Prioritizing Wild Edible Plants for potential new crops based on Deciduous Forest traditional knowledge by a Rancher community

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Botanical Sciences
95 (1): 47-59, 2017

DOI: 10.17129/botsci.772

Abstract

Background: Several ethnobotanical indices evaluate the importance of wild edible plants (WEPs), but most of them consider mainly anthropological/cultural information; thus, their appropriate use for selection of priority species for developing new crops is difficult. In Mexico, few ethnobotanical studies involve ranchers of non-indigenous communities and the distribution of their knowledge.

Hypotheses: Application of a proper ethnobotanical index and taking account the plant culinary characteristics permit the selection of the most important WEPs for food security. Knowledge about WEPs is homogeneously distributed among the ranchers.

Study site and dates: Fifty-three semi-structured interviews about the use of WEPs among the ranchers of Southern Baja California were conducted in 2015.

Methods: Plant importance was determined by the Food Significance Index (FSI) and the Salience Index (SI). Priority species for food security were selected by analyzing the index values of plants and their culinary uses.

Results: Fifty-one taxa of WEPs were recorded, mostly fruits and vegetables. FSI grouped a more diverse selection of plant-foods in the top rated species than SI; however, both identified almost the same priority species after considering the culinary prioritization of the analyzed species. The number of WEPs cites was higher for men (26) than for women (19).

Conclusions: Analysis of WEPs using ethnobotanical indexes (FSI/SI) and culinary information permits the selection of food priority species reducing the bias of the index for one kind of food. *Stenocereus thurberi*, *S. gummosus*, *Matelea cordifolia*, and *Cnidoscolus maculatus* were the selected priority species with potential to be new crops.

Key word: Wild edible plants, deciduous forest, dry forest, ethnobotany, ethnobotanical indices, Southern Baja California

Priorizando las plantas silvestres comestibles con uso potencial para nuevos cultivos con base en el conocimiento tradicional del bosque caducifolio.

Resumen

Antecedentes: Varios índices etnobotánicos evalúan la importancia de las plantas silvestres comestibles (PSCs); sin embargo, la mayoría de ellos consideran principalmente características antropológicas/culturales, por lo que es difícil emplearlos para seleccionar especies prioritarias para desarrollarse como nuevos cultivos. En México, existen pocos estudios etnobotánicos enfocados en la cultura del ranchero de grupos no indígenas y sobre cómo su conocimiento está distribuido.

Hipótesis: La aplicación de un índice etnobotánico adecuado y tomando en cuenta la diversidad culinaria de las PSCs, permitirá la selección de las especies más apropiadas para la seguridad alimentaria de la región. El conocimiento sobre las PSCs se distribuye homogéneamente entre los rancheros.

Sitio y año de estudio: Durante el 2015, se realizaron 53 entrevistas semi-estructuradas acerca del uso de plantas silvestres comestibles entre los rancheros de la Región del Cabo, Baja California Sur.

Métodos: La importancia de las especies se estimó mediante el Índice de Importancia Alimentaria (IIA) y el Índice de Prominencia (IP). Las especies prioritarias se establecieron mediante el valor de los índices y sus usos culinarios.

Resultados: Se registraron 51 taxa de plantas silvestres comestibles, principalmente frutos y vegetales. Entre las especies mejor evaluadas, el IIA agrupó una mayor diversidad de alimentos, comparado con el IP; sin embargo, ambos identificaron prácticamente las mismas especies prioritarias cuando la selección se realizó en base a las prioridades culinarias. El número de PSCs citadas por los hombres (26) fue mayor que el de las mujeres (19).

Conclusiones: El empleo de los índices etnobotánicos (IIA/IP) junto con la información culinaria permite seleccionar a las PSCs prioritarias para la seguridad alimentaria, reduciendo el sesgo de los índices por algún tipo de alimento. *Stenocereus thurberi*, *S. gumossus*, *Matelea cordifolia* y *Cnidoscolus maculatus* fueron las especies prioritarias con mayor potencial de establecerse como nuevos cultivos.

Palabras clave: Plantas silvestres comestibles, bosque caducifolio, selvas secas, etnobotánica, índices etnobotánicos, Región del Cabo, Baja California Sur

Author Contributions
Pío-León and Ortega-Rubio conceived and design the original idea; Pío-León performed the field work and wrote the first draft of manuscript; Delgado-Vargas and León-de la Luz participated in consolidation of study idea and with critical review of the manuscript. All authors participated in the data analysis and read and approved the final manuscript.

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Mexico is a megadiverse country where several of the most-consumed foods worldwide (*e.g.* maize, beans, tomatoes, chili, and cacao) were originated and/or domesticated (Neyra-González & Durand-Smith 1998). Mexico also has a long tradition in ethnobotanical studies, which are the basis to select wild plants for use, conservation and domestication purposes. However, most of these studies have been focused in population of the south-central region (the states of Puebla, Oaxaca, Veracruz, Yucatán, Morelos, Guerrero, Tabasco, Mexico, and Hidalgo) and indigenous (mainly Maya, Nahua, Mixtec, Otomí, and Totonac) people (Caballero *et al*. 1998, Yetman & Van Devender 2002, Camou-Guerrero *et al*. 2008, Vázquez-Alonso *et al*. 2014, Narchi *et al*. 2015, Camou-Guerrero *et al*. 2016), whereas other people living immerse in nature with their own accumulated knowledge have been relegated, as it occurs with the ranchers. Some examples of ethnobotany works in Mexican non-indigenous rural communities are the studies about the native tree species used by ranchers of the central Veracruz (Suárez *et al*. 2012), the medicinal plants used by ranchers of Tabasco (Gómez-Álvarez 2012), and the ethnobotany of farmers in Rayones, Nuevo León (Estrada-Castillon *et al*. 2014).

Several quantitative approaches have been used to evaluate the importance of wild edible plants for a community, but most of them are focused in anthropological/cultural information (*e.g*. cultural heritage, gender perspective, socioeconomics, and cooking of edible species) (Pieroni 2001, da Silva *et al*. 2006, do Nascimento *et al*. 2013, Alonso-Aguilar *et al*. 2014, Sujarwo *et al*. 2014). Moreover, few of these approaches include plant features more closely related with food security such as its role in diet, conversion into processed products, or post-harvest life (features from the perspective of the food science and technology). For example, the Pieroni's index uses disproportionate rating scales, it favors green vegetables (1.5 points) or condiments (1.0 points) over the seeds (0.5) or those consumed in soups (0.75 points). The scale of da Silva *et al*. (2006) is inflexible (low value =1, high value = 2) in the measurement of preference or frequency of use. Joshi *et al*. (2015) include some good parameters related to food security, such as the commercial value and the existence of processed products; however, their scales are inflexible and the selection of the priority species takes into account only the value of the general index.

