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As Proficient as Adults: Distribution of Children's Knowledge of Wild Edible Plants in an Arid Environment in Madagascar

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Abstract

In drylands, where resources are scarce, wild edible plant (WEP) knowledge is crucial to overcome food scarcity. Understanding the distribution pattern of local ecological knowledge (LEK) about WEP and identifying knowledge holders are key steps to assessing the resilience and vulnerability of knowledge systems. However, little is known about how WEP knowledge is distributed across life stages and gender of people living in arid regions. Here, we study the distribution of WEP knowledge within a small-scale society from southwestern Madagascar, a region known for its dry climate and related food crises. We worked with Tanalana male and female children and adults using semi-structured interviews and free listings. Tanalana people display a sophisticated LEK adapted to the extreme environment in which they live, with a distinct distribution pattern regarding theoretical and practical knowledge across life stages and gender. While women and men cited similar WEP, children and adults cited different sets of WEP, suggesting they hold differentiated bodies of theoretical knowledge, however our results suggest similarity in practical knowledge across life-stage and gender. We argue that resource limitation and food scarcity might be so pervasive in the area that extensive sharing of knowledge on WEP could be an adaptation to the extremely dry environment.

Keywords Children · Cultural learning · Drylands · Local ecological knowledge · Wild edible plants · Xerophytic thicket · Tanalana · Southwestern Madagascar

Introduction

Drylands are challenging environments characterised by unpredictability and scarcity of resources that directly affect the food systems and water access (Coughlan de Perez et al., 2019). Sustaining agro-pastoral systems in such highly stochastic environments entails constantly adjusting herding and crops irrigation strategies to maintain food security (Randolph et al., 2007; Reynolds et al., 2007) based on sophisticated local ecological knowledge (LEK) (Brand & Cherikoff, 1985; Cruz García, 2006; Golden et al., 2011). Knowledge about wild edible plants (WEP) is particularly valuable for small-scale societies that rely heavily on their environment for their livelihoods and are therefore vulnerable to abrupt environmental changes (Diaz et al., 2019). Indeed, knowledge of WEP constitute a safety net during food crises by providing alternative sources of carbohydrates and micronutrients that contribute to enhancing daily diet diversification (Golden et al., 2011) and hydration (Brand & Cherikoff, 1985). For instance, among the Baka of Cameroon, frequently consumed WEP, such as *Gnetum africanum* Welw. and yams (*Dioscorea* L.) provide an important source of protein and increase dietary diversity, especially in the lean season (Dounias, 1996; Gallois et al., 2020). Many plants with water storage properties, such as the bamboo and liana in the Amazon or kurrajong and yam roots in Australia, are known for their thirst-quenching properties (Brand & Cherikoff, 1985; Cámara-Leret et al., 2017). While plant biodiversity in tropical rainforests and

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corresponding LEK have been extensively studied, biodiversity in tropical dry forests has received less attention (Quesada et al., 2009).

An important step to assess people's exposure to food insecurity and water scarcity is to identify how WEP knowledge is distributed among individuals or groups of individuals. The more LEK is distributed within a population, the more likely it is able to deal with disturbance (Blanco & Carrière, 2016). Nevertheless, as bodies of knowledge differ across and within social groups, gender, or age (Diaz-Reviriego et al., 2016; Porcher et al., 2022), it is also important to explore differences in the knowledge held by different sub-groups of the population, as knowledge diversity can contribute to the resilience of the knowledge system (Díaz-Reviriego et al., 2016). For example, Gallois et al. (2017) concluded that children from different small-scale societies hold specific bodies of knowledge, not necessarily shared by adults, and Crittenden (2015) found that children's knowledge about WEP enables them to actively engage in foraging activities. However, little is known about how WEP knowledge is distributed across life stages and gender of people living in arid regions (de Campos et al., 2015), particularly children.

Children are a repository of unique knowledge and also important agents in knowledge transfer among themselves and across generations (Cruz García, 2006; Gallois et al., 2018). Most cultural learning occurs during childhood, including acquisition of knowledge about wild edible plants (Schniter et al., 2021). However, while many studies have looked at cultural learning from an evolutionary standpoint mainly within hunter-gatherer societies, hypothesizing that human childhood is a long period of training to learn difficult foraging tasks (Kaplan et al., 2000; 3 et al.,2021), few have analysed cultural learning as a potential adaptive response to food scarcity.

We assess the diversity of WEP knowledge among the Tanalana people (a subgroup of Mahafaly people) living in tropical dry forests in southwest Madagascar and the distribution pattern of WEP knowledge across life stages and gender, with particular attention to children's knowledge and skills. The region is particularly vulnerable to food insecurity, with above 40% prevalence of insufficient food consumption and 41.6% of children affected by chronic malnutrition (WFP, 2020). Despite the unique and fragile biodiversity of the area (Randriamalala et al., 2019), local WEP remain understudied, with the exception of Andriamparany et al.'s (2014) study focusing on the consumption of six different species of edible yams, which found that wild yam collection was directly linked with low income, demonstrating the importance of this food resource.

Methods

Study Site

We conducted fieldwork in a Tanalana village located in the district of the Atsimo-Andrefana, at about 60 km of Toliara, in the northern Mahafaly region of southwest Madagascar (Fig. 1A). The Mahafaly region is one of the most arid areas of Madagascar, with average 300 mm of precipitation per year and six to seven dry months (from April to October). The landscape is mainly constituted from the east to the west by a limestone plateau (up to 300 m high) and a coastal plain, neither of which them retain water on the surface. Both are covered by dry and spiny vegetation called the xerophytic thicket and are listed among the most important ecological regions in the world (Elmqvist et al., 2007) as home to numerous unique animal and plant species with one of the highest endemism levels of the island. This dry vegetation is distinct from typical tropical dry forests owing to its particularly low canopy and hyper-specialised plant species (Randriamalala et al., 2019). Most plant species from the xerophytic thicket display a diversity of adaptations to dry conditions, where organisms have physically evolved to reduce water loss, store moisture efficiently, and prevent herbivory (Rosell, 2022). Water storage organs adapted to low precipitation are also potential water reservoirs for humans and cattle. Plant species distribution in the xerophytic thicket is mainly influenced by soil composition, particularly two main poor soil types: the lixisol and the calcisol (Randriamalala et al., 2019). All along the coast from west to east, these two main soil types induce distinct vegetation and species composition (Fig. 1a).

Despite its constraining climatic conditions, several ethnic groups (e.g., Vezo, Mikea, Mahafaly) have settled and adapted to the region deploying a diversity of livelihood activities (e.g., fishing, foraging, agro-pastoralism). Like most other Mahafaly, Tanalana people (speaking the Antanalana dialect) rely on a mixed economy derived from agriculture and pastoralism (Noromiarilanto et al., 2016; Hänke & Barkmann, 2017), complemented by hunting and gathering (Andriamparany et al., 2014). The Tanalana diet is based on the cassava, as a staple, pastoral products such as goat meat and milk, and fish, which they buy or exchange with the Vezo. Apart from watermelon and squash, very few fruits and vegetables are grown. The supply of vitamins and micronutrients from agriculture is therefore limited and relies on consumption of WEP, especially during the lean season (from November to April), when hunting and the collection of WEP and honey are crucial to cope with agricultural food scarcity (Fig. 1B) and the lack of water (Cirad, 2015; Noromiarilanto et al., 2016). Furthermore, the availability of fresh and drinkable water follows a seasonal

