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ADAPTING A BITE CODING GRID FOR SMALL RUMINANTS BROWSING A DECIDUOUS TROPICAL FOREST

[ADAPTACIÓN DE UNA TABLA DE CODIGOS DE BOCADOS PARA PEQUEÑOS RUMIANTES RAMONEANDO EN UNA SELVA TROPICAL CADUCIFOLIA]

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SUMMARY

The aim of this study was to build a bite coding grid that considers the diversity of plant parts consumed by sheep and goats in the heterogeneous vegetation of a deciduous tropical forest. The architecture of plant species and the form and size of the plant parts consumed by sheep and goats grazing in Yucatán, México (20°52'N, 89°37'W) were recorded. This information was used to create a bite coding grid with 33 bite categories (BC). This new grid was validated using the direct observation method with 3 sheep and 3 goats during the dry and rainy seasons. The coding grid enabled the classification of all the plant architectures consumed (grasses, herbs, leafs of woody mono- and dicotyledoneans, bipinnate leafs and creeper plants) as well as other parts of plants consumed by the animals (round/oblong leafs, elongated leafs, steams, vines, flower, fruits, pods). It also considered the mixture of dry leafs and pods consumed directly from the ground. The size (length) of the BC varied from < 1 cm to up to 20 cm. The new grid incorporated BC specific for the deciduous tropical forest of Yucatán, such as plants with bipinnate leafs, creepers' leafs and vines, as well as fallen pods collected from the ground. Of the 33 BC possible in the new coding grid, 28 and 32 BC were used during dry and rainy seasons respectively. Thus, the adapted bite coding grid can be used together with the direct observation method to investigate feeding behavior of sheep and goats browsing in the tropical forests.

Key words: Feeding behaviour; direct observation; bite categories; sheep; goats; bite categories.

RESUMEN

El objetivo del estudio fue construir una tabla de categorías de bocados que considere la diversidad de partes de plantas consumidas por ovejas y cabras en la vegetación heterogénea de una selva tropical caducifolia. Se registró la arquitectura de las especies de plantas así como la forma y tamaño de las partes de las plantas consumidas por ovejas y cabras pastoreando en Yucatán, México (20°52'N, 89°37'W). La información se utilizó para crear una tabla con 33 categorías de bocados (CB). Esta nueva tabla fue validada usando el método de observación directa con tres ovejas y tres cabras durante las épocas de seca y lluvia. La tabla permitió clasificar todas las arquitecturas de plantas consumidas (pastos, herbáceas, leñosas mono- y dicotiledóneas, hojas bipinada y enredaderas) así como las partes de las plantas consumidas por los animales (hojas de forma oblonga, hojas de forma elongada, tallos, lianas, flores, frutos, vainas). También incluyó la mezcla de hojas secas y vainas consumidas directamente del suelo. El tamaño (largo) de las CB varió desde < 1 cm hasta 20 cm. La nueva tabla incorporó nuevas CB específicas para la selva tropical caducifolia, tales como las hojas bipinadas, hojas y lianas de enredaderas, y vainas colectadas del suelo. De las 33 CB posibles en la nueva tabla, 28 y 32 categorías fueron utlizadas durante la época de sequía y lluvias respectivamente. Por lo tanto, la tabla de códigos de bocados puede ser utilizada junto con el método de observación directa para investigar la conducta de alimentación de ovejas y cabras ramoneando en la selva tropical.

Palabras clave: Comportamiento de ingestión; observación directa; ovejas, cabras; categorías de bocado.

INTRODUCTION

Rangelands are heterogeneous sources of food with multi-stratified distribution of feed resources and seasonal variation in terms of nutritional quality and the quantity of available biomasses (Meuret et al., 1991). Previous exposure to grazing by animals could influence the range of plant species and plant materials that are considered a feed resource (Provenza, 2003). In the case of the low deciduous tropical forests of the Yucatan, the vegetation is composed of more than 260 plant species, including a wide variety of bushes, trees, creepers, climbers, and herbs (Flores et al., 2006). This variability reflects the typical circumstance in which animals are fed. The direct observation of the feeding behaviour is a methodology that was developed and validated for the identification of the feeding behaviour either *in situ* (Reppert, 1960; Neff, 1974; Bourbouze, 1980) or under simulated free grazing conditions (Meuret, 1988). The improved direct observation method developed by Agreil and Meuret (2004) allowed for the continuous observation of the feeding behaviour of sheep and goats. This method has been used for conducting research on feeding behavior and identify the diversity and variability of part plants consumed by ruminants in grasslands and shrubby rangelands (Agreil et al, 2005, Pontes et al, 2010) of temperate regions. Those results showed that small ruminants were capable of adjusting the size of their bites, as well as the plant species they consumed.