The objectives of this research were: 1) identify the wild edible plants used by the Southern Baja California ranchers who live in the driest deciduous forest of Mexico, 2) identify the priority species for domestication or potential new crops that could contribute to food security, and 3) evaluate how the knowledge about the use of wild edible plants is distributed among people surveyed. The hypotheses were: 1) the a application of a proper ethnobotanical index (with those features related with food security mentioned above) to ranchers of Southern Baja California and taking account the plant culinary characteristics permit the selection of the most important WEPs for food security in the area; these include a culinary diverse group of plants rather than a single group of foods. 2) Knowledge about WEPs is homogeneously distributed among the older and younger ranchers.

The proposed methodology for selecting priority species uses the ethnobotanical indices, either the Food Significance Index (FSI) or the Salience Index (SI), and culinary information. The ranchers surveyed live in areas of the Tropical Deciduous Forest, one of the most representatives and endangered ecosystems in Mexico, characterized by the limited water availability and hot summer air temperatures; thus, successful establishment of production systems based on selected wild plant species of this area is feasible.

Materials and methods

Study area. The Baja California Tropical Deciduous Forest is located at the southern top of the Baja California peninsula, in the Cape Region, between 500–1,000 m; the annual average rainfalls and temperatures are 200–400 mm and 22–24 °C, respectively (González-Abraham *et al*. 2010, León de la Luz *et al*. 2012). The flora of this area is represented by species such as *Bursera epinnata*, *Colubrina viridis*, *Jatropha cinerea*, *Karwinskia humboldtiana*, *Lysiloma candidum*, *Lysiloma microphyllum*, and *Stenocereus thurberi* (León de la Luz *et al*. 2012). Our research was carried out in the municipality of La Paz and it included localities in the "Ejido Álvaro Obregón", community of "San Blas-Los Divisaderos", and "Sierra Cacachilas" (Figure

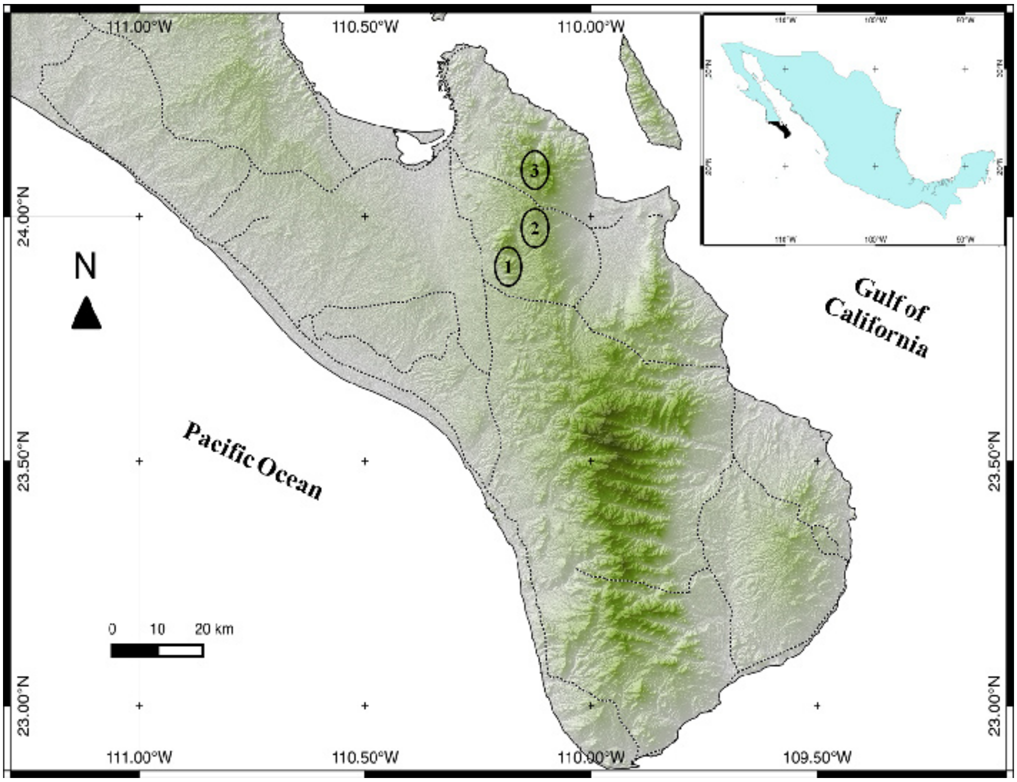

Figure 1. Localities of the Cape Region where the study was conducted: Ejido Alvaro Obregón (1), San Blas-Los Divisaderos (2), and Sierra Cacachilas (3).

1). The studied populations in these communities are scattered in small settlements from 1 to 30 houses, but for our analysis were included only the smallest (under 10 houses) by considering they are more related with wildness in contrast with the formal villages. In selected communities, people call themselves ranchers (rancheros, in Spanish), defined as people living in rural communities (ranches) in which livestock farming is their main economic activity, complemented with cheese works, home gardens, construction, public services, and sale of non-timber forest products (*e.g*. fruits *Stenocereus*). The ranches appeared just after retirement of the Jesuit missions in 1768 which started with small scale agriculture and livestock farming; later, immigrant ranchers from northwest Mexico had facilities for land tenure and adapted their knowledge to the semi-desert environment of this region, rising the current culture of the Southern Baja California ranchers; there is no native indigenous people in this area because the native hunter-gatherer Prericúe and Guaycura disappeared after the conquest (Urciaga-García 2008). The selected area also has one of the largest concentrations of scattered settlements in the Cape Region and in the Tropical Deciduous Forest of Baja California peninsula.