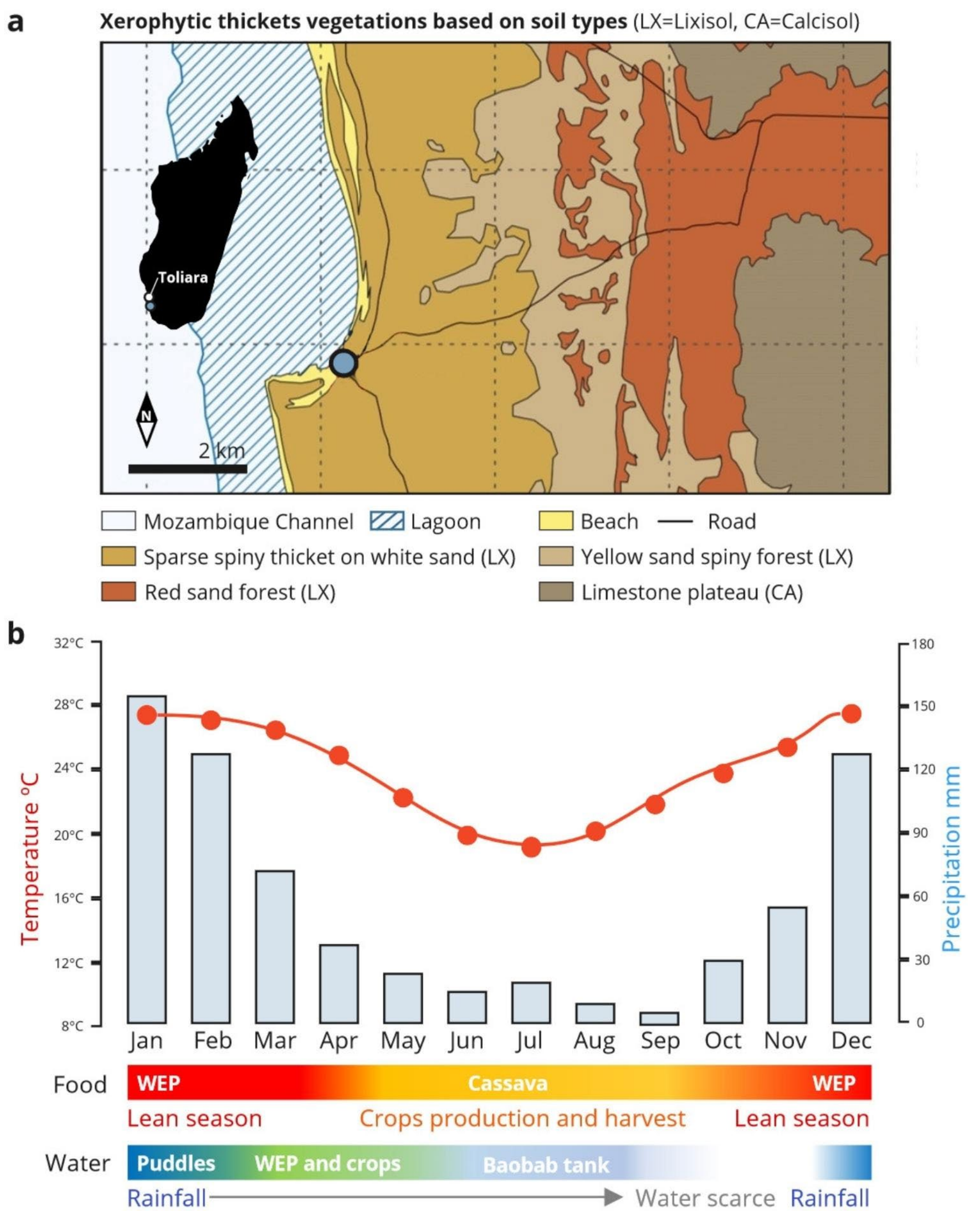

Fig. 1 Study site: Ecosystem distribution, weather, and food and water availability. **(a)** Map of the study site displaying the different xerophytic vegetation according to soil types. The blue dot indicates the position of the village in which we conducted the research. **(b)** Monthly mean precipitation (mm) and temperature (ºC) of Atsimo-Andrefana region for 1991–2020 (weather data from Climate Change Knowledge Portal, https://climateknowledgeportal.worldbank.org/) and corresponding food and water procurement and origin (Cirad, 2015)

pattern (Fig. 1B) (Cirad, 2015). From December to late February, water is collected from rain and temporary ponds and puddles and stored in household baobab water tanks for use during the hottest months (June, July, and August). From March to May, people rely on water stored in plants. Several plants (WEP and crops) are locally known and consumed for their high-water content, such as watermelon, baobab spongy flesh, or yams (Ratsihoarana, 2019). These sources are also used for cooking, especially to boil rice. Prickly pear rackets, usually used for watering cattle, are also used during severe droughts. During October and November, drinkable water is very restricted, and the risk of dehydration is high. In addition, people use daily seawater or non-potable water cooking and showering.

Hunting, trade, pastoralism, and the need to collect WEP and water drive Tanalana mobility, which differs across life stages and gender. During adolescence, women move to their partners' village (Neudert et al., 2015). Men's mobility is more temporal and determined by seasonal grazing patterns across the xerophytic thicket landscapes (Feldt & Schlecht, 2016) as well as by exchange of goods, hunting, water collection, and plant gathering for food and medicinal purposes. Several times a year, and mainly during the lean season, adult men (sometimes accompanied by children) travel for several weeks to look for WEP and water, while women and girls stay and look after the crops and the school children. Outside the transhumance period, boys look after the livestock (zebu and goat) around the village. In general, Tanalana children explore the surroundings of their villages during games or in search of snacks (WEP) and small animals for entertainment (e.g., crickets).

Sample

We conducted fieldwork in April 2019 in a village in the Atsimo-Andrefana region. We interviewed 35 Tanalana informants. Participant selection was based on a convenient sampling method (Etikan et al., 2016). We are aware of the limitations of nonprobability sampling, i.e., the non-representativity of the sampling and the potential bias. However, we aimed to limit these biases by selecting informants from different households and parts of the village to obtain a balanced and intersectional sample combining life stage (adult vs. child) and gender (male vs. female). Accordingly, our sample includes eight women, 10 men, nine girls, and eight boys. We consider children as below 15 years old, which corresponds to the average age of the first weddings and the creation of new households among the Tanalana. Marriage implies a significant move for girls, who set up their new home in their husband's village and a change in the activities of both girls and boys, who now have new responsibilities linked to their new status, e.g., the acquisition of livestock and their first child, which might influence their ethnobotanical knowledge. Our sample of children includes girls and boys from seven to 15 years old. The interviews were carried out by a research team of one local researcher, D.C., who had previous experience working in the region, and two foreign researchers, including two women (D.C & X.L) and one man (V.P). The interviews were conducted in the Malagasy Mahafaly-Antanalana language, with the help of D.C. The notes were then translated from Malagasy into English for analysis by D.C and V.P. Before starting data collection, we obtained the agreement from the local authorities (Fokontany chefs) and oral free prior and informed consent (FPIC) from each informant (see detail in ethical approval). No children or adults declined to participate to the study. The Code of Ethics of the International Society of Ethnobiology was followed, giving participants the right to withdraw from the study at any time.

Data Collection

To document the diversity of locally known WEP and how they are collected and prepared, we conducted interviews following a two-step process. First, we used free listings to document the species known by each informant (Paniagua-Zambrana et al., 2018). Specifically, we asked informants to list the local names of all the WEP they knew. In a second round we conducted a semi-structured interview in which we asked participants to name the plant parts consumed, and to explain whether they provided food, water, or both., We then asked each informant which three of the WEP in their free listing they considered the most important and why. We concluded by asking our informants to describe how they collected and prepared the three WEP species they considered most important (Supplementary Method S1). To facilitate work with the children and to gain their trust, we arrange for a walk in the woods together to collect WEP. To avoid the children identifying the free listing and semi-structured interviews as schoolwork, were conducted outside school, mostly at their homes. We allowed parents to assist in the interview but asked them to avoid influencing the children's responses.

For all WEP reported, scientific names were obtained after identification in the field by the first author and D.C with the help of a local botanist from the University of Toliara. Taxonomic verification was made using the last update of World Flora Online (2022).

Data Analysis

To document WEP knowledge distribution across life stages and gender, we used the information collected through free listing and semi-structured interviews. To explore WEPs knowledge variation among our informants, we built sub-samples based on life stage (i.e., adults vs. children) and gender (i.e., female vs. male), and the combination of both (i.e., women, men, girls, and boys).

WEP Species Identified

We counted the number of WEP species reported by each informant during free listing. To check for variability in knowledge distribution across life stage and gender, we used a Poisson generalised linear model (GLM) with the log link function to make the model fit in a linear form.

We also plotted the accumulation curves of the number of known species against the number of informants in each sub-sample and calculated the sample completeness by comparing the estimated richness with the observed richness. We estimated the theoretical number of WEP known – i.e., the estimated richness– using the bootstrap estimator, i.e., the asymptote of the accumulation curve of species cited (Smith & van Belle, 1984). This allowed us to compare the maximum knowledge threshold in WEP species for an optimal sample of children and adults.

We also explored differences in the WEPs composition – the different WEP species reported by informants – between life stages and gender. First, we built a dissimilarity matrix from the informants vs. species matrix, using the Raup-Crick index. Then, we analysed variance using distance matrices testing for differences between life stages and gender using a permutational multivariate analysis of variance (McArdle

& Anderson, 2001). Analysis was processed using the R vegan package (Oksanen et al., 2022).

WEP Characteristics

Because the uses of WEP might relate to plant morphology, for each species recorded during the free listing, we obtained information of three characteristics: life form, water-provider type, and nutritional contribution. To classify plants according to 'life forms,' we considered "trees" as plants with a single trunk, "shrubs" as plants with multiple woody stems, "climbers" as support-dependent plants, "non-woody shrubs" as arborescent monocots (i.e., palms, tree aloes), and "herbaceous" as short-lived plant species without a trunk, usually non-woody (Phillipson et al., 2006). We used information provided by respondents and based on the parts consumed for water to classify water-providing species into four categories: fruits, leaves, tubers, and water tubers. We distinguished between "tubers," which are species usually consumed for carbohydrates, but which also provide aqueous sources, and "water tubers," which are species mainly consumed for their massive water supply. Finally, the nutritional contribution of each WEP was determined using the FAO food groups (Kennedy et al., 2011) based on the part consumed. Reported WEP species were classified into five categories: VA-rich fruits (VA = Vitamin A); white roots and tubers; VA-rich vegetables; pulses and nuts; and spices and condiments.

In our analysis, for each life form and part consumed providing food and water, we counted the number of species and displayed the proportions reported by children, adults, and both. We used the Chi-squared test to compare the distribution of plants in each subcategory, known by children, adults, and both.