The feeding behavior of free grazing animals under tropical conditions is scarce and have focused on preference studies (Becker and Lohrmann, 1992; Kronberg and Malechek, 1997). In the Yucatan, the pioneering work on this topic was developed in the first half of the 1980's for hair sheep (Ortega-Reyes et al., 1985) and for goats (Rios and Riley, 1985). Both studies reported qualitative information for the plants consumed, but lacked quantitative measurements for the ingested plant materials (plant species and plant parts), as well as the size and mass of the bites, which may be used to characterize the harvesting strategies of sheep and goats in this tropical forest. This information is needed for the sustainable management of the vegetation and could also be applied to investigate supplementation strategies adapted to the conditions of the tropical forests of Yucatan. To achieve this, it is essential to adapt a tool for the conditions of the heterogeneous vegetation in the tropical forests. The objective of this study was to build a bite coding grid that considers the diversity of plant parts consumed by sheep and goats in the heterogeneous vegetation of a deciduous tropical forest.

MATERIALS AND METHODS

Study site

The study was conducted in the central zone of Yucatán, 15.5 km South of Mérida, México (20°52' 7.14" N and 89°37' 24.04" W). The prevailing climate is tropical warm sub-humid with summer rainfall (AW_0). The study focused on the vegetation of a low deciduous tropical forest (112 ha) (Flores et al., 2006). The observations were conducted from January to May 2012, and from July to August covering the dry and rainy season.

Plant architecture, plants species, and plant parts consumed

The harvesting behaviour of sheep and goats was observed to determine the plant architectures, plant species, and plant organs consumed during the biting action or collected from the fallen leafs on the ground. Observations were performed over three consecutive days at two different time points during January and February 2012 (four observations points). Observations were performed ten days apart. A flock of 30 sheep and 70 goats was accompanied on their normal grazing circuits, which lasted for four hours. The consumption of all the plant materials was recorded for three sheep and three goats previously habituated to the presence of the human observers. Data was recorded from the different plant materials harvested to obtain information concerning the plant and bite arquitecture:

(i) The architecture of plants. The shape/form of the harvested plants was classified according to the following categories: (a) grasses, (b) herbs, (c) ramified woody plants, (d) woody plants of bipinnate leafs, and (f) climber or creeper plants.

(ii) The botanical identification of the plant materials consumed. The botanical identification of the plants consumed by sheep or goats was conducted by the staff of the herbarium at the Faculty of Veterinary and Animal Science (UADY).

(iii) The architecture of bites. A bite was defined as the material that was harvested with the mouth, either directly from the plants or collected from the floor of the tropical forest. The bites included a variety of harvesting procedures, including: cutting, ripping out, plucking, stripping, or picking up with the animal's mouthparts. The bites varied in size (from the very small leafs removed one by one, to the large branches separated from the plant in a single bite). The definition of a bite did not consider either mastication or deglution. Thus, the architecture of the bites was the form of the materials removed by the biting

action, and is categorised as round or oblong leafs, elongated leafs, steams, vines, leafs with steams, leafs with vines, flowers, leafs and/or steams with flowers, leafs and/or vines with flowers, and pods. The materials were measured (cm) from simulated bites performed on plants similar to those harvested (Wallis De Vries, 1995).