Field work. Semi-structured interviews were conducted from March to November 2015. A total of 53 people were interviewed: 27 men and 26 women. The mean age for men participants was 49 ± 16 (from 20 to 81) and 58 ± 14 (from 34 to 86) for women. A maximum of two participants per home were included, mostly by individual interviews. A base of three simple questions was used:

1. Could you tell the name of all the wild edible plants you know?
2. Which are the edible parts and how do you prepare it?
3. Could you mention your three favorite wild edible plants?

Previously, a checklist of edible plants was created with local names and pictures from the local literature (Rebman & Roberts 2012, León de la Luz *et al*. 2014); this checklist was used when the interviewed did not mention any new species. After the interview, volunteer participants were involved in field work for *in situ* identification of plant species and to get additional information, photographs and/or samples for the herbarium. The voucher specimens were identified and deposited in the herbarium "Annetta Mary Carter" (HCIB) of the Centro de Investigaciones Biológicas del Noroeste (CIBNOR).

Food Significance Index. Only those species with three or more mentions were considered. A simplified Food Significance Index (FSI) applied in a previous study (Pío-León J.F., pers. com., submitted for publication) was used and defined by the following equation:

$$FSI = CV \times CrV$$

where CV and CrV are Cultural Value and Crop Value sub-indices, respectively.
Cultural Value (CV) is calculated as CV = $ci + ca + pr$. Where: ci is the citation index defined as the number of participants who cited a species divided by the total number of participants; ca is the food category of the specie and represents its role in diet; and pr is the preference rank of the plant. In relation with ca, four categories were considered: staple foods, complements, seasoning and teas, and minor foods. Staple foods provide most of the calories and vegetal proteins to diet (*e.g*. cereals, legumes, potatoes); complements are important foods, but they are not the main sources of protein and calories (fruits, vegetables, and almond-like seeds); seasoning and teas add desirable sensory features to foods or water, but do not represent significant amounts of calories or other nutrients (such as pepper, oregano, green tea); minor foods are small fruits consumed occasionally in field, usually as a candy, and hardly became regular eating or take away hunger. ca values are 1.0 for staple foods, 0.75 for complements, 0.25 for seasoning and teas, and 0.1 for minor foods. On the other hand for the preference parameter (pr), each participant listed three species of their choice and the parameter was calculated as $pr = [(p1/t)/1] + [(p2/t)/2] + [(p3/t)/3]$, where, for a specific plant, $p1$, $p2$, and $p3$ are the number of people who cite it as their first, second, or third choice; t is the total number of participants. Participants could list more than one species in each position when they so desired, such as two plants in $p1$, one in $p2$ and two in $p3$. The maximum theoretical value of pr for a species is 1 (preferred food by all participants) and the minimum is 0 (not cited in any position).

The Crop Value sub-index (CrV) was determined as CrV = $pl + pp + neo$. pl is the postharvest shelf life of the food under ambient conditions; three levels of pl were defined: non-perishable foods (*e.g*. almond-like seeds, dry leaves) (1 point value), medium term perishable (*e.g*. potatoes, semi-dry fruits) (0.5 points value), and highly perishable (fresh fruits and vegetables). pp is processed product with market potential; it is considered when the food item of the species is transformed into a marketable or potential marketable product, such as fermented beverage, jam or prickle. Those fresh foods which already have a commercial value were included as pp. Foods having a pp attribute were assigned a value of 1, otherwise it is 0. nep is the number of edible organs/parts of the plant. A number of maximum four edible organs were established: 1) underground organs, 2) leaves of branches, 3) fruits, and 4) seeds. For every edible part a value of 0.25 was given.

Sub-indices were multiplied in order to increase the variability of FSI and to identify differences between species. In a previous work (Pío-León J.F., pers. com., submitted for publication), a Management Value was included as a third sub-index; however, people in the interviewed communities have done few efforts for management or domestication of the wild species. The use of the Management Value sub-index is recommended for other areas where the researcher detects the management/ domestication of wild plant species.
Salience Index. Salience Index (SI) was proposed by Smith (1993) to analyze free list surveys and was recently recommended by Kujawska & Łuczaj (2015) to select the most important wild edible species. Results of the SI were compared with those of the FSI. For each species, Salience Index is defined as the average of the following ratio in all the free list interviews:

Salience Index = (total number of species in the interview – rank order position of the species (starting from 0 for the first species)) / total number of species cited in the interview.

Selection of the priority species. The priority species for food and conservation purposes were designated according to a selection system that promotes the culinary diversity. First, species were grouped based on the type of food: 1) seeds, 2) fruits and candy-type foods, 3) seasoning or tea, and 4) vegetables. Species in each group were sorted in descending order according their FSI and the lowers limits of the first, second, and third quartile were calculated, corresponding to the lower limits of FSI for the species in the Priority Group 1, Priority Group 2, and Priority

Group 3, respectively. Equations were formulated as follow:

FSI of *Priority Group 1* = >FSI_L + [(FSI_H – FSI_L) × 0.75]
FSI of *Priority Group 2* = > FSI_L + [(FSI_H – FSI_L) × 0.5] – FSI of *Priority Group 1*
FSI of *Priority Group 3* = > FSI_L + [(FSI_H – FSI_L) × 0.25] – FSI of *Priority Group 2*

FSI_L and FSI_H are the lowest and the highest values of FSI for each group of food, respectively. Using this selection system the priority group 1 was ensured to include at least one species of each group of foods. We used this selection system to avoid the likely bias of the indices for some kind of food. The same procedure was applied for the values of SI instead of FSI.

Results

Fifty-one taxa of wild edible plants were recorded with more than three mentions, which represent about 8 % of the total taxa for the deciduous forest in the Baja California peninsula (León de la Luz *et al*. 2012). Families with higher number of taxa were Cactaceae (11), Fabaceae (7), Solanaceae (3), and Verbenaceae (3) (Table 1). Out of the 51 taxa, 25 were used as fruits, nine as vegetables, four as almonds-like or nuts, four as recreational tea, eight as candy, and two as seasonings (Table 2). Only the acorns of *Quercus brandegeei* were identified as staple food; at its harvesting season (November-December), acorns are mostly consumed as *atole*, a kind of thick drink prepared by mixing and boiling the toasted and ground acorns with milk. People usually drink *atole* during breakfast or dinner. *Atole* is also commonly prepared with the seeds of *Quercus tuberculata* or *Cnidoscolus maculatus*; however, these are less preferred and mostly consumed as almond-like seeds.