Criteria for Important WEP Species

To assess WEP importance, we analysed the terms used by informants to answer the question: "Why is this WEP important?" and classified them into five categories: organoleptic, nutritional, food accessibility, economic, and food security. We then calculated the frequency of use of the different categories for our four subsamples. To assess the differences in the distribution of terms used between life stages and gender, we used a Chi-square test.

Comparing Collection and Preparation Practices

We used the information on food collection and preparation methods to assess the plant part consumed and the processing methods, tools and materials and products or condiments used to prepare them. We categorised the information using the Economic Botany Data Collection Standard (Cook, 1995) to create a matrix that linked each participant to the WEP species, and their associated preparation method reported. We then built bipartite graphs to display the knowledge networks of children and adults.

To test whether there were differences in collection and preparation methods across life stages and gender, we built two indices: (1) collection skills (*CS*) and (2) preparation skills (*PS*), which captured informant's skills based on the practices they reported and their level of complexity. For a given practice (i), we established the level of complexity based on three main elements: the number of tools (NT_i), the number of steps (NS_i), and the number of condiments (NC_i) used in the preparation. We calculated the respective level of complexity of each practice by summing the above variables, setting the baseline at one to avoid a zero score – e.g., when a WEP is eaten raw. We then calculated informants' *CS* and *PS* scores by averaging the complexity level of practices reported per informant. We compared the mean *CS* and *PS* score across life stages and gender using a normal GLM.

Results

Informants listed 59 WEP species, once synonyms were resolved (see Tab. S1). Two additional species ('tabozebozety' and 'tavenala') were listed but for which we could not determine their characteristics and excluded them from the analysis. The species reported belong to 26 botanical families and 40 genera with more than 50% of endemism at the species level (Fig. S1). The most represented family was *Malvaceae*, with seven species distributed in two genera *Adansonia* L. and *Grewia* L. The genera *Grewia* L. (including five species) and *Opuntia* Mill (including four species) were the most cited, reported 49 and 41 times respectively. Nine WEP species were reported by all subsamples (i.e., women, men, girls, and boys) and by almost all informants. The most represented taxa were *Ziziphus spina-christi* (L.) Willd. ('tsinefo') reported by all informants (n = 35) and *Salvadora angustifolia* Turill ('sasavy') cited by 80% of informants. Six species were cited by 50–70% of the sample: *Sclerocarya birrea* (A.Rich.) Hochst. ('sakoa'), *Terminalia ulexoides* H. Perrier ('fatra'), *Boscia angustifolia* A.Rich. ('lalangy'), *Flacourtia indica* (Burm. F.) Merr. ('lamoty'), *Grewia leucophylla* Capuron. ('sely'), *Dioscorea bemandry* Jum. & H.Perrier ('baboky') and *Dioscorea alatipes* Burk. & H.Perr. The remaining 51 species were cited less than ten times (i.e., by less than 30% of the informants).

Number and WEP Species Cited

Children and adults listed a similar number of WEP species. Adults cited 49 species while children cited 45 species (Fig. 2a and b); the GLM showing that there is no statistically significant relation between informants' life stages and the number of species cited (estimate = -0.058, Std. error = 0.153, z value = -0.381, *p*-value = 0.703). The number of WEP species cited by children and adults was high in relation to the estimated total sampling completeness (respectively 77.5% and 81.2%) and tended to a similar estimated richness (58.0 species for children and 60.3 species for adults, Fig. 2b, Tab. S2). Results for Chao2, bootstrap, first-order and second-order Jackknife estimators are presented in Supplementary Table S2.

Children and adults listed 33 known WEP species in common. But children listed 12 species that were not reported by adults and adults listed 16 species that were not reported by children (Table S1). In other words, although children and adults listed the same number of WEP, they did not list the same species ($F = 19.63$, $R2 = 0.33$, $p < 0.05$), suggesting that children and adults recognise a distinct body of species.

Males cited more WEP species than females (53 vs. 37; Fig. 2a). Results from the GLM indicate a strong relation between gender and the number of species cited (estimate = 0.334, Std. error = 0.099, z value = 23.358, *p*-value < 0.001). The number of WEP species cited by females and males in relation to the estimated total sampling completeness was similar (respectively 79.17% and 77.48%), however they tended to a distinct estimated richness (46.73 species for females and 68.40 species for males, Fig. 2c, S2. Tab). Females listed eight species not reported by males and males listed 24 species not reported by females, while 29 species were listed by both females and males. Despite the difference in numbers, both genders reported similar species ($F = 6.77$, $R2 = 0.11$, $p = 0.183$), suggesting that females and males have more known species in common than known species specific to their gender.

Wild Edible Plants Characteristics

The most reported WEP species were trees (22) and shrubs (18), followed by climbers (9), herbs (6), and non-woody shrubs (4) (Fig. 3b & c). Among WEPs, some are not only edible but also "drinkable," locally known for providing water in quantity (Fig. 3b& c) and used in periods of drought. According to our informants, most of these species receive special care, including non-destructive collection practices to allow for annual harvesting of the consumed parts and drinking water resources extracted from these plants. Amongst the 59 species listed, 23 were reported as hydrating or used for thirst-quenching. More than half of these species provide water through their tubers (9) and fruits (8). Four species are consumed for water contained in their leaves and two species are known to provide large quantities of water through their tubers (water tubers). Regarding food groups, 34 WEP reported are classified as having fruits rich in vitamin A (VA-rich fruits); eight WEP fall into the category of white roots and tubers; six species are VA-rich vegetables and pulses and nuts. Only one WEP falls in the category of spices and condiments (Fig. 3b & c). We found no significant differences between life stages or gender in the listing of species belonging to different life form, water-provider type, and nutritional composition. The distribution of species listed in these categories was not significantly different from random expectations (see Table S3.), meaning that children and adults cited approximately the same number of WEPs in each subcategory of WEP characteristics. Results are similar when comparing the lists of females and males in each subcategory of WEP characteristics.

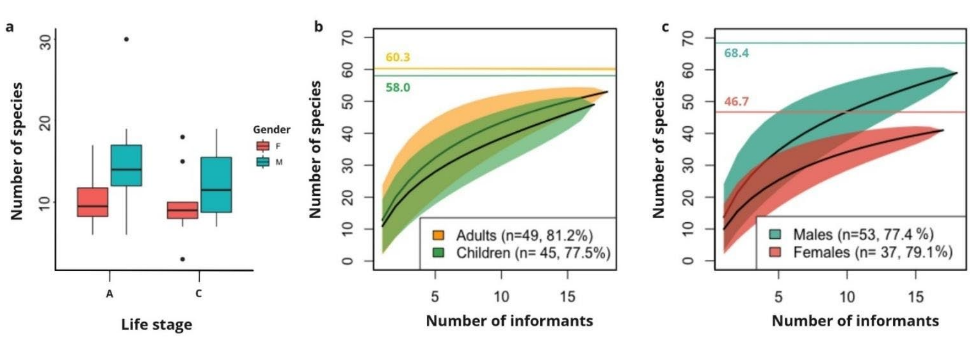

Fig. 2 Number of WEP species cited by informants and data saturation. **(a)** Number of WEP species cited by A = Adults, C = Children, F = Female (red box) and M = Male (blue box). The black dots represent the outliers. **(b & c)** Accumulation curves and sampling completeness for adults (yellow), children (green), male (blue) and female (red). The yellow, green, blue, and red numbers indicate the respective richness expected for adults and children, calculated with the bootstrap estimator. n = observed richness. The percentage indicates the sampling completeness