Adapting the bite coding grid for a tropical forest

The information obtained from the preliminary observations on the plant species, the different plant architectures, the architecture of the observed bites, and the range of sizes observed (cm) was used to adapt the coding grid of Agreil and Meuret (2004) for deciduous tropical vegetation. The original version consisted of 41 possible BC, describing (in cm) the part clipped on plants from grasses (12 BC), shrubs and ramified dicotyledonous herbaceous plants (seven BC), tree foliages (eight BC), creeper plants (four BC), flowers (five BC), and fruits (five BC). This coding grid had been used to identify a total of 105 different plant species harvested by sheep and goats in different temperate ecosystems containing shrubby and grassland vegetation (Agreil and Meuret, 2004). Due to the size of the leaves and stems of some tropical plants, such as the bipinnate, it was difficult to estimate the BC at 1 cm of precision. Therefore, the new grid only took into consideration larger sizes ranges (i.e. 1–3 cm) rather than the BC included in the original BC grid (i.e., 1 cm, 2 cm, and 3 cm). The grass plants of different tiller (with few or many stems) were included as one classification only. Therefore, the new grid did not require six BC for grass plants. The shrubs, trees plants, and fallen leafs are included in the same BC. Thus, three BC from the original coding grid were not used. The new grid did not use the eight BC from the original grid to describe flowers and fruits, but rather it considered one BC for flowers and one BC for fruits, since their size is closely related to each plant species, which were always identified during the BC data collection. Finally, nine additional BC were designed to describe materials removed from creepers (two new BC), woody bipinnate plants (six BC), and pods collected from ground (one BC).

Validation of the adapted bite coding grid using sheep and goat in a tropical forest

The improved direct observation of feeding behaviour (Agreil and Meuret, 2004) was implemented in the study site using the new BC and the adapted grid. We used the same flock used during the identification of the plant architectures and plant species harvested. Three sheep and three goats (already familiarised to the constant presence of human observers) were observed from March to May 2012 and from July to August covering the dry and rainy season. For each animal, the feeding behaviour was observed during three consecutive days using the focal sampling technique (Altman, 1974). Behaviour was observed at three different times every day: (i) early morning (7:00–8:20 AM), (ii) mid-morning (8:20–9:40 AM), and (iii) late-morning (9:40–11:10 AM). Animals were observed according to a Latin square design, allowing for observations at different time periods during grazing. The procedure accounted for the heterogeneity of available plants due to grazing area, environmental conditions, and the change of the shepherd. Animals were closely followed while observers registered on audio devices the plant species and the corresponding codes from the adapted BC grid during browsing. Every 10 days, a three day observation period was performed, and a total of four complete days of grazing were recorded for every experimental animal.

RESULTS

Plant architecture, plants species, and plant parts consumed

Thirty-four different plant species were identified as effectively harvested by sheep and goats during the dry and rainy seasons. The leaves of woody and woody bipinnate plants accounted for 42.4% (n = 14) of the plants species harvested, followed by herbs (33.3%; n = 11), creepers (15.2%; n = 5). The grass represented only 9% (n = 3) and 11% (n = 4) of the species harvested in the dry and rainy seasons respectively (Table 1). The architecture of the bites included: round, oblong leafs, bipinnate leafs, elongated leafs, steams, vines, flowers, fruits, pods, and fallen dry leafs consumed from the ground. The size of the harvested materials ranged from less than 1 cm to 20 cm (Table 1).

Description of the adapted BC grid

Figure 1 represent the adapted bite coding grid which consisted of 33 BC descriptors. The description of each BC correspond to the following aspects:

The ideograms. The ellipse schematises the mandible. The circles and straight lines illustrate the leafs and stems. The small triangles connected by a sinuous line schematise the BC for creepers plants. The small, oblong, parallel circles represent the leaves of bipinnate plants.

The columns. From left to right, the first column classifies the harvest, consisting of single rounded or oblong leafs on herbs, woody shrubs and trees, and fallen leafs and creeper plants. The second column classifies the same plants, but for those cases when the bite included more than one leaf and a portion of the stems or branches of plants. The third column classifies the bites on creeper plants when they include leafs and vines. The fourth column classifies the bites of woody plants of bipinnate leafs (steam, leaf, and branch included). The fifth column categorise the bites on leafs and stems of grasses, as well as herbs with straight elongated leafs.

The rows. Every row corresponds to a limited range of bite size depending on the length of the harvested material (not stretched or compressed). The size is indicated in cm at the left of the grid.