The 10 species with the highest FSI included a high culinary diverse group of food: two seeds (*Quercus brandegeei* and *Cnidoscolus maculatus*), four fruits (*Ficus petiolaris*, *Stenocereus thurberi*, *Stenocereus gummosus*, and *Cyrtocarpa edulis*), one recreational tea (*Turnera diffusa*), two seasoning (*Lippia palmeri* and *Capsicum annuum*), and one vegetable (*Pithecellobium dulce*). *Pithecellobium dulce* arils are commonly consumed as fruits (raw fresh arils) in other parts of Mexico and Asia (Parrotta 1991, Monroy & Colín 2004), but people from this region used them as vegetables accompanying cooking. For this purpose, fresh arils were blanched and mixed with meat or other vegetables. Differences were detected among SI and FSI; in general, the highest values were for seeds (FSI) and fruits (SI); the top 10 species with the highest SI included a less culinary diverse group than FSI (Table 2). Salience Index was more related with the preference parameter (*pr*) and the Cultural Value (CV) (most popular species) than with FSI or the Crop Value (CrV).

As processed products with marketing potential, ranchers produced: marmalade/jams from eight fruits (*Ficus petiolaris*, *Stenocereus thurberi*, *Stenocereus gummosus*, *Cyrtocarpa edulis*, *Diospyros californica*, *Pachycereus pecten-aboriginum*, *Pachycereus pringlei* and *Pithecellobium dulce*) and the stems of *Ferocactus townsendianus*; wine or liqueur from the fruits of *S. thurberi*, *S. gummosus*, *C. edulis*, and *Vitis peninsularis*; prickles from *C. edulis*, *Matelea cordifolia*, and *Capsicum annuum*; coffee-like substitutes and powder to make *atole* from the seeds of *Quercus brandegeei*, *Cnidoscolus maculatus*, and *Quercus tuberculata*; and three are sold as dehydrated products for tea (*Turnera diffusa*) and seasoning (*Lippia palmeri* and *C. annuum*).

The fresh fruits of *Stenocereus thurberi* and *S. gummosus* ("pitayas") are the best-selling products throughout the year. *Stenocereus thurberi* fruits has the highest economic value; these fruits are smaller, sweeter, and their harvesting season is shorter (July-August) than those of *S. gummosus* (August-December). There are two main *S. thurberi* phenotypes (red and white fruits), both of them are sold as fresh fruits, but marmalade is produced only from the red ones. Many people of the studied communities work in *S. thurberi* harvesting, but only some of them are involved in the commercialization in nearby urban centers, directly without going through supermarkets. By contrast, *S. gummosus* has only one main phenotype (red fruits), its postharvest shelf life is few days longer and they are expended in the supermarkets of the nearby urban centers.

Men cited more species than women. The age did not affect the average number of listed species by men, but the younger women cited less than the older ones (Table 3).

Selection of the priority species. Ten species were included in the Priority Group 1 using FSI

Table 1. Wild edible plants in the dry deciduous forest of the Cape Region, Mexico (* source: Rebman and Roberts (2012) and EOL (2014)).