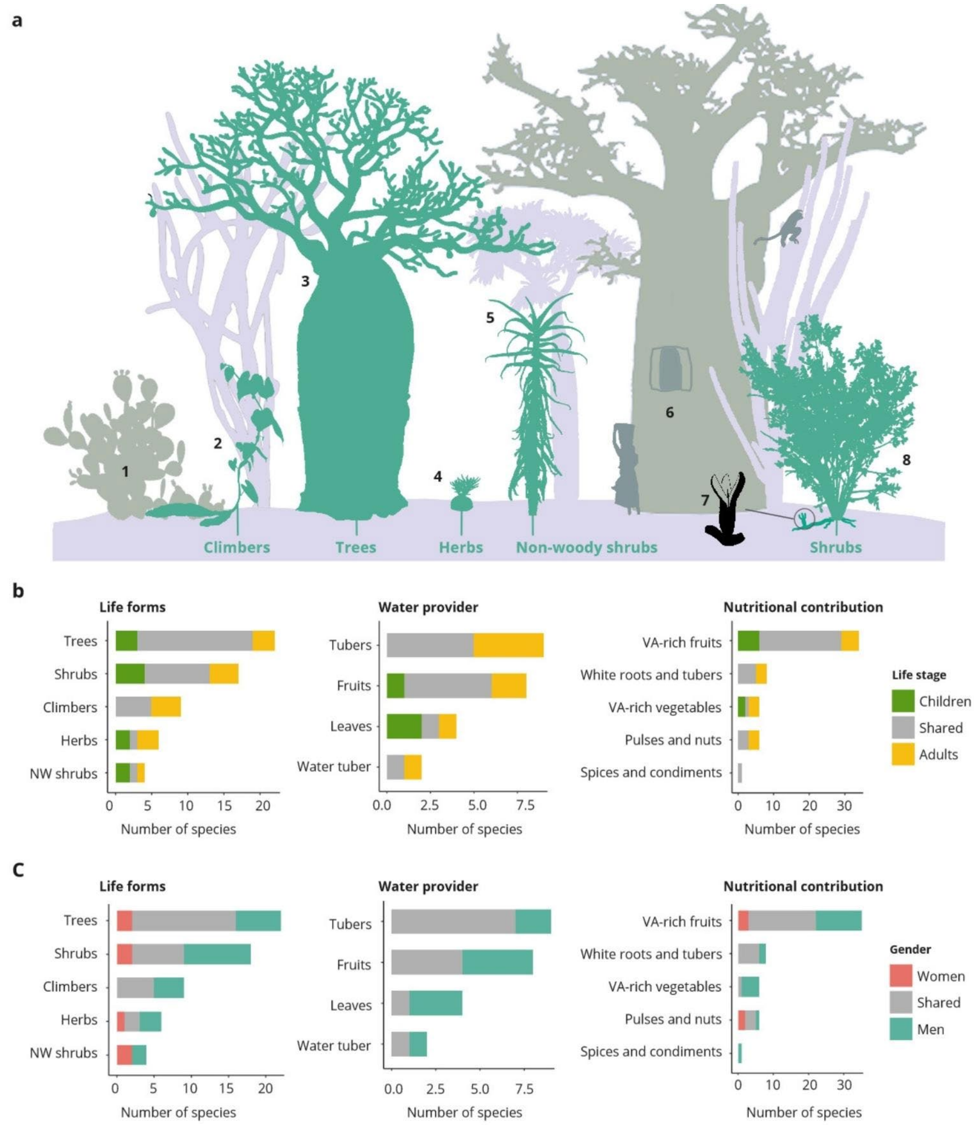

Fig. 3 Plant life forms and resources in the xerophytic thicket. **(a)** Xerophytic thicket plant life-forms diversity (in green) on the lixisol, (1) *Opuntia stricta* 'raketa', (2) *Dioscorea bemandry* 'baboky' water tuber, (3) *Adansonia fony var. rubrostipa* 'fony', (4) *Ipomoea bolusiana* 'moky', (5) *Aloe divaricata* 'vahomdrandro', (6) opening on *Adansonia za* 'za', hollowed out to be used as a water tank without killing the tree, (7) *Hydnora esculenta* 'voatany' holoparasitic plant growing on the roots of other trees, (8) *Azima tetracantha* 'tsingilo'. **(b)** Number of species known by adults (yellow), by children (green), and by both (grey) and **(c)** number of species known by women (red), by men (bleu), and by both (grey), by life forms, water-provided type, and nutritional contribution

Criteria for Important Species

Twenty-three of the 59 WEP species were listed as important by at least one informant. *Ziziphus spina-christi*, *Flacourtia indica*, *Salvadora angustifolia*, *Grewia leucophylla*, and *Boscia angustifolia* were the species most frequently cited as important (Fig. S2). The criteria belonged to five main categories: organoleptic (64 times), nutritional (42 times), food accessibility (10 times), economy (3 times) and food security (1 time). Regardless of informant's life stage and gender, the criteria most often used to define a WEP as important related to its *organoleptic* characteristics, mainly taste. The term 'mamy' (sweet) was the most used (45 times), followed by 'soa' (good taste) (17 times), and finally 'masiloka' (acid) cited twice. *Nutritional* aspects were also used to define WEP as important, particularly related to the feeling of fulfilment. The term 'voky' (satiating) was used 18 times, followed by 'menaka' (fat and oily) cited eight times, 'sakafo' (edible) cited four times, 'salama' (healthy) cited four times (usually referring to the vitamin), and finally 'jabobo' (provide water) cited three times. Terms related to *food accessibility* were also used, with the term 'miharamaky' (abundant), referring both to the species productivity and its ecological abundance, being reported eight times and the term 'manavanana' (effortless to collect) being cited twice. Few people used criteria related to *economic* aspects with the term 'mahaletake' (i.e., marketable) being cited three times. Finally, one informant used the term 'avotsiky' (preservable) referring to a *food security* aspect and the need to anticipate the lean season by storing wild food (Fig. S2).

We find differences in the number of mentions of these criteria between adults and children (Chi-square = 24.256, df = 11, p-value = 0.0117). Children used the criteria "good taste" more often than adults, while adults used "satiating" and "abundant" as criteria to define WEP as important more frequently (Table S4). However, we did not find differences between men and women (Chi-square = 15.108, df = 11, p-value = 0.1776).

Comparing Collection and Preparation Practices

During semi-structured interviews, four collection and 16 preparation methods were described for 31 of the 59 species listed, with multiple variations in the techniques, tools, or condiments used for preparation (Table S5). Regardless of life stage or gender, all informants used the same collection methods. Most of the WEP are trees and thorny shrubs collected with the help of a stick to make the fruit fall into a net on the ground. Tubers are usually collected with a spade ('fangale') or with the hands when the tuber is not deep. Our GLM did not detect any effect of life stage (estimate = 0.092, Std. error = 0.150, z value = 0.616, p-value = 0.543) or gender (estimate = 0.220, Std. error = 0.151 z value = 1.458, p-value = 0.156) on the use of different collection skills (Fig. 4a).

Many techniques are used to prepare WEP for consumption (e.g., roasted, boiled, leached, ground, squeezed, fermented), which involve a diverse use of condiments and tools. Similarly, there are many techniques to prepare WEP as an additive for the preparation of other foods, for example as fermenting agents to prepare goat milk (S5. Table). Women described nine different preparation methods, of which three were not reported by men. Men described 14 preparation methods, including eight that women did not mention. Adults described 13 preparation methods, of which seven were not mentioned by children (Fig. 4c) and children described nine preparation methods, of which three were not described by adults. Both children and adults reported one preparation method linked to one species not mentioned by the other group (Fig. 4c). Among the 31 species for which preparation methods were described, 16 WEPs were mentioned by all subsamples, with similar preparation. Regarding preparation skills, GLM indicated that adults were more knowledgeable in terms of WEP preparation than children (estimate = -1.338, Std. error = 0.383, z value = -3.489, p-value < 0.01). Moreover, while we did not find any gender differences in preparation skills among adults, we found that girls have a lower score in preparation skills compared to boys (estimate = 0.8976, Std. error = 0.4130, z value = 2.173, p-value < 0.05) (Fig. 4b).

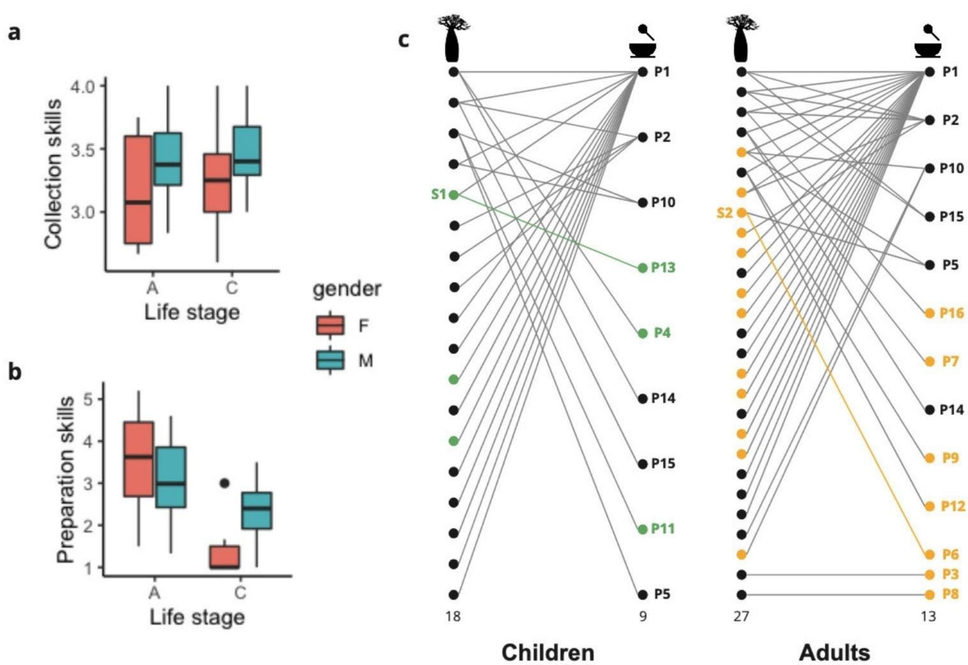

Fig. 4 Collection and preparation skills per life stage and gender and preparation knowledge network. **(a)** collection skills and **(b)** preparation skills. A = Adults, C = Children, F = Female (red box) and M = Male (blue box), the black dots represent outliers. **(c)** Preparation knowledge network for children and adults. Nodes under the baobab tree and kitchen tool represent the species and preparation methods. Links between nodes represent knowledge linking a WEP species and a preparation method. Node colours indicate species or preparation common to children and adults (black), specific to children (green) or to adults (yellow). Numbers under the nodes indicate the respective number of species and preparation methods known by children and adults. The preparation methods from P1 to P16 are described in Supplementary Table S5

Discussion

Tanalana people hold a great diversity of WEP knowledge in common, although they also display intracultural variation in WEP knowledge distribution, as shown by the distinct distribution pattern regarding theoretical and practical knowledge across life stages and gender. Thus, in free listings, children and adults cited different sets of species, suggesting differentiated bodies WEP theoretical knowledge. As for gender, men cited more WEP than women. We found low intracultural variation in WEP collection and preparation methods, suggesting that all Tanalana share them. We discuss such insights in terms of learning opportunities and how these might contribute to the resilience of local knowledge systems constituting a risk-management strategy. We argue that the harsh environmental conditions of the area might shape Tanalana WEP knowledge distribution and the early acquisition of this LEK by children.

