Oral History Reveals Landscape Ecology in Ecuadorian Amazonia: Time Categories and Ethnobotany among Waorani People[1]

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Oral History Reveals Landscape Ecology in Ecuadorian Amazonia: Time Categories and Ethnobotany among Waorani People. Waorani oral history in Ecuadorian Amazonia reveals that traditional ecological knowledge contributes to the understanding of the natural environment of this human group. When the Waorani interpret the landscape, they identify certain elements that stand out for their cultural and practical value, as these are products of past and present settlements. The oral history and management practices, by two family clusters settled at the riverbanks of the Nushiño River, contributed to assembling an analytical tool called "Waorani time categories." These four time categories were analyzed with floristic composition based on a matrix formed by 522 plant species collected at 12 forest patches, which either had or lacked social history. The aim of this research was to examine how Waorani oral history records the ecological dynamics of some Amazonian forest patches. The use of multivariate statistical methods made establishing differences in plant diversity, evenness, and richness between managed and unmanaged forests plots possible, thus revealing human impact at specific places in Amazonia. This research confirms that it is important to intertwine social history and landscape ecology in ethnobotany with quantitative statistical interpretation, because it permits the association of a human group with a particular forest.

La historia oral revela la ecología del paisaje en la Amazonía ecuatoriana: categorías de tiempo y etnobotánica Waorani. La historia oral de los Waorani en la Amazonía del Ecuador revela que su conocimiento tradicional ecológico aporta a la comprensión de su entorno natural. Los Waorani cuando leen el paisaje identifican ciertos elementos que sobresalen por su valor cultural y uso, porque son producto de asentamientos de ayer y hoy. La historia oral y las prácticas de manejo de dos grupos de familias indígenas asentadas en el río Nushiño contribuyeron para construir una herramienta analítica denominada "categorías de tiempo Waorani". Las cuatro categorías se evaluaron con un análisis de composición florística a partir de una matriz de 522 especies de plantas recolectadas en 12 parcelas de bosque con y sin historia social. El objetivo de esta investigación fue examinar la manera que la historia oral Waorani registra las dinámicas ecológicas de algunas parcelas del bosque amazónico. La utilización de métodos estadísticos multivariados permitió establecer las diferencias que existen en diversidad, equitabilidad y riqueza vegetal entre bosques manejados y no manejados, evidenciando la influencia del impacto humano en ciertos lugares de la Amazonía. La investigación confirma que en etnobotánica es importante imbricar historia social y ecología del paisaje con estadística cuantitativa, porque permite vincular un grupo humano con un determinado bosque.

Key Words: Waorani people, oral history, human management, time category, quantitative ethnobotany, forest plots, Amazonian landscape.

Introduction

A culture is linked to the memory of ancestors who established the extant sociocultural and ecological order in the landscape (Bonnemaison 1981). Oral history is a source of insight for discerning ecological dynamics orchestrated by humans. This

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is true because remembrance of an event is registered in a place within the forest and transmitted from one generation to the next (Basso 1995; Reeve 1988). Memories and cultural values tied to a specific location motivate new visits to this same geographic site, leading to continuous manipulation of the environment. For example, during the fruiting season of the peach palm (*Bactris gasipaes* Kunth) in the Ecuadorian Amazon, Waorani family clusters travel to places where the presence of this palm is attributed to past management by their forebears (Rival 2002:84–86). Additionally, while trekking across the forest, several wild and cultivated plants are recognized by the Waorani and represent material references for evoking the past. Current actions of consuming and managing these plant populations by the Waorani keep their intergenerational relationships alive, reproduce social memory, and promote the growth of plant populations on the landscape.

To describe a mental map for a particular region implies positioning physical elements, as well as ecological and social knowledge, in such a way that it becomes useful to navigate the space of the forest and govern the landscape (Thornton 2008:67). In particular, the Waorani landscape is composed of tangible features: geomorphological and hydrological elements, places with history characterized by anthropogenic floristic compositions, as well as intangible traits expressed as emotions of the remembrance of past social episodes.

Some of the most important landscape elements involved in indigenous mental maps are individual plants and plant populations dispersed in the forest as the result of human management. The presence of certain plant species is indicative of past management practices that relate to historical narratives of itineraries and activities in the forest. This enables the reconstruction of spatial and temporal dimensions in historical ecology through orally transmitted information (Basso 1995; Dean 2009).