Key	Family	Species	Common name Spanish/English*	Edible parts	Gastronomic classification
1	Amaranthaceae	*Amaranthus watsonii* Standl.	Quelite	Aerial parts	Vegetable
2	Anacardiaceae	*Cyrtocarpa edulis* (Brandegee) Standl.	Ciruela/cape wild plum	Fruit and seed	Fruit and almond
3	Apocynaceae	*Matelea cordifolia* (A. Gray) Woodson	Talayote/sonoran milk vine	Fruit	Vegetable
4	Apocynaceae	*Matelea pringlei* (A. Gray) Woodson	Talayote chino/	Fruit	Vegetable
5	Arecaceae	*Brahea brandegeei* (Purpus) H.E. Moore	Palmilla/fan palm	Fruit	Dry fruit
6	Arecaceae	*Washingtonia robusta* H. Wendl.	Palma/Mexican fan palm	Buds	Vegetable
7	Asparagaceae	*Agave aurea* Brandegee	Maguey, quiote/-	Stem	Candy (sugar cane-like)
8	Asparagaceae	*Yucca capensis* L.W. Lenz/ *Yucca valida* Brandegee	Datilillo/Baja California tree yucca	Flower	Vegetable
9	Asteraceae	*Porophyllum gracile* Benth.	Hierba de venado/slender poreleaf	Aerial parts	Tea
10	Cactaceae	*Cylindropuntia cholla* (F.A.C. Weber) F.M.Knuth	Choya/cholla	Fruit	Fruit
11	Cactaceae	*Ferocactus townsendianus* var. *townsendianus* (Britton & Rose) G.E. Linds.	Biznaga/Townsed barrel cactus	Stem	Candy (preserves in sugar)
12	Cactaceae	*Lophocereus schottii* (Engelm.) Britton & Rose	Carambullo/oldman cactus	Fruit	Fruit
13	Cactaceae	*Mammillaria* Haw. spp./ *Mammillaria phitauiana* (E.M. Baxter) Werderm.	Viejitos/pincushion cactus	Fruit	Fruit
14	Cactaceae	*Opuntia* Mill. spp.	Nopal/pricklypear	Leaves and fruit	Vegetable
15	Cactaceae	*Pachycereus pecten-aboriginum* (Engelm. ex S. Watson) Britton & Rose	Cardón barbón/ aborigine's comb cactus	Fruit and seed	Fruit
16	Cactaceae	*Pachycereus pringlei* (S. Watson) Britton & Rose	Cardón pelón/elephant cactus	Fruit	Fruit
17	Cactaceae	*Peniocereus striatus* (Brandegee) Buxb.	Jarra matraca/dahlia-root cereus	Fruit	Fruit
18	Cactaceae	*Pereskiopsis porteri* (Brandegee ex F.A.C. Weber) Britton & Rose	Alcajer/Porter pereskiopsis	Fruit	Fruit
19	Cactaceae	*Stenocereus gummosus* (Engelm.) A. Gibson & K.E. Horak	Pitaya agria/sour pitaya	Fruit	Fruit
20	Cactaceae	*Stenocereus thurberi* (Engelm.) Buxb. var. thurberi	Pitaya dulce/organ pipe cactus	Fruit	Fruit
21	Cannabaceae	*Celtis reticulata* Torr.	Vainoro/net-leaf hack berry	Fruit	Fruit
22	Convolvulaceae	*Ipomoea bracteata* Cav.	Jícama/wild jicama	Tuber	Fruit (sweet tuber)
23	Ebenaceae	*Diospyros californica* (Brandegee) I.M. Johnst.	Guayparín/wild persimmon	Fruit	Fruit
24	Euphorbiaceae	*Cnidoscolus maculatus* (Brandegee) Pax & K. Hoffm.	Caribe/bad woman	Seed	Almond
25	Euphorbiaceae	*Jatropha cinerea* (Ortega) Müll. Arg.	Lomboy/ashy limberbush	Seed	Almond
26	Fabaceae	*Acacia farnesiana* (L.) Will.	Vinorama/sweet acacia	Stem exudate	Candy
27	Fabaceae	*Haematoxylon brasiletto* H. Karst.	Brasil/brazilwood	Heart wood	Tea
28	Fabaceae	*Lysiloma candidum* Brandegee.	Palo blanco/-	Stem exudate	Candy
29	Fabaceae	*Lysiloma microphyllum* Benth.	Mauto/-	Stem exudate	Candy
30	Fabaceae	*Parkinsonia florida* (A. Gray) S. Watson	Palo verde/mexican palo verde	Aril	Candy
31	Fabaceae	*Parkinsonia praecox* (Ruiz & Pav.) Hawkins.	Palo brea/-	Stemexudate	Candy
32	Fabaceae	*Pithecellobium dulce* (Roxb.) Benth.	Guamúchil/manila tamarind	Stemexudate	Vegetable or fruit
33	Fabaceae	*Prosopis articulata* S. Watson	Mezquite/mezquite		Candy
34	Fagaceae	*Quercus brandegeei* Goldman	Encino/brandegeeoak	Seed	Almond
35	Fagaceae	*Quercus tuberculata* Liebm.	Roble/red oak	Seed	Almond
36	Malpighiaceae	*Malpighia diversifolia* Brandegee	Manzanita/	Fruit	Fruit
37	Moraceae	*Ficus petiolaris* Kunth	Zalate/wild fig	Fruit	Semi-dry fruit
38	Myrtaceae	*Psidium sartorianum* (O. Berg) Nied.	Arrayan/-	Fruit	Fruit
39	Oxalidaceae	*Oxalis drummondii* A. Gray	Agritos/-	Tuber	Fruit
40	Passifloraceae	*Turnera diffusa* Willd.	Damiana/damiana	Leaves	Tea
41	Passifloraceae	*Passiflora arida* (Mast. & Rose) Killip	Sandillita/Sonoran passion flower	Fruit	Fruit
42	Portulacaceae	*Portulaca oleracea* L.	Verdolaga/purslane	Aerial parts	Vegetable
43	Rubiaceae	*Randia capitata* DC.	Papache/papache	Fruit	Fruit
44	Sapotaceae	*Sideroxylon peninsulare* (Brandegee) T.D. Penn.	Bebelama/western bumelia	Fruit	Fruit
45	Solanaceae	*Capsicum annuum* L. var. *aviculare* (Dierb.) D'Arcy & Eschbaugh	Chilpitines/bird pepper	Fruit	Spicy seasoning
46	Solanaceae	*Physalis* L.	Tomatillo/-	Fruit	Fruit
47	Solanaceae	*Solanum nigrescens* M. Martens & Galleotti	Hierva mora/nightshade	Fruit	Fruit
48	Verbenaceae	*Lippia palmeri* S. Watson	Orégano/Mexican oregano	Leaves	Seasoning
49	Verbenaceae	*Aloysia barbata* (Brandegee) Moldenke	Santimia/-	Leaves	Tea
50	Verbenaceae	*Lantana velutina* M. Martens & Galeotti	Confiturilla/-	Fruit and leaves	Fruit and tea
51	Vitaceae	*Vitis peninsularis* M.E. Jones	Uva/wild grape	Fruit	Fruit

- non defined

Table 2. Food Significance Index (FSI) and Salience Index (SI) of the wild edible plants used by Sudcalifornian ranchers. *ci* = citation index, *ca* = food category, *pr* = preference, CV = Cultural Value, *neo*= number of edible organs, *pl* = postharvest shelf life, *pp* = processed product with commercial potential, CrV = Crop Value, FSI = Food Significance Index.