Intracultural Variation Through Life Stage and Gender Lenses

Our results produced an important insight into the differences in plants named by children and adults, which suggests the existence of a separate children's culture. Children reported different species and methods of WEP preparation than adults, and also define important WEPs differently. Similar findings have been observed across small-scale societies and ecological regions including two cases in Madagascar (Gallois et al., 2017; Tucker & Young, 2017; Porcher et al., 2022). Thus, our results reinforce the idea that children hold specialised knowledge and potentially what has been termed "a children's culture" (Johanson, 2010; Gallois et al., 2017). Differentiated children's knowledge might be explained by several mechanisms driven by sociocultural and environmental contexts. One of the current theories behind children's specific knowledge is the importance of horizontal transmission among children (Reyes-García et al., 2016), which fosters the acquisition of specific knowledge not shared with adults. While vertical transmission – knowledge transfer from adults, usually from parents to children – is the most intuitive process occurring, some studies argue that horizontal transmission might be a predominant mechanism among children in small-scale societies (Hewlett & Cavalli-Sforza, 1986; Gallois et al., 2018; Santoro et al., 2020). This transmission process is usually supported by subsistence activities that encourage prosocial behaviour like playing, foraging, and food sharing (Crittenden, 2015; Frazao-Moreira, 1997).

Tanalana children who regularly experience the effects of the lean season might rely in food sharing, which supports knowledge transmission among them. This mechanism adds to others, such as the *fihavanana* – the set of traditional rules and norms, built on values of sharing, trust, social peace, and interpersonal solidarity – which structure Tanalana society and condition their cultural learning (Richter, 2001). Here, we hypothesize that environmental conditions and food scarcity might partially explain the diversified body of knowledge held by Tanalana children. Together with the transmission process, children might also create their own knowledge about their environment (Lancy, 2010) through their growing period (Ingold, 2003). Thus, the difference in species cited by children in relation to adults might also be the result of foraging decisions made by children to collect WEP best adapted to their strength, size, and preferences (Gallois et al., 2017). This might be the case for the tuber of *Hydnora esculenta*, only cited by children (Andriamisaina, 2019), which usually grow a few centimetres underneath the soil and require less energy to be collected than *Dioscorea* tubers, generally several metres deep and weighing several kilograms (depending on the species). In addition, the difference between adults and children can also be due to vegetation changes over generations, such as the "shifting baseline syndrome," which can influence knowledge dynamics (Hanazaki et al., 2013).

In contrast to most previous studies, we found that Tanalana women display a particularly reduced theoretical body of WEP knowledge, reflected in the absence of a set of WEP species specific to women and in the low number of WEP known. We argue that this finding might be explained through the ecological context of this society and women's reduced mobility pattern. Across cultural groups and ecoregions, women hold extensive plant knowledge (Miara et al., 2018) and particularly knowledge of WEP growing in home gardens (Díaz-Reviriego et al., 2016b) with a high specialisation in herbaceous WEP (Voeks, 2007; Porcher et al., 2022). The reduced presence of herbaceous WEP in Tanalana women's list might be explained by the xerophytic thicket being too dry for such life forms. Indeed, the only herbaceous WEP found in the region were hyper-specialised to dry conditions with succulent leaves (Fig. 2). For example, the traditional "anana" (in Malagasy), a leafy vegetable herbaceous species that can grow wild or cultivated and is consumed boiled and accompanying the staple food (rice, cassava), an unavoidable dish in the Malagasy diet, is absent here. This, and the almost non-existence of home gardens impact an important part of knowledge that women generally master in other Malagasy regions. Moreover, it seems likely that women and girls' reduced mobility due to their domestic-sphere-oriented activities also affect their knowledge of WEP. Recent work in the high plateau of Madagascar shows the importance of mobility in the knowledge differentiation pattern across life stage and gender (Porcher et al., 2022). Pastoralism among the Tanalana, as with other Malagasy people, is a predominantly male activity, which promotes men's but restricts women's mobility. In addition, during the lean season in this region men travel several weeks away from the village to collect WEP and water. These seasonal trips allow men to encounter different types of vegetation and thus to expand their knowledge of WEP. In contrast, women only have access to nearby WEP. For example, from our interviews and additional sources (Cirad, 2015), we know that women are actively involved in collecting water when the baobab tanks are full in the dry season. These household baobab trees can be found several kilometres from the village and therefore imply a certain seasonal mobility of women across the xerophytic thicket. Importantly, women's reduced knowledge about WEP might have a direct effect on their nutritional intake and, by extension, their ability to cope with food crises (Jackson et al., 2020). Further studies involving socio-cultural perspectives are needed to explore gendered knowledge transmission and women's knowledge acquisition in this region.

It has been shown that many gender-related factors, such as early marriage, gender inequality, school dropout syndrome, difficulties in agricultural production or migration, could affect women's acquisition of LEK, which in turn could increase their vulnerability (Noromiarilanto et al., 2016; Randriamparany & Randrianalijaona, 2022). This is reflected in our finding that girls display lower preparation skills than boys, and women providing a lower number of WEP than men. Although further research would be necessary to elucidate this gap, we believe that it may be associated with to the shyness displayed by girls and women during interviews. Therefore, our results may not be representative of females' actual practical knowledge. Verbalization of complex ideas can be a limitation for children during interviews and induce shyness in addition to an existing gender-shame (Gazelle et al., 2014), so that drawing methods may be better adapted for work with children.

Explaining Early Learning and Children's Knowledge

An important finding of our study that Tanalana children know as much as adults, citing a similar number of WEP species as adults, while reporting different species, has not, to the best of our knowledge, been reported for other societies. Indeed, regarding theoretical knowledge (i.e., the number of WEP species known), children almost reach the maximum threshold predicted for WEP species known by adults. Our results also show that useful WEP traits (life forms and resources) are widely recognized across the community, without variation across life stage and gender. This implies that Tanalana children do not accumulate new WEP species knowledge, or very little, as they grow and that they already have information about WEP useful traits as part of their LEK. These findings are consistent with previous studies that challenge the assumption that individuals' LEK accumulation is linear, resulting in greater expertise or skills in older individuals (Koster et al., 2016). Here, we argue that high expertise for a given knowledge domain may be acquired early. According to Schniter et al. (2021), knowledge related to wild edible or toxic plants might a knowledge domain acquired earliest during a lifespan. It is also true for practical knowledge, as Tanalana children share a similar level of WEP collection skills and know almost half of the preparation methods reported by adults. Knowledge about WEP is acquired through children's daily involvement in gathering and preparing WEP, where most of the species are eaten raw and collected without specific tools. These relatively low complexity techniques might thus foster an early acquisition of skills, in contrast with other subsistence activities such as hunting, for which it has been shown that skills acquisition requires a long period of time (Demps et al., 2012; Lew-levi et al., 2021; Koster et al., 2016 and, 2020). This pattern of "early knowledge acquisition" has been also observed among Mikea children, a neighbouring ethnic group of hunter-gatherers living in similar environmental conditions (Tucker & Young, 2017). Furthermore, other factors such as time allocation during childhood, access to schools, and the presence or absence of adults within children's daily activities might be factors shaping children's knowledge of WEP (Gallois et al., 2017). Further research is needed to explore the link between time allocation and children's knowledge acquisition in Tanalana societies. The fact that children from different ethnic groups from the same arid ecoregion but with different livelihood activities, i.e., hunter-gatherers and agro-pastoralists, hold complex subsistence skills at an early age suggests an effect of the environment on children's knowledge. In this region, children's "dwelt-in world" (Ingold, 2003), or the way they experience their environment, is particularly constrained by the harsh environmental conditions and might imply a certain engagement vis-à-vis foraging for resources, resulting in a contextual specialized and early knowledge acquisition or "enskilment" (Ingold, 2003). Considering the extreme living conditions of xerophytic thicket, quickly learning how to recognize, collect, and prepare WEP is definitively crucial to limiting food risk and, by extension, to survival. According to Tucker and Young (2017) this self-learning can be enhanced in a safe environment (e.g., free from predators, venomous animals, or poisonous plants) such as the xerophytic thicket, where wrong plant identification is less risky than in other environments.