For the Amazon region, vegetation structure can be indicative of previous settlements, cultivation sites, and historical events. In Brazil, the cognitive maps of the Kayapó are linked to a system of trails, ancient settlements, and fallows, demarked by Brazil nut trees (*Bertholletia excelsa* Bonpl.) and palm populations (*Attalea speciosa* Mart. ex Spreng., *Euterpe oleracea* Mart., *Oenocarpus bacaba* Mart.) (Posey 2002:200–216). In Ecuador and Venezuela, some Amazonian groups use fruit or palm trees to recognize and delimit a family territory, thus establishing land rights for future generations (Lu 2001; Zent and Zent 2006). As shown by Balée (2013:181–2) the comparison of floristic composition in tropical forests at Malaysia, Africa, and Amazonia that have experienced ancient human management practices can be frequently recognized by the presence of specific indicator species.

The presence of indicator plant species at places with history allows inhabitants to establish continuity between the past and present. As Thornton (2008:22) states, "Although different cultures may conceptualize time in different ways, time is everywhere inseparable from place because it is through temporarily situated interactions with specific locales that culture and individual conceptions of place are formed." For the Waorani, their ancestors inhabited places scattered throughout the forest, and their human activities modified the floristic composition. Current indigenous populations continue to manage and transform plant resources in and around their settlements. The previous considerations can be used as a tool to locate, classify and quantify space within a genealogical framework. Thus, genealogy allows an understanding of the past and present spatial distribution of human settlements according to their alliances and conflicts (Marques 2013:727-8).

Some Waorani people can trace their genealogy up to five (Yost 1981) or six generations in the past. This represents a span of time between one to two hundred years. It is a complex task to corroborate the accuracy of Waorani genealogies (Rival pers. comm. 2014). However, storytelling of historical events and the management of plants at places with social history are an effort by the Waorani to preserve their living past.

The reconstruction of the historical processes of human occupation in the forest by means of oral history presents some challenges, the main one being generation-bound fragmented memory (Alencar 2010:42). Additionally, Balée (1994:131) considers that egalitarian, nonliterate societies have a shortness of historical memory, as is the case for Tupi-Guarani groups. Balée (2013:66) also states that social history is limited to current generations, as they cannot define the original intentionality of their forebears who transformed the characteristics of their environment. Furthermore, reliability of past events is weakened when narrators assess past from present. In this sense, remembering their ancestors' actions in a place collectively builds the social memory of landscape in accordance to their contemporary strategies (Alencar 2010). Although insightful, the former statements on understanding the process of social memory reconstruction inscribed in the landscape cannot be considered as universal, because space and time are uniquely constructed within each culture.

Further studies are necessary concerning the temporal dimension of landscape for a deeper understanding about how local people interpret and learn the transformation of vegetation through time (Zurita Benavides 2014). Therefore, the present study used the content of narratives, the vocabulary of time, and the geographical location of places within the forest to concatenate and understand the succession of time in Waorani social history. The three former factors (i.e., narratives, time vocabulary, and location) allowed for a heuristic reconstruction of "Waorani time categories." This is an analytical tool that was used to place different kinds of stories in chronological order and determine the approximate period of time—represented as distance from the present—in which specific management practices and corresponding patterns of forest transformation occurred.

This *etic* analysis tries to imitate the Waorani conception of time, not in days or years, but in accordance to the local ways of experiencing the succession of events. Thus, "Waorani time categories" are defined by the following four levels: 1) *Titeiri kewënko*, or "the time when tapirs dwelt," refers to stories where animals and supernatural beings had the ability to communicate with humans through language. In Waorani society, mythical stories do not refer to specific places and are ubiquitous along the extension of Waorani territory; 2) *Durani bai*, or "as the ancestors," are narratives of events that took place over six generations ago (i.e., the source person did not experience the event); 3) *Pikenani bai*, or "as the elders," are life histories stretching back to three generations in the past (i.e., the source person may have experienced or observed the event). This time category includes Waorani people over 50 years old, born before the first contact with Western society in 1958; 4) *Ñowene*, or "today," focuses on the pragmatic experiences of members within a family cluster. Time in this category is determined by the lifespan of family members and defines with further accuracy the period of a settlement and/or cultivation site in the forest. These categories were submitted to the Waorani people for validation and authentication (Zurita Benavides 2014).

This research considers landscape elements, and how Waorani interpret them, as evidence to reconstruct social history and infer local historical ecology. The origin of this people is poorly known (Cabodevilla 1994; Rival 2002), and their historical ecological construction of the past remains alive in the present through oral history as well as present subsistence activities (e.g., slash-and-mulch agriculture, hunting, gathering, and fishing). In this context, landscape constitutes an open book for Waorani history. The activities of their forebears are registered in places that describe past events and shape collective memory (Lu 2001; Rival 2002).

