. He told me, "I'm never going back to the Sierra—I'm going to be a Mestizo." So Silvino's comments and life story still give me pause and demand a complex social analysis of changing lifeways and transformed environmental relationships.

In designing research to further understand the complex processes of children's experiences learning plant knowledge, it is not enough to consider just the 'stuff' of plant knowledge as pieces of information unrelated to the social context they inhabit. If ecological knowledge is to be understood in all its wealth and complexity, as both continuously in flux and as carrying threads of the actions and experiences of the past into the present, we need to understand the ways knowledge and learning are embedded and embodied in relationships, social structures and informal education processes (Wyndham 2002). We must pay attention when epistemological disjunctions arise between researchers and the communities we work in, acknowledging the theoretical and methodological insights that come from these interactions. And as Silvino reminds us, we must continue to listen to the voices and opinions of the children themselves as they experience changing social and biophysical environments. For the Rarámuri, changes in what children know about plants are but one part of a larger process of political, economic, ecological and cultural transformations. The questions we ask as to the nature and process of children's learning environments are important ones, not only to conservationists, nutritionists, healers and indigenous rights advocates, but also to the core of human ecological inquiry.

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