The code names of every BC. Mono and bi-syllabic codes placed above the icons identifies every BC. The new grid includes thirty BC codes (five columns and six rows) and three codes that were not associated with a particular size: “flo” identified the harvest of flowers, “fru” was used for the fruits, and “vai-sol” (the only bi-syllabic code) was used for the pods collected from the ground. These three codes could be used as single BC or in addition to the any other BC when the harvesting included more than one of these structures.

These codes were designed to be easy to learn and to dictate after the name of the plant species during the feeding observation of small ruminants. Thus, the first two or three words in the codes correspond to especific columns and to the particular architecture of the leaves, stems, and branches of the plants. The last vowel of the code correspond to the rows and their alphabetical order is determined by the size of the corresponding BC.

Validation of the adapted BC grid for sheep and goat in the tropical forest

Of the 33 BC available in the adapted BC grid, 28 and 32 categories were used during the observations at dry and rainy season (Table 2). The largest number of plant species harvested by sheep and goats in the tropical forest corresponded to the first column of the BC: (a) single rounded or oblong leafs of herbs, (b) leafs of woody shrubs and trees, and (c) leafs of creepers plants. The second column of the grid contained the second most common types of harvested plant parts (steams with leafs). The third most common type of plant parts corresponded to woody bipinnate plants (4th column of the BC). The third and fifth columns of the coding grid were used unfrequently and included a small number of plant species such as vines of creepers (3th column) and grasses (5th column).

Irrespective of season, the BC with highest frequency was oba (n = 28311), followed by obe (n=12712), roba (n = 8651), and robe (n = 5986) BC. The lower frequency corresponded to the obu (n = 66), ro (n = 62), fru (n = 44), and ru (n = 10) (Table 2).

DISCUSSION

Plant architecture, plant species, and plant parts consumed

The wide range of plant architectures (five columns, Table 1), as well as the sizes of bites (six rows, table 1; from less than 1 to 20 cm), corresponded well with the expected variability of materials available for harvesting in the heterogeneous vegetation of the tropical forest. The botanical diversity and the heterogeneous arrangement of the vegetation in multi-stratified levels are characteristic of the vegetation in the tropical deciduous forest (Flores et al., 2006, White and Hood, 2004). Thus, a considerable number of combinations of plant architecture, bite architecture, and size of bites were possible. While the grass plants only provided the elongated leaf form of bite architecture, the herbs, woody bipinnate, and creeper plants provided more types of bite architectures, including round or oblong leafs, steams, vines, flowers, fruits, and pods in a large range of sizes (Table 1). Thus, the adapted grid was flexible enough to be used in a variety of harvest possibilities found in the tropical forests.

The plant species identified in the present study were similar to the plant species harvested by goats in a similar period (from January to May) reported in an earlier study performed in the central zone of Yucatan (Rios and Riley, 1985). These results also suggest that, in spite of the different methodologies employed, both studies were able to identify similar plant species.