Dean (2009) and Reeve (1988) organized the narratives of Amazonian societies from their origins to the present day, and reconstructed oral history in terms of periods. The order of the succession of past events imbricated with historical episodes characterized incidents such as the contact with Europeans or the rubber boom. Instead, in the present research, time categories served to assess the impact of Waorani management practices on the stages of vegetation succession in the Amazonian forest. The interpretation of time is possible when ecology and social history are combined for a particular place, especially because Waorani spatialize time.

By relating local time recognition (i.e., Waorani time categories) and floristic composition, the aim of this research was to examine how Waorani oral history registers the ecological dynamics of some Amazonian forest patches. In other words, to assess the concordance between the time period of the establishment of a settlement or cultivation site according to the Waorani, and the stages of vegetation succession according to the floristic composition. A relationship between the timing of human management and the ecological stage of vegetation succession is expected, meaning that the indigenous time categories should correspond to the observed stage of vegetation succession, evaluated by the analysis of floristic composition. It is also hypothesized that the comparison between managed and unmanaged forest patches will show that human manipulation results in increased plant diversity.

Materials and Methods

Study Area

This study was conducted between March 2011 and February 2013 in two Waorani villages, Dayuno (1°06'03"S; 77°19'31"W) and Tepapare (1°06'33.1"S; 77°15'25.9"W), located along the banks of the Nushiño River, in the Ecuadorian Amazon (Fig. 1). They are accessible by foot or

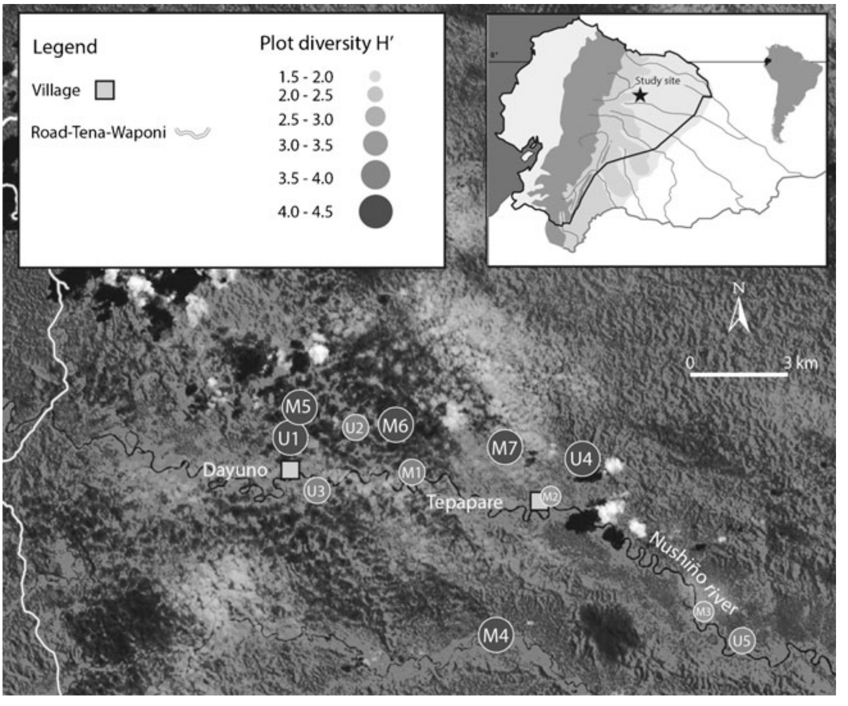

Fig. 1. Location of two villages and 12 forest plots analyzed with the Shannon-Weaver index (H') at the Waorani Ethnic Territory, Ecuadorian Amazon.

canoe, the nearest roads being at 12 km and 25 km, respectively. The elevation varies between 250 and 400 m, and the average precipitation for 2011 was 3,755 mm, with a monthly mean of 270 mm (meteorological information recorded by Jatun Sacha Research Station, Suárez pers. comm. 2013).

Sociopolitical organization in the two villages illustrates Waorani traditional structure. It is based on the family cluster or *nanikabo*, where territory rights were defined two generations previous to the current inhabitants. A cluster represents a residential unit whose members used to live together in a longhouse (Rival 2002:98). Currently at the study sites, village residents are members of a family cluster who live separately in nuclear family houses. The current subdivision of Waorani Ethnic Territory reflects past spatial organization, where toponyms currently serve to legitimize land rights belonging to family clusters (Lu 2001).