Risk-management Strategy as a Component of Tanalana's LEK

We identify three main aspects of the Tanalana's LEK that contribute to resilience and thus constitute a risk-management strategy. First, in their environment of xerophytic thicket, which offers limited water and food resources, Tanalana people have developed sophisticated knowledge to identify and prepare what is available, mostly in tree species and shrubs with fruits rich in vitamin *A* (57% of the WEP reported) and tubers used as staple food. One of the specificities of their ecological knowledge, and one of our striking results, is the large proportion of WEPs known for providing water resources, reflecting the magnitude of water stress in the region. Despite the human pressure on the xerophytic thicket (Randriamalala et al., 2019), several species particularly important for providing water receive specific care and are protected by traditional management rules, or 'fady.' For example, according to our informants, the collection of the water tubers of *Dioscorea bermandry*, 'baboky,' is done in a non-destructive manner to ensure sustainable collection (cf. Dounias, 1996). *Adansonia za*, 'za,' appreciated for its fruits, is also used as a water tank (Fig. 3a 6) able to contain up to 800 L by carving out the trunk without killing the tree (Cirad, 2015).

A second aspect is the structure of the LEK system and in particular its distribution and age of knowledge acquisition. We found that while children and adults look for similar plant traits, they cited different WEP species and used different criteria to define WEP as important. This utilitarian redundancy might enforce adaptive capacity and knowledge system resilience (Díaz-Reviriego et al., 2016). Blanco and Carrière's work in Morocco (2016) shows that sharing knowledge about WEP might be an adaptation to the harsh conditions of scarce and unpredictable precipitation directly affecting the food system. They argue that the reduced knowledge variation might allow the whole community to collect most of a plant and maximise resource collection. Our results support this argument. Indeed, the observed "shared" distribution of WEP knowledge of Tanalana people (including children's early knowledge acquisition) might also be an adaptation to the difficult and unpredictable environmental conditions. In addition, Tucker and Young (2017) argue that the early skills of children advance the age of "positive net production" and thus reduce the physical and economic burdens of adults. While we did not collect any data on foraging time allocation or foraging productivity, our field observations suggest a certain autonomy of children towards WEP collection and consumption. In this sense, while we cannot prove that Tanalana children's WEP foraging proficiency reduces adults' burdens, we do suggest that it might at least improve children's nutritional status by providing micronutrients through daily snacking habits (cf. Golden et al., 2011).

A third aspect of Tanalana knowledge resilience is the symbolic values they attribute to and their behaviour towards WEP. If basic needs play an important role in WEP knowledge distribution, other socio-cultural factors are also in play. Optimal foraging theory (OFT) states that foraging is driven by the balance between energy spent to acquire or prepare food and the energy obtained from it (Winterhalder & Alden Smith, 1981). Targeting tree species bearing fruits that do not need specific preparation (see Fig. 4c P1) and provide a high energy rate due to their sugar and micronutrients, aligns with this theory of effort-gain optimization. However, several studies have shown that the cost of the gathering is not always a limiting factor and that low-energy resources are often collected despite their high cost (Hagino & Yamauchi, 2016; Gallois & Henry, 2021) challenging this neoclassical approach. The act of foraging itself, in some cases, might be perceived locally and culturally as more important than the resource provided, particularly when it relies on a collective activity because it supports socio-cultural interactions, knowledge transfer, cultural learning process, and group cohesion (Gallois & Duda, 2016). Indeed, diet, including food selection and collection, depends on many psycho-cultural factors (Gaoue et al., 2017; Gallois & Henry, 2021). As Trémolière (1962) put it: "[a] human is a consumer of symbols as much as of food." In the Malagasy culture, the symbolic act of sharing is more important for a sweet food, such as fruits. In Malagasy, the word "*mamy*" means both sugar/sweet and happiness. By analogy, to share sweetness, it is also to share happiness, but above all, a "sharing" and the expression of the *fihavanana*, the feeling of solidarity; in sum, to make a group (Ravololomanga, 2006). Thus, considering sweet WEP as important WEP is not only revealing a nutritional need but a more complex food representation learnt at an early age involving social behaviours such as solidarity and cooperation that enhance the group's ability to overcome crises through a social risk-management strategy (Moritz et al., 2011).

However, while these strategies might enhance knowledge system resilience, they do not necessarily fully protect people from food crises. Indeed, despite the great WEP knowledge held by the Tanalana people, malnutrition remains a critical challenge in this region (WFP, 2020). Recent work has stated that indigenous food system vulnerability to disaster might be approached through emphasising the socio-ecological system framework while addressing several aspects of this system such as the historical, human, economic, environmental, and governance dimensions (Jackson, 2020). Indeed, according to historical sources and local experiences (Ralaingita et al., 2022), before the current food crisis with a debated climatic origin, the region experienced several episodes of intense drought followed by food crises in the 1920 and 1930 s. Furthermore, the 200 years of French colonisation that ended in 1960 also deeply affected the local knowledge system's integrity and resilience (Raschke & Cheema, 2008). In addition, migration, poverty, decrease in WEP abundance due to overexploitation (Schunko et al., 2022), vegetation loss (Randriamalala et al., 2019), and bad governance might deeply affect the current vulnerability of the local food system. Thus, knowledge distribution is an important dimension to understanding Indigenous and local knowledge and food system vulnerability, but it has also to be analysed in a broader context.

Conclusion

Our results show that Tanalana people hold a great diversity of WEP knowledge in common, while revealing a different body of theoretical knowledge between children and adults. The distinct distribution pattern regarding theoretical and practical knowledge across life stages and gender attests to the complexity of understanding knowledge system distribution, which might be deeply linked to the knowledge domain itself. In addition to the social components, such as life stage and gender, we argue that the environment and, in particular, resource limitations, might also shape knowledge distribution patterns and knowledge acquisition. We believe that WEP knowledge widely shared in the community might allow maximising resource collection and more individual autonomy toward WEP proficiency. Our findings provide further evidence of children's expertise in their ecological environment, which is acquired early in life. Such insights are of major relevance, especially in the design of food security policies and development programs, which should take into consideration not only the local ecological and cultural variabilities, but also include all social groups of the impacted communities.

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Authors' contributions V.P., X.L, S.M.-C., S.G., V.R.-G. conceived and designed the study. V.P., X.L and D.C did the ethnobotanical fieldwork, V.P. and S.A.-F. analysed the data and V.P. wrote the first draft of the paper and prepared the figures. All authors: V.P., X.L, D.C, S.A.-F., S.M.-C., S.G., V.R.-G. discussed the results and commented on the manuscript.

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Data Availability The data presented in this study are available from the corresponding author upon reasonable request. They are not available online as they contain sensitive data that should not be released to protect local knowledge holders.

Declarations

Ethical Approval and Informed Consent This research was approved by the ethics committee of the Autonomous University of Barcelona (CEEAH 4902) and was carried out following the ethical charter of Ethical Research Involving Children (Graham et al., 2013). Before starting data collection, we obtained the agreement from the relevant administrative-territorial organisations (Fokontany chefs). Oral free prior and informed consent (FPIC) was obtained from each informant before conducting interviews. For children, we asked for both their own and their parents' FPIC, always reiterating to the children their right to withdraw from the study at any time. To illustrate local ecological knowledge and valorise it in the academy, we cite informants, including children, in references, as knowledge repositories using the citation template developed by MacLeod (2021). To protect knowledge holders including their village locations, we used pseudonyms while keeping the age and gender of the knowledge owners.

Competing interests The authors declare no competing interests.

References

Andriamisaina, M. (2019). 13 years old girl. Mahafaly Tanalana community. Mahafaly Plateau, Southwest of Madagascar. Preparation knowledge of wild edible plants. personal communication.

Andriamparany, J. N., Brinkmann, K., Jeannoda, V., & Buerkert, A. (2014). Effects of socio-economic household characteristics on traditional knowledge and usage of wild yams and medicinal plants in the Mahafaly region of south-western Madagascar. *Journal of Ethnobiology and Ethnomedicine*, *10*(1), 1–21. https://doi.org/10.1186/1746-4269-10-82.

Blanco, J., & Carrière, S. M. (2016). Sharing local ecological knowledge as a human adaptation strategy to arid environments: Evidence from an ethnobotany survey in Morocco. *Journal* *of Arid Environments*, *127*, 30–43. https://doi.org/10.1016/j.jaridenv.2015.10.021.

Brand, J. C., & Cherikoff, V. (1985). The nutritional composition of australian Aboriginal food plants of the desert regions. *Plants for arid lands* (pp. 53–68). Springer. https://doi.org/10.1007/978-94-011-6830-4_5.

Cámara-Leret, R., Faurby, S., Macía, M. J., Balslev, H., Göldel, B., Svenning, J. C., & Saslis-Lagoudakis, C. H. (2017). Fundamental species traits explain provisioning services of tropical american palms. *Nature Plants*, *3*(2), 1–7. https://doi.org/10.1038/nplants.2016.220.

Cirad (2015). Baobabs, réservoirs de vie à Madagascar. https://www.youtube.com/watch?v=1JVIn5urKc8 (accessed 10 november 2022).

Cook, F. E. (1995). *Economic botany data collection standard*. Royal Botanic Gardens (Kew).