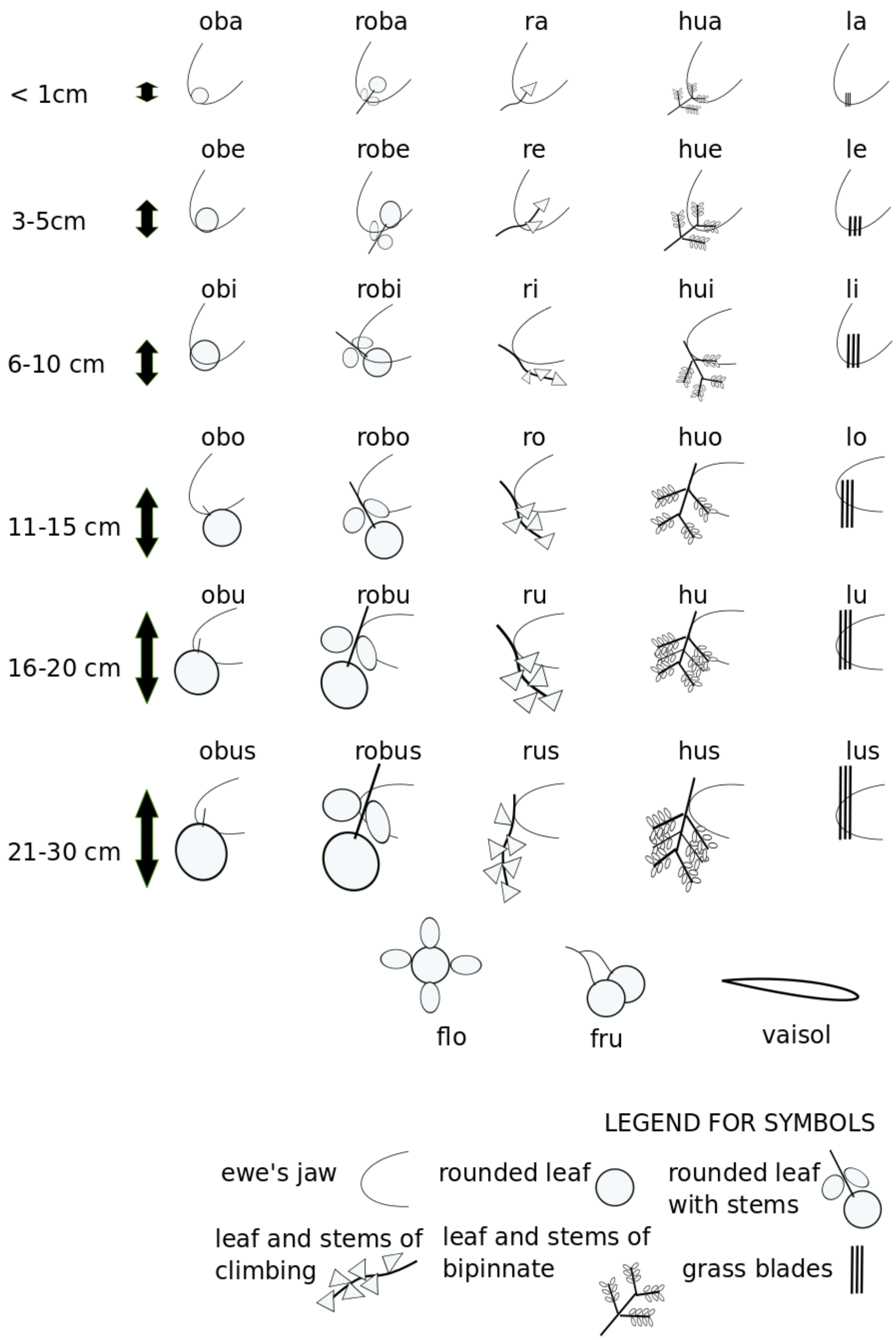

Figure 1. Bites categories (BC) adapted to the deciduous tropical forest vegetation. The codes used during the observation are given above the icons. The length of removed materials is indicated in cm (left of the grid). The BC from left to right (columns 1 to 5) were: (1) when bites included single rounded or oblong leafs (herbs, woody shrubs, trees, and climbers or creepers); (2) the same plants when bites included more than one leaf and a portion of the stem or branch; (3) when bites included climbers and creeper plants with leafs and vines; (4) when bites included woody plants of bipinnate leafs (with steam, leafs, and branches); and (5) when bites included leafs and stems of grass, as well as of herbs of straight, elongated thin leafs. The codes "flo" and "fru" were used to identify the harvest of flowers and fruits, and the code "vai-sol" was used for the fallen pods consumed from the ground. The last three codes could be used as single BC or in addition to the other codes when the bite also included some of these structures.

Table 1. Plant species, plant architecture, and size of the plant organs harvested by sheep and goats obtained from preliminary observations of feeding behaviour during January and February 2012.