Species	CV and parameters				CrV and parameters				FSI	SI
	ci	*pr*	*ca*	CV	*pl*	*pp*	*neo*	CrV		
Plants used as almonds										
Quercus brandegeei	0.792	0.110	1	1.903	1	1	0.25	2.25	4.281	0.481
Cnidoscolus maculatus	0.698	0.000	0.75	1.448	1	1	0.25	2.25	3.258	0.318
Quercus tuberculata	0.302	0.019	0.75	1.071	1	1	0.25	2.25	2.409	0.157
Jatropha cinerea	0.057	0.000	0.10	0.157	1	0	0.25	1.25	0.196	0.020
Plants used as fruit or candy										
Ficus petiolaris	0.981	0.211	0.75	1.942	0.5	1	0.25	1.75	3.398	0.785
Stenocereus thurberi	1.000	0.563	0.75	2.313	0.1	1	0.25	1.35	3.122	0.894
Stenocereus gummosus	1.000	0.437	0.75	2.187	0.1	1	0.25	1.35	2.953	0.800
Cyrtocarpa edulis	0.887	0.173	0.75	1.810	0.1	1	0.5	1.6	2.896	0.576
Ferocactus townsendianus	0.585	0.019	0.75	1.354	0.1	1	0.5	1.6	2.166	0.236
Diospyros californica	0.755	0.028	0.75	1.533	0.1	1	0.25	1.35	2.070	0.426
Pachycereus pecten-aboriginum	0.566	0.006	0.75	1.322	0.1	0.5	0.5	1.1	1.455	0.352
Ipomoea bracteata	0.755	0.110	0.75	1.615	0.5	0	0.25	0.75	1.211	0.573
Lysiloma microphyllum	0.585	0.000	0.25	0.835	1	0	0.25	1.25	1.044	0.191
Pachycereus pringlei	0.189	0.000	0.75	0.939	0.1	0.5	0.25	0.85	0.798	0.098
Vitex peninsularis	0.302	0.000	0.1	0.402	0.1	1	0.25	1.35	0.543	0.137
Cylindropuntia cholla	0.585	0.019	0.75	1.354	0.1	0	0.25	0.35	0.474	0.294
Brahea brandegeei	0.472	0.019	0.1	0.591	0.5	0	0.25	0.75	0.443	0.182
Prosopis articulata	0.245	0.000	0.10	0.345	1	0	0.25	1.25	0.432	0.091
Psidium sartorianum	0.283	0.019	0.75	1.052	0.1	0	0.25	0.35	0.368	0.142
Oxalis drummondii	0.264	0.000	0.75	1.014	0.1	0	0.25	0.35	0.355	0.060
Agave aurea	0.208	0.000	0.75	0.958	0.1	0	0.25	0.35	0.335	0.127
Randia capitata	0.132	0.000	0.75	0.882	0.1	0	0.25	0.35	0.309	0.033
Acacia farnesiana	0.132	0.000	0.1	0.232	1	0	0.25	1.25	0.290	0.034
Lantana hispida	0.321	0.000	0.1	0.421	0.1	0	0.5	0.6	0.252	0.073
Parkinsonia praecox	0.075	0.000	0.1	0.175	1	0	0.25	1.25	0.219	0.029
Lysiloma divaricatum	0.075	0.000	0.1	0.175	1	0	0.25	1.25	0.219	0.031
Malpighia diversifolia	0.434	0.000	0.1	0.534	0.1	0	0.25	0.35	0.187	0.197
Celtis reticulata	0.415	0.000	0.1	0.515	0.1	0	0.25	0.35	0.180	0.282
Mammillaria armillata/M. phitauiana	0.302	0.000	0.1	0.402	0.1	0	0.25	0.35	0.141	0.066
Sideroxylon peninsulare	0.283	0.000	0.1	0.383	0.1	0	0.25	0.35	0.134	0.142
Lophocereus schottii	0.189	0.006	0.1	0.295	0.1	0	0.25	0.35	0.103	0.058
Pereskiopsis porteri	0.151	0.000	0.1	0.251	0.1	0	0.25	0.35	0.088	0.061
Parkinsonia florida	0.132	0.000	0.1	0.232	0.1	0	0.25	0.35	0.081	0.026
Solanum nigrescens	0.094	0.000	0.1	0.194	0.1	0	0.25	0.35	0.068	0.022
Passiflora arida	0.075	0.000	0.1	0.175	0.1	0	0.25	0.35	0.061	0.038
Peniocereus striatus	0.057	0.000	0.1	0.157	0.1	0	0.25	0.35	0.055	0.016
Plants used as tea or seasoning										
Turnera diffusa	0.981	0.060	0.25	1.291	1	1	0.25	2.25	2.904	0.453
Lippia palmeri	0.925	0.019	0.25	1.193	1	1	0.25	2.25	2.685	0.332
Capsicum annuum	0.811	0.028	0.25	1.090	1	1	0.25	2.25	2.452	0.286
Aloysia barbata	0.660	0.009	0.25	0.920	1	0	0.25	1.25	1.150	0.217
Haematoxylon brasiletto	0.208	0.000	0.25	0.458	1	0	0.25	1.25	0.572	0.071
Porophyllum gracile	0.075	0.000	0.25	0.325	1	0	0.25	1.25	0.407	0.013
Plants used as vegetable										
Pithecellobium dulce	0.906	0.129	0.75	1.785	0.1	1	0.25	1.35	2.409	0.588
Matelea cordifolia	0.830	0.101	0.75	1.681	0.1	1	0.25	1.35	2.269	0.525
Opuntia spp.	0.377	0.019	0.75	1.146	0.1	0	0.5	0.6	0.688	0.169
Portulaca oleracea	0.981	0.063	0.75	1.794	0.1	0	0.25	0.35	0.628	0.426
Amaranthus watsonii	0.509	0.000	0.75	1.259	0.1	0	0.25	0.35	0.441	0.188
Washingtonia robusta	0.302	0.000	0.75	1.052	0.1	0	0.25	0.35	0.368	0.117
Matelea pringlei	0.226	0.000	0.75	0.976	0.1	0	0.25	0.35	0.342	0.180
Physalis spp.	0.057	0.009	0.75	0.816	0.1	0	0.25	0.35	0.286	0.039
Yucca capensis/Y. valida	0.057	0.000	0.75	0.807	0.1	0	0.25	0.35	0.282	0.020

Table 3. Number of wild edible plants cited by Sudcalifornian ranchers (men and women) of different ages. N = number of individuals in the group, * different superscript letters in the column shows differences ($P < 0.05$) by the Duncan's multiple range test.

Gender/ age range	N1	Age (mean ± SD)	No. of species (mean ± SD*)
Men	27	49.3 ± 16.0	25.8 ± 6.9^{a,b}
> 50 years	12	63.8 ± 9.4	25.7 ± 7.0^{a,b}
≤ 50 years	15	37.7 ± 9.2	25.9 ± 7.1^{a,b}
< 40 years	9	32.1 ± 7.1	28.2 ± 7.2^{a}
Women	26	57.6 ± 14	18.7 ± 7.7^{c,d}
> 50 years	17	64.6 ± 11.4	21.4 ± 8.2^{b,c}
≤50 years	9	44.6 ± 5.7	13.7 ± 2.3^{d}
Total	53	53.4 ± 15.4	22.3 ± 8.1

values: one almond (*Quercus brandegeei*) (source of proteins and lipids), four fruits (*Ficus petiolaris*, *Stenocereus thurberi*, *Stenocereus gummosus*, and *Cyrtocarpa edulis*) (source of sugars, fiber, vitamins and minerals), one tea (*Turnera diffusa*) (source of secondary metabolites and minerals), two seasonings (*Capsicum annuum* and *Lippia palmeri*) (source of secondary me-

Table 4. Wild edible plants included in priority groups based on both Food Significance Index (FSI) and Salience Index (SI) values coupled to the selection system based on culinary diversity. * Priority groups were established using the quartile values.