Crittenden, A. N., & Zes, D. A. (2015). Food sharing among Hadza hunter-gatherer children. *PloS One*, *10*(7), e0131996. https://doi.org/10.1371/journal.pone.0131996.

Cruz García, G. S. (2006). The mother–child nexus. Knowledge and valuation of wild food plants in Wayanad, Western Ghats, India. *Journal of Ethnobiology and Ethnomedicine*, *2*(1), 1–6. https://doi.org/10.1186/1746-4269-2-39.

de Campos, O., Albuquerque, L. Z., Peroni, U. P., N., & Araujo, E. L. (2015). Do socioeconomic characteristics explain the knowledge and use of native food plants in semiarid environments in northeastern Brazil? *Journal of Arid Environments*, *115*, 53–61. https://doi.org/10.1016/j.jaridenv.2015.01.002.

de Coughlan, E., van Aalst, M., Choularton, R., van den Hurk, B., Mason, S., Nissan, H., & Schwager, S. (2019). From rain to famine: Assessing the utility of rainfall observations and seasonal forecasts to anticipate food insecurity in East Africa. *Food Security*, *11*(1), 57–68. https://doi.org/10.1007/s12571-018-00885-9.

Demps, K., Zorondo-Rodríguez, F., García, C., & Reyes-García, V. (2012). Social learning across the life cycle: Cultural knowledge acquisition for honey collection among the Jenu Kuruba, India. *Evolution and Human Behavior*, *33*(5), 460–470. https://doi.org/10.1016/j.evolhumbehav.2011.12.008.

Díaz, S., Settele, J., Brondízio, E. S., Ngo, H. T., Agard, J., Arneth, A., & Zayas, C. N. (2019). Pervasive human-driven decline of life on Earth points to the need for transformative change. *Science*, *366*(6471), eaax3100. https://doi.org/10.1126/science.aax310.

Díaz-Reviriego, I., Fernández-Llamazares, A., Salpeteur, M., Howard, P. L., & Reyes-García, V. (2016a). Gendered medicinal plant knowledge contributions to adaptive capacity and health sovereignty in Amazonia. *Ambio*, *45*(3), 263–275. https://doi.org/10.1007/s13280-016-0826-1.

Díaz-Reviriego, I., González-Segura, L., Fernández-Llamazares, Á., Howard, P. L., Molina, J. L., & Reyes-García, V. (2016b). Social organization influences the exchange and species richness of medicinal plants in amazonian homegardens. *Ecology and Society*, *21*(1), https://doi.org/10.5751/ES-07944-210101.

Dounias, E. (1996). Sauvage ou cultivé? La paraculture des ignames sauvages par les pygmées Baka du Cameroun. *L'alimentation en forêt tropicale: interactions bioculturelles et perspectives de développement. UNESCO, Paris, France*, 939–960.

Elmqvist, T., Pyykönen, M., Tengö, M., Rakotondrasoa, F., Rabakonandrianina, E., & Radimilahy, C. (2007). Patterns of loss and regeneration of tropical dry forest in Madagascar: The social institutional context. *Plos One*, *2*(5), e402. https://doi.org/10.1371/journal.pone.0000402.

Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics*, *5*(1), 1–4. https://doi.org/10.11648/j.ajtas.20160501.11.

Feldt, T., & Schlecht, E. (2016). Analysis of GPS trajectories to assess spatio-temporal differences in grazing patterns and land use preferences of domestic livestock in southwestern Madagascar. *Pastoralism*, *6*(1), 1–17. https://doi.org/10.1186/s13570-016-0052-2.

Frazão-Moreira, A. (1997). Meninos entre árvores e lianas - A aprendizagem do mundo e das plantas pelas crianças nalus (Guiné-Bissau). *Educação Sociedade & Culturas*, *7*(1), 75–108.

Gallois, S., & Duda, R. (2016). Beyond productivity: The socio-cultural role of fishing among the Baka of southeastern Cameroon. *Revue d'ethnoécologie*, (10), https://doi.org/10.4000/ethnoecologie.2818.

Gallois, S., & Henry, A. G. (2021). The cost of gathering among the Baka Forager-Horticulturalists from southeastern Cameroon. *Frontiers in Ecology and Evolution*, 952. https://doi.org/10.3389/fevo.2021.768003.

Gallois, S., Duda, R., & Reyes-García, V. (2017). Local ecological knowledge among Baka children: A case of children's culture? *Journal of Ethnobiology*, *37*(1), 60. https://doi.org/10.2993/0278-0771-37.1.60.

Gallois, S., Lubbers, M. J., Hewlett, B., & Reyes-García, V. (2018). Social networks and knowledge transmission strategies among Baka children, southeastern Cameroon. *Human Nature*, *29*(4), 442–463. https://doi.org/10.1007/s12110-018-9328-0.

Gallois, S., Heger, T., van Andel, T., Sonké, B., & Henry, A. G. (2020). From bush mangoes to bouillon cubes: Wild plants and diet among the Baka, forager-horticulturalists from Southeast Cameroon. *Economic Botany*, *74*(1), 46–58. https://doi.org/10.1007/s12231-020-09489-x.

Gaoue, O. G., Coe, M. A., Bond, M., Hart, G., Seyler, B. C., & McMillen, H. (2017). Theories and major hypotheses in ethnobotany. *Economic Botany*, *71*(3), 269–287. https://doi.org/10.1007/s12231-017-9389-8.

Gazelle, H., Peter, D., & Karkavandi, M. A. (2014). Commentary: Bashful boys and coy girls: A review of gender differences in childhood shyness. *Sex Roles*, *70*(7), 285–308. https://doi.org/10.1007/s11199-014-0361-0.

Golden, C. D., Fernald, L. C., Brashares, J. S., Rasolofoniaina, B. R., & Kremen, C. (2011). Benefits of wildlife consumption to child nutrition in a biodiversity hotspot. *Proceedings of the National Academy of Sciences*, *108*(49), 19653–19656. https://doi.org/10.1073/pnas.1112586108.

Graham, A., Powell, M. A., Anderson, D., Fitzgerald, R., & Taylor, N. J. (2013). *Ethical research involving children*. UNICEF Office of Research-Innocenti.

Hagino, I., & Yamauchi, T. (2016). High motivation and low gain: Food procurement from rainforest foraging by Baka hunter-gatherer children. *Social learning and innovation in contemporary hunter-gatherers* (pp. 135–144). Springer. https://doi.org/10.1007/978-4-431-55997-9_11.

Hanazaki, N., Herbst, D. F., Marques, M. S., & Vandebroek, I. (2013). Evidence of the shifting baseline syndrome in ethnobotanical research. *Journal of Ethnobiology and Ethnomedicine*, *9*(1), 1–11. https://doi.org/10.1186/1746-4269-9-75.

Hänke, H., & Barkmann, J. (2017). Insurance function of livestock, Farmers coping capacity with crop failure in southwestern Madagascar. *World Development*, *96*, 264–275. https://doi.org/10.1016/j.worlddev.2017.03.011.

Hewlett, B. S., & Cavalli-Sforza, L. L. (1986). Cultural transmission among Aka pygmies. *American Anthropologist*, *88*(4), 922–934.

Ingold, T. (2003). Two reflections on ecological knowledge. *Nature knowledge: ethnoscience, cognition, identity*, 301 – 11.

Jackson, G., McNamara, K. E., & Witt, B. (2020). System of hunger: Understanding causal disaster vulnerability of indigenous food systems. *Journal of Rural Studies*, *73*, 163–175. https://doi.org/10.1016/J.JRURSTUD.2019.10.042.

Johanson, K. (2010). Culture for or by the child? Children's culture and Cultural Policy. *Poetics*, *28*, 386–401. https://doi.org/10.1016/j.poetic.2010.05.002.

Kaplan, H., Hill, K., Lancaster, J., & Hurtado, A. M. (2000). A theory of human life history evolution: Diet, intelligence, and longevity. *Evolutionary Anthropology: Issues News and Reviews: Issues News and Reviews*, *9*(4), 156–185. https://doi.org/10.1002/1520-6505(2000)9:4<156::AID-EVAN5>3.0.CO;2-7.

Kennedy, G., Ballard, T., & Dop, M. C. (2011). Guidelines for measuring household and individual dietary diversity. Nutrition and Consumer Protection Division, Food and Agriculture Organization of the United Nations. *Accessed on 2016/03/06*.

Koster, J., Bruno, O., & Burns, J. L. (2016). Wisdom of the elders? Ethnobiological knowledge across the lifespan. *Current Anthropology*, *57*(1), 113–121. https://doi.org/10.1086/684645.

Koster, J., McElreath, R., Hill, K., Yu, D., Shepard Jr, G., Van Vliet, N., & Ross, C. (2020). The life history of human foraging: Cross-cultural and individual variation. *Science Advances*, *6*(26), eaax9070. https://doi.org/10.1126/sciadv.aax9070.

Lancy, D. F. (2010). Learning from nobody: The Limited Role of Teaching in Folk Models of children's development. *Childhood in the Past*, *3*, 79–106. https://doi.org/10.1179/cip.2010.3.1.79.