Plant species	Plant architecture	Bite architecture							Size of bite
		Round/oblong leaf	Elongated leaf	steam	Vine	flower	fruit	pod	(cm)
Chloris inflata	grass		✔						< 1–10
Eragrostis ciliaris	grass		✔						< 1–20
Eragrostis amabilis	grass		✔						< 1–15
Althernatera flavescens	herb	✔		✔					< 1–5
Blechum pyramidatum	herb	✔		✔					< 1–5
Cnidoscolus aconitifolius	herb	✔		✔					3–20
Bourreria pulchra	herb	✔		✔					< 1–20
Parthenium hysterophorus	herb	✔		✔		✔			< 1–15
Sida acuta	herb	✔		✔					< 1–10
Solanum trydiamum	herb	✔		✔					< 1–20
Viguiera dentata	herb	✔		✔		✔	✔		< 1–20
Waltheria indica	herb	✔		✔		✔			< 1–15
Morinda royoc	herb	✔		✔					< 1–15
Tetramerium nervosum	herb	✔				✔			3–10
Bunchosia swartziana	woody	✔		✔		✔			< 1–20
Caesalpinia gaumeri	woody	✔							< 1–15
Cordia alliodora	woody	✔		✔					< 1–20
Dyospirus anisandra	woody	✔		✔					< 1–15
Gymnopodium floribundum	woody	✔		✔		✔	✔		< 1–20
Neomillspaughia emarginata	woody	✔		✔					< 1–15
Piscida piscipula	woody	✔		✔				✔	< 1–20
Randia aculeata	woody	✔		✔					< 1–15
Acacia collinsi	woody bipinnate	✔							< 1–20
Senegalia gaumeri	woody bipinnate	✔							< 1–10
Acacia pennatula	woody bipinnate	✔						✔	< 1–5
Leucaena leucocephala	woody bipinnate	✔				✔			< 1–20
Lysiloma latisiliquum	woody bipinnate	✔							< 1–20
Mimosa bahamensis	woody bipinnate	✔				✔			< 1–10
Bahuinia divaricate	creeper	✔		✔	✔				< 1–15
Ipomea crinicalyx	creeper	✔		✔	✔	✔			< 1–20
Ipomea nill	creeper	✔		✔	✔	✔			< 1–15
Passiflora foetida	creeper						✔		3–5
Cardiospermum halicacabum L.	creeper	✔		✔					< 1–10
Mix a: mixture of pods of *L. leucocephala, L. latisiliquum, A. pennatula*	woody bipinnate	✔							< 1–15
Mix b : mixture of dry leafs of *C. alliodora, D. anisandra, G. floribundum, P. piscipula*	woody	✔							< 1–15

BC grid adapted to the deciduous tropical forest

Seventeen BC from the grid used by Agreil and Meuret (2004) were not included in the new grid adapted to the conditions of deciduous tropical forests. Nevertheless, those codes could be required to describe the harvest under tall perennial rainforest (e.g. in silvopastoral systems) or areas with trees or conifers (highlands). The large diversity of creepers in the study site required the addition of 2 new BC as well as 6 new BC for the specific bipinnate plants which are endemic for the deciduous tropical forest (Flores et al., 2006). Finally, one BC was added to identify the pods collected from the ground. The latter was frequently observed in the harvest of sheep and goats along the dry season (n = 1505 bites; Table 2).

Validation of the adapted bite coding grid using sheep and goats in a tropical forest

Of the 33 BC from the new grid, 32 were used during the direct observation of feeding behaviour performed on sheep and goats during the dry and rainy season. Although there were a lower number of BC reported in the present trial (n = 33) as compared to the work reported by Agreil and Meuret (2004) (n = 41), the new grid did not require additional codes when it was implemented in the tropical forest. All of the materials consumed by sheep and goats were easily classified using their corresponding BC code (Table 2). Also, the last row of the grid (for BC of very large size; Figure 1) was not used in the dry season (penultimate row; Table 2), but was included since it could be required during the wet season. The materials collected from the ground, such as the mixture of pods and dry leafs, were easy to classify in their corresponding BC during the direct observations.

CONCLUSION

The new bite coding grid adapted for the vegetation of the deciduous tropical forest includes 33 BC, of which nine new BC were added to describe the diversity of the bites observed on creeper plants and the tree leafs from the fabaceae family (legume trees with bipinnate leafs). The adapted BC grid was suitable to identify the plant materials harvested by sheep and goats in the dry and rainy seasons. The grid can be easily used to study the feeding behaviour of sheep and goats using the direct observation method. The plant species harvested by sheep and goats in tropical forests provide include a wide range of materials, such as leafs, steams, vines, flower, fruit, and pods in a large range of sizes. Combinations of these materials and those collected from the ground (i.e. pods and fallen leafs) can also be classified using this grid.