Priority groups (PG)*	Grouping criteria of wild edible plants	
	FSI	SI
PG 1	**Almonds (FSI > 3.26):** *Quercus brandegeei*	**Almonds (SI > 0.366):** *Quercus brandegeei*
	Fruits (FSI > 2.56): *Ficus petiolaris*, *Stenocereus thurberi*, *Stenocereus gummosus*, and *Cyrtocarpa edulis*	**Fruits (SI > 0.593):** *Ficus petiolaris*, *Stenocereus thurberi*, and *Stenocereus gummosus*
	Tea and seasoning (FSI > 2.28): *Turnera diffusa*, *Lippia palmeri*, *Capsicum annuum*	**Tea and seasoning (SI > 0.343):** *Turnera diffusa*
	Vegetables (FSI > 1.88): *Pithecellobium dulce* and *Matelea cordifolia*	**Vegetables (SI > 0.446):** *Pithecellobium dulce* and *Matelea cordifolia*
PG 2	**Almonds (FSI > 2.24 < 3.26):** *Cnidoscolus maculatus*	**Almonds (SI > 0.250 < 0.366):** *Cnidoscolus maculatus*
	Fruits or candy (FSI > 1.73 < 2.56): *Ferocactus townsendianus*, *Diospyros californica*	**Fruits or candy (SI > 0.400 < 0.593):** *Cyrtocarpa edulis*, *Diospyros californica*, and *Ipomoea bracteata*
	Tea and seasoning (FSI > 1.66 < 2.28): No species	**Tea and seasoning (SI > 0.233 < 0.343):** *Lippia palmeri* and *Capsicum annuum*
	Vegetables (FSI > 1.35 < 1.88): No species	**Vegetables (SI > 0.304 < 0.446):** No species
PG 3	**Almonds (FSI > 1.22 < 2.24):** *Quercus tuberculata*	**Almonds (SI > 0.135 < 0.250):** *Quercus tuberculata*
	Fruits or candy (FSI > 0.89 < 1.73): *Pachycereus pecten-aboriginum*, *Ipomoea bracteata*, *Lysiloma microphyllum*.	**Fruits or candy (SI > 0.208 < 0.400):** *Ferocactus townsendianus*, *Pachycereus pecten-aboriginum*, *Cyllindropuntia cholla*, and *Celtis reticulata*
	Tea (FSI > 1.03 < 1.66): *Aloysia barbata*	**Tea (SI > 0.123 < 0.233):** *Aloysia barbata*
	Vegetables (FSI > 0.81 < 1.35): No species	**Vegetables (SI > 0.162 < 0.304):** *Opuntia* spp.

tabolites), and two vegetables (*Pithecellobium dulce* and *Matelea cordifolia*) (source of fiber, vitamins, and minerals) (Table 4). The seeds of *Cnidoscolus maculatus* (Priority Group 2) had higher FSI value than most plant species in the Priority Group 1; however, they are the second choice after those of *Quercus brandegeei*. Foods in Priority Group 3 were diverse; they were the option by scarcity of foods of the Priority Group 1 or 2. For example, the consumption of *Pachycereus pecten-aboriginum* was more important in seasons when fruits of *Stenocereus thurberi* and *S. gummosus* were scarce. The acorns of *Quercus tuberculata* are very known by the ranchers, but this species is distributed only in the highest mountains and is consumed by few people. Another example is *Lysiloma microphyllum*, its gum is highly consumed by ranchers, but they prefer the tastier and more nutritious fruits of the Priority Group 1.

The use of SI values generated a similar pattern of diversity in grouping. The Priority Group 1 included almost the same species, but *Cyrtocarpa edulis*, *Lippia palmeri* and *Capsicum annuum* were moved to Group 2. Moreover, *Cylindropuntia cholla* and *Celtis reticulata* were included in the priority groups and *Lysiloma microphyllum* was excluded.

Discussion

Seeds as cereals and legumes are the staple foods for humanity and they have played a crucial role in human society development (Cordain 1999); almond-like seeds are also important complements and source of proteins and lipophilic nutrients, thus a good Food Significance Index should be able to identify such kind of seeds as important complementary food. Fruits and vegetables play a similar role in diet; both are complements to the staple foods and are the main source of dietary fiber, vitamins and minerals. In our study, fruits showed higher FSI values than vegetables. People usually prefer fruits and their transformation into non-perishable or marketable products (*e.g.* jams, marmalades, dehydrated fruits, juices) is easier. Other authors have also reported higher preference for fruits than for vegetables (do Nascimento *et al*. 2013, Kujawska & Łuczaj 2015).

The FSI and the SI showed moderate differences in the ordered rank of the species. SI was better than the FSI to reflect the preference (*pr*); thus, it was biased towards most popular species, but not always for the best options for food security. For example, seeds showed the highest FSI, but the fruits with the highest citation index (*ci*) were for SI. Seeds are more caloric and non-perishable foods and they could be better for food security; this failure was corrected in the FSI by including the Crop Value (CrV). Moreover, SI values for *Malpighia diversifolia* and *C. reticulata* (0.201–0.287) were similar to those of *Cylindropuntia cholla* and *Cnidoscolus maculatus* (0.294–0.318). The first two are very small fruits consumed only in the field as a candy and they hardly could deal with hunger; this failure was corrected in the FSI by including the food category (*ca*).

The FSI included higher culinary diversity in the higher valuated species than the SI. The first 12 species chosen by the FSI included four fruits, three seeds, two vegetables, two seasoning, and one tea. By contrast, SI only included seven fruits, three vegetables, one seed, and one tea. However, the selection of the most important species (Priority Groups) showed only minor differences among FSI and SI if it was included the culinary diversity system (selection by type of food), instead of a selection using only the rank values of both indices. For example, *Pithecellobium dulce* and *Matelea cordifolia* were the vegetables with the highest FSI values and the only two vegetables with a processed product; however, their FSI were lower than the most popular seeds, fruits and seasonings reported in this study. The exclusion of these species of the priority groups means a lost in the culinary diversity, and they would be excluded based only in the highest values of the index as suggested in previous researches (Joshi *et al*. 2015); for instance, selection of only those with FSI values higher than 3.0. Alike, all seeds were excluded from Priority Group 1 using the SI values. Although, SI is easier to assess, it is recommended FSI because provides more information about the food (*e.g.* role in diet, postharvest shelf life, processed products) and not only its popularity as measured by the SI.

Different results are expected with others indices reported in literature. The Pieroni Food Significance Index (Pieroni 2001) favors the wild green vegetables over other parts of the plants; however, we consider that other factors as the role in the diet or the postharvest shelf life are more important than just the organ that is consumed. For example, a representative green vegetable such spinach or lettuce cannot be more important for food security than those typical seeds used as staple foods (*e.g*. maize, rice, beans); moreover, two different seeds can represent different role in diet and so their importance should vary from a staple food such as chickpea to a complement such as peanut.