Lew-Levy, S., Ringen, E. J., Crittenden, A. N., Mabulla, I. A., Broesch, T., & Kline, M. A. (2021). The life history of learning subsistence skills among Hadza and BaYaka foragers from Tanzania and the Republic of Congo. *Human Nature*, *32*(1), 16–47. https://doi.org/10.1007/s12110-021-09386-9.

MacLeod, L. (2021). More Than Personal Communication: Templates for citing indigenous elders and knowledge keepers. *KULA*, *5*(1), 1–5. https://doi.org/10.18357/kula.135.

McArdle, B. H., & Anderson, M. J. (2001). Fitting multivariate models to community data: A comment on distance-based redundancy analysis. *Ecology*, *82*, 290–297. https://doi.org/10.1890/0012-9658(2001)082[0290:FMMTCD]2.0.CO;2.

Miara, M. D., Bendif, H., Hammou, M. A., & Teixidor-Toneu, I. (2018). Ethnobotanical survey of medicinal plants used by nomadic peoples in the algerian steppe. *Journal of Ethnopharmacology*, *219*, 248–256. https://doi.org/10.1016/j.jep.2018.03.011.

Moritz, M., Giblin, J., Ciccone, M., Davis, A., Fuhrman, J., Kimiaie, M., & Senn, M. (2011). Social risk-management strategies in pastoral systems: A qualitative comparative analysis. *Cross-Cultural Research*, *45*(3), 286–317. https://doi.org/10.1177/1069397111402464.

Neudert, R., Goetter, J. F., Andriamparany, J. N., & Rakotoarisoa, M. (2015). Income diversification, wealth, education and well-being in rural south-western Madagascar: Results from the Mahafaly region. *Development Southern Africa*, *32*(6), 758–784. https://doi.org/10.1080/0376835X.2015.1063982.

Noromiarilanto, F., Brinkmann, K., Faramalala, M. H., & Buerkert, A. (2016). Assessment of food self-sufficiency in smallholder farming systems of south-western Madagascar using survey and remote sensing data. *Agricultural Systems*, *149*, 139–149. https://doi.org/10.1016/j.agsy.2016.09.005.

Oksanen, J., Simpson, G., Blanchet, F., Kindt, R., Legendre, P., Minchin, P., O'Hara, R., Solymos, P., Stevens, M., Szoecs, E., Wagner, H., Barbour, M., Bedward, M., Bolker, B., Borcard, D., Carvalho, G., Chirico, M., De Caceres, M., Durand, S., Evangelista, H., FitzJohn, R., Friendly, M., Furneaux, B., Hannigan, G., Hill, M., Lahti, L., McGlinn, D., Ouellette, M., Ribeiro Cunha, E., Smith, T., Stier, A., Ter Braak, C., & Weedon, J. (2022). _vegan: Community Ecology Package_. R package version 2.6-2, https://CRAN.R-project.org/package=vegan.

Paniagua-Zambrana, N. Y., Bussmann, R. W., Hart, R. E., Huanca, A. L. M., Soria, G. O., Vaca, M. O., & Siripi, E. (2018). To list or not to list? The value and detriment of freelisting in ethnobotanical studies. *Nature Plants*, *4*(4), 201–204. https://doi.org/10.1038/s41477-018-0128-7.

Phillipson, P. B., Schatz, G. E., Lowry, P. P., & Labat, J. N. (2006). A catalogue of the vascular plants of Madagascar. *African plants: Biodiversity, ecology, phytogeography and taxonomy*, 613–627.

Porcher, V., Carrière, S. M., Gallois, S., Randriambanona, H., Rafidison, V. M., & Reyes-García, V. (2022). Growing up in the Betsileo landscape: Children's wild edible plants knowledge in Madagascar. *PloS One*, *17*(2), e0264147. https://doi.org/10.1371/journal.pone.0264147.

Quesada, M., Sanchez-Azofeifa, G. A., Alvarez-Anorve, M., Stoner, K. E., Avila-Cabadilla, L., Calvo-Alvarado, J., & Sanchez-Montoya, G. (2009). Succession and management of tropical dry forests in the Americas: Review and new perspectives. *Forest Ecology and Management*, *258*(6), 1014–1024. https://doi.org/10.1016/j.foreco.2009.06.023.

Ralaingita, M., Ennis, G., Russell-Smith, J., Sangha, K., & Razanakoto, T. (2022). The Kere of Madagascar: A qualitative exploration of community experiences and perspectives. *Ecology and Society*, *27*(1), https://doi.org/10.5751/ES-12975-270142.

Randolph, T. F., Schelling, E., Grace, D., Nicholson, C. F., Leroy, J. L., Cole, D. C., & Ruel, M. (2007). Invited review: Role of livestock in human nutrition and health for poverty reduction in developing countries. *Journal of Animal Science*, *85*(11), 2788–2800. https://doi.org/10.2527/jas.2007-0467.

Randriamalala, J. R., Randriarimalala, J., Hervé, D., & Carrière, S. M. (2019). Slow recovery of endangered xerophytic thickets vegetation after slash-and-burn cultivation in Madagascar. *Biological Conservation*, *233*, 260–267. https://doi.org/10.1016/j.biocon.2019.03.006.

Randriamparany, S. T., & Randrianalijaona, T. M. (2022). The vulnerability of Antandroy women to droughts in Ambovombe Androy (Madagascar). *International Journal of Disaster Risk Reduction*, *72*, 102821. https://doi.org/10.1016/j.ijdrr.2022.102821.

Raschke, V., & Cheema, B. (2008). Colonisation, the New World Order, and the eradication of traditional food habits in East Africa: Historical perspective on the nutrition transition. *Public Health Nutrition*, *11*(7), 662–674. https://doi.org/10.1017/S1368980007001140.

Ratsihoarana, M., 25 years old man. Mahafaly. (2019). Tanalana community. Mahafaly Plateau, Southwest of Madagascar. Knowledge about wild edible plants providing aqueous sources. personal communication.

Ravololomanga, B. (2006). Le repas à Madagascar: L'on invite et l'on partage, Madagascar fenêtres. *Aperçus sur la Culture Malgache vol*, *2*, 134–143.

Reyes-García, V., Gallois, S., & Demps, K. (2016). *A Multistage Learning Model for Cultural Transmission: Evidence from three indigenous Societies* (pp. 47–60). Springer. https://doi.org/10.1007/978-4-431-55997-9_4.

Reynolds, J. F., Smith, D. M. S., Lambin, E. F., Turner, B. L., Mortimore, M., Batterbury, S. P., & Walker, B. (2007). Global desertification: Building a Science for dryland development. *Science*, *316*(5826), 847–851. https://doi.org/10.1126/Science.1131634.

Richter, H. G. (2001). *Kinderzeichnung interkulturell [Children's drawings between cultures]*. Lit. Verlag.

Rosell, J. A., Olson, M. E., Martínez-Garza, C., & Martínez-Méndez, N. (2022). Functional diversity in woody organs of tropical dry forests and implications for restoration. *Sustainability*, *14*(14), 8362. https://doi.org/10.3390/su14148362.

Santoro, F. R., Chaves, L. S., & Albuquerque, U. P. (2020). Evolutionary aspects that Guide the Cultural Transmission Pathways in a Local Medical System in Northeast Brazil. *Heliyon*, *6*(6), e04109. https://doi.org/10.1016/j.heliyon.2020.e04109.

Schniter, E., Macfarlan, S. J., Garcia, J. J., Ruiz-Campos, G., Beltran, D. G., Bowen, B. B., & Lerback, J. C. (2021). Age-Appropriate

Wisdom? *Human Nature*, *32*(1), 48–83. https://doi.org/10.1007/s12110-021-09387-8.

Schunko, C., Li, X., Klappoth, B., Lesi, F., Porcher, V., Porcuna-Ferrer, A., & Reyes-García, V. (2022). Local communities' perceptions of wild edible plant and mushroom change: A systematic review. *Global Food Security*, *32*, 100601. https://doi.org/10.1016/j.gfs.2021.100601.

Smith, E. P., & van Belle, G. (1984). Nonparametric estimation of species richness. *Biometrics*, *40*, 119–129. https://doi.org/10.2307/2530750.

Trémolières, J. (1962). *Manuel élémentaire d'alimentation humaine* (Vol. 1). Éditions sociales françaises.

Tucker, B., & Young, A. G. (2017). Growing up Mikea: Children's time allocation and tuber foraging in southwestern Madagascar. *Hunter-gatherer childhoods* (pp. 147–171). Routledge.

Voeks, R. A. (2007). Are women reservoirs of traditional plant knowledge? Gender, ethnobotany and globalization in northeast Brazil. *Singapore Journal of Tropical Geography*, *28*(1), 7–20. https://doi.org/10.1111/j.1467-9493.2006.00273.x.

WFO (2022). World Flora Online. Published on the Internet. http://www.worldfloraonline.org. (accessed 10 november 2022).

WFP (2022). World Food Programme, Hunger Map. https://hungermap.wfp.org/. (accessed 10 november 2022).

Winterhalder, B., & Smith, E. A. (Eds.). (1981). *Hunter-gatherer foraging strategies: Ethnographic and archeological analyses*. University of Chicago Press.