Table 2. Bite categories (BC) used during the direct observation of feeding behaviour performed with the adapted BC grid for sheep and goats. The frequency of the observed bites is indicated in the parenthesis above the BC and the plants species involved are indicated by the numbers.

Bite Size	Single round or oblong leafs	Stems + single rounded or oblong leafs	leafs + vines	bipinnate leafs	Elongated leafs + stems
< 1 cm	**oba** (n= 28311) 4, 5, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21, 29, 30, 31, 33, Mix b	**roba** (n= 8651) 4, 5, 8, 9, 10, 11, 12, 16, 17, 18, 19, 20, 21, Mix b	**ra** (n= 613) 29, 30, 31, 33	**hua** (n= 4001) 22, 23, 24, 25, 26, 27, 28	**la** (n=2922) 1, 2, 3,
3–5 cm	**obe** (n= 12712) 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 29, 30, 31, 33, Mix b	**robe** (n= 5986) 4, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 20, 21, Mix b	**re** (n= 569) 29, 30, 31,	**hue** (n= 2533) 22, 23, 24, 25, 26, 27, 28	**le** (n= 1905) 1, 2, 3,
6–10 cm	**obi** (n= 2718) 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 29, 30, 31, 33, Mix b	**robi** (n= 1784) 8, 9, 11, 12, 13, 16, 17, 18, 20, 21, Mix b	**ri** (n= 210) 29, 30, 31	**hui** (n= 946) 22, 23, 25, 26, 27, 28	**li** (n= 834) 1, 2, 3
11–15 cm	**obo** (n= 813) 7, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21, 29, 30, 31, Mix b	**robo** (n= 971) 6, 7, 8, 11, 12, 16, 17, 18, 20, 21, Mix b	**ro** (n= 62) 30	**huo (**n= 76) 22, 25, 26, 28	**lo** (n= 151) 2, 3
16–20 cm	**obu** (n= 66) 7, 10, 11, 16, 20, 30, Mix b	**robu** (n= 1430) 7, 11, 12, 15, 16, 18, 20, Mix b	**ru** (n= 10) 30	**hu** (n= 215) 22, 25, 26,	**lu** (n= 150) 2
21–30 cm	**obus** (n= 0) 30*, 9*, 19*, 10*	**robus** (n= 0) 30*, 11*, 18*, 11*, 12*	**rus** (n= 0)	**hus** (n= 0) 25*	**lus** (n= 0) 34* 2*
			flo (n= 130) 8, 11, 12, 14, 15, 18, 26, 28, 30, 31	**fru** (n= 44) 18, 32	**vaisol**(n= 1985) 20, 24, Mix a

Grass	**Herbs**	**Woody**	**Woody bipinnate**
1 C. inflata	*4 A. flavescens*	*15 B. swartziana*	*22 A. collinsi*
2 E. ciliaris	*5 B. pyramidatum*	*16 C. alliodora*	*23 S. gaumeri*
3 E. amabilis	*6 C. aconitifolius*	*17 D. anisandra*	*24 A. pennatula*
34 *P. maximum*	*7 B. pulchra*	*18 G. floribundum*	25 *L. leucocephala*
	8 P. hysterophorus	*19 N. emarginata*	
Creepers	*9 S. acuta*	*20 P. piscipula*	*26 L. latisiliquum*
29 B. divaricata	*10 S. trydanum*	*21 R. aculeata*	*27 M. bahamensis*
30 I. crinicalyx	*11 V. dentata*		*28 C. gaumeri*
31 I. Nill	*12 W. indica*	***** Only observed during rainy season	
32 P. foetida	*13 M. royoc*		
33 C. halicacabum	*14 T. nervosum*		

Mix a: mixture of pods of *L. leucocephala, L. latisiliquum,* and *A. pennatula*

Mix b: mixture of dry leafs of *C. alliodora, D. anisandra, G. floribundum,* and *P. piscipula*

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