Unlike the reported for some indigenous communities (Eyssartier *et al*. 2011, Cruz *et al*. 2013, Sujarwo *et al*. 2014, Narchi *et al*. 2015), knowledge erosion was no observed among the younger and the older male ranchers, at least in the number of species they cited. This result agrees with the reported for a non-indigenous community in Rayones, Nuevo León, Mexico; however, unlike our finding, they found that women cited more species (edible and no edible) than men (Estrada-Castillon *et al*. 2014). A review from European communities shows economic activities such as farming and those involving long walks in nature are closely related with high traditional knowledge in the use of wild edible plants (Łuczaj *et al*. 2012); such activities are very similar to the life style of the Sudcalifornian ranchers and are practiced from an early age, this might explain why younger and older men cited a similar number of plant species.

An outstanding feature of the ranchers was the importance of eating the seeds of oaks (*Quercus* spp.), which does not seem to be important for many indigenous cultures of Mexico (Camou-Guerrero *et al*. 2008, Vázquez-Alonso *et al*. 2014). This custom was like the registered for the rural populations from Spain or Europe (García *et al*. 2014). Acorns were an important food for pre Columbian people from Mesoamerica and California, but today they are considered as secondary or emergency foods (Clarke 1997, Mapes & Basurto 2016, Zizumbo-Villareal *et al*. 2016). The development of this knowledge could be due to the Spanish origin of the missions combined with the hard conditions for agriculture establishment and the scarcity of basic grains. Therefore, they learned about the local source of seeds.

Recommendations for use, conservation, and domestication. *Quercus brandegeei*, *Ficus petiolaris*, *Cyrtocarpa edulis*, and *Pithecellobium dulce* (species in Priority Group 1) are slow-growing trees, and domestication process would be hard and slow. However, considering their food importance several strategies could be established such as: inclusion in local reforestation programs, monitoring the health of trees, determining the best harvesting season, and assessing their productivity. It must be also considered these three species are important for local wildlife. The application of these strategies is particularly important for *Q. brandegeei*, which is endemic to the Cape Region and abundant in the studied area. On the other hand, use and domestication of *Cnidoscolus maculatus* (placed in Priority Group 2) is more feasible because is a perennial herb, endemic and widespread in Baja California Sur state; thus, it could provide greater agronomic facilities and less ecological risk that a slow-growing tree. A similar case is for the vegetables such as *Matelea cordifolia* (Priority Group 1). Moreover, there are some progress about the management and domestication of several species of the genus *Stenocereus* and other Mexican columnar cacti (Casas *et al*. 1999, Parra *et al*. 2012, Pérez-Negrón *et al*. 2014, Pérez-González *et al*. 2015), knowledge that must be the base of integral programs for the sustainable use of *S thurberi* and *S. gummosus*. By contrast, there are many regional studies about the domestication of *Turnera diffusa* and *Capsicum annuum* (Araiza-Lizarde *et al*. 2011) that can be adopted for this area.

There are not nutritional studies about the acorns of *Quercus brandegeei*, the fruits of *Ficus petiolaris*, *Stenocereus thurberi*, *Stenocereus gummosus*, and *Cyrtocarpa edulis*, and the vegetable *Matelea cordifolia*. However, acorns have been reported as moderate source of protein (7.5 mg/100 g) and tocopherols (2–11.2 mg/100 g) (Cantos *et al*. 2003, Kilic *et al*. 2010), whereas domesticated species of *Ficus* (*F. carica*, the common fig) is a good source of dietary fiber and calcium (Morton 1897). In addition, only one preliminary study shows the nutritional composition of the *Cnidoscolus maculatus* seeds (misreported as *C. angustidens*), these are high in proteins (30–36 %) and lipids (26 %) (León-de la Luz *et al*. 1999). By contrast, the *Pithecellobium dulce* arils have been better studied; they are rich source of dietary fiber, vitamin C and phenolic compounds (Pío-León *et al*. 2013).

Accordingly with our discussion and considering their food importance in the studied area, their possible agronomic advantages, and the lack of studies in domestication or nutritional composition, future studies are recommended for the selected priority species and specially for *Cnidoscolus maculatus*, *Stenocereus thurberi*, *S. gummosus*, and *Matelea cordifolia*. *Stenocereus thurberi* and *M. cordofolia* which are widely distributed in the northwestern of Mexico; therefore, any progress in their domestication process might have local and regional impact. Others authors had documented the food importance of *S. thurberi*, and *M. cordifolia* for indigenous communities in the northwestern Mexico (Felger & Moser 1976, Yetman & Van Devender 2002).

Conclusions

The Southern Baja California ranchers showed a good knowledge about the use of wild edible plants, and this was homogenously distributed in 20 to 81 years old men. Although Food Significance Index (FSI) and Salience Index (SI) showed differences, the plant species grouped in the Priority Group 1 were mostly the same when inclusion was decided considering information about culinary diversity. Thus, application of this strategy can improve the results of other ethnobotanical indices. Based on their food importance and potential agronomical facilities, *Stenocereus thurberi*, *S. gummosus*, *Matelea cordifolia*, and *Cnidoscolus maculatus* are the priority species recommended for further studies about composition, biological activities and domestication with the prospective of their future introduction as new crops for the northwestern of Mexico.

Acknowledgements

The authors thank to: José Abelino Cota for helping with field work; Alfonso Medel and Reymundo Cadena from the "Anetta Mary Carter" Herbarium (HCIB), and Jon Rebman (San Diego Natural History Museum) for taxonomic identification of plant material; Alfonso Medel also helped us with edition of Figure 1; inhabitants of the communities who participated in this study for shared their invaluable knowledge. Funding was provided by CONACYT Ciencia Básica Grant 251919, CONACYT-Redes Temáticas Grant 269540. J.F.P.L. is a recipient of a doctoral fellowship from Consejo Nacional de Ciencia y Tecnología (CONACYT grant 229853). The authors acknowledge to Dr. Juan Núñez-Farfán, Dra. Graciela García-Guzmán and two anonymous reviewers all the time and effort devoted to improve an earlier version of this manuscript.

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Received:
April 8th, 2016

Accepted:
July 25th, 2016

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