Between 1972 and 1990, Dayuno was the second most densely populated Waorani village with 200 inhabitants. It was established around a school and an airstrip (Rival 2002). At that time, the inhabitants of Dayuno used what are currently Tepapare lands for hunting and gathering, while the inhabitants of the latter resided in another place. Currently, Dayuno's population consists of 18 inhabitants, 9 of whom are older than 12 years of age; and Tepapare has 28 inhabitants, 14 of whom are past 12 years old. Ethnohistorical and ethnobotanical information was recorded from the entire elder population, six at Dayuno and ten at Tepapare.

Field research authorization was obtained from the "Asociación de Mujeres Waorani del Ecuador" (AMWAE) and the "Nacionalidad Waorani del Ecuador" (NAWE). Prior verbal informed consent (PIC) was obtained from inhabitants at the two villages, who approved the first author's fieldwork. This research followed the International Society for Ethnobiology's code of ethics (International Society of Ethnobiology 2006).

Places with History at Tepapare and Dayuno, and Floristic Inventory

Between March 2011 and March 2012, Zurita Benavides conducted ten visits to the two Waorani villages, each visit lasting from one to three months. Participant observation was used as a technique to collect data. Spontaneous conversations and narratives, relating to each place, were recorded in the forest and the cultivation sites. In order to triangulate people, history, and landscape, semistructured interviews were conducted in households with the source person who narrated a historical event related to a particular place and with other elders from the villages.

A total of 38 places with history around these villages were recorded with a GPS. At these places, some plant species were assigned to a corresponding management practice, and served as material support to recount a particular Waorani family event. This provided a list of 33 plant species, called "family landmarks" (Table 2).

Between January and February 2013, an ethnobotanical inventory was conducted in fallows previously identified during the establishment of the 38 places with history. The slash-and-mulch agriculture practiced by the Waorani has low impact on the environment; thus, a similar regeneration rate was assumed for both fallows of ancient settlements and cultivation sites. Seven plots were selected in each village representing three time categories: *durani bai* (M5, M6, M7), *pikenani bai* (M3, M4), and *ñowene* (M1, M2) (Table 1). The Waorani who shared their experiences in this study were identified by their peers as the holders of traditional ecological knowledge (TEK). The field guides who participated in the floristic inventory at Tepapare were Cabe Nonge (80 years old), Yewe Ima (60), Guihue Ima (58), and at Dayuno, Dayo Irumenga (60) and Cogui Enomenga (61).

A comparison of floristic diversity was established between seven managed plots (M1–M7), according to Waorani narratives, and five unmanaged plots (U1–U5), that lacked social history and belonged to the time category *titeiri kewënko*. The unmanaged plots were chosen 1 to 2 km apart from managed plots (Fig. 1). As previously explained, time category *titeiri kewënko* or mythical time is ubiquitous in the extension of the ethnic territory; therefore, to compare between places with Waorani social history and those without it, this study adopts *titeiri kewënko* to represent unmanaged forests.

Since previous human groups other than Waorani may have changed the floristic composition of Amazonia, it was not possible to assert that all studied patches of forest had not been disturbed throughout history. Furthermore, the Waorani field guides may not have known or recognized transformations initiated by other human groups. However, in this study, local time categories were reconstructed according to the perceptions and activities of current inhabitants; it is significant that ancestors' activities survive in today's collective memory and management practices.

Waorani who narrated landscape history also selected the 12 plots used in this study, and the resulting narratives allowed the first author to order sites according to the heuristic tool of "Waorani time categories." The inventoried plots were chosen to represent the mosaic of forest across vegetation succession exhibited through Waorani oral history. The stages of vegetation succession were defined as follows: 1) the initial stage was colonized by pioneer plant species; 2) the intermediate stage was secondary forest composed of a set of sun-loving and shade-tolerant plant species; and 3) the advanced stage was

TABLE 1. CHARACTERISTICS OF 12 FOREST PLOTS IN THE WAORANI ETHNIC TERRITORY IN ECUADORIAN AMAZONIA: STAGES OF ECOLOGICAL SUCCESSION, TIME CATEGORIES, AND PLANT DIVERSITY INDEXES.

Plot name	Village	Stages of ecological succession	Waorani time categories	Distance plot–village (km)	Richness	Shannon-Weaver index (H′)	Evenness index (J)
M1	Dayuno	Intermediate	*Ñowene*	6.08	77	3.81	0.88
M2	Tepapare	Initial	*Ñowene*	0.35	58	3.33	0.82
M3	Tepapare	Intermediate	*Pikenani bai*	10.3	65	3.58	0.86
M4	Tepapare	Intermediate	*Pikenani bai*	3.6	86	4.08	0.92
M5	Dayuno	Intermediate	*Durani bai*	2.07	84	4.08	0.92
M6	Dayuno	Advanced	*Durani bai*	3.05	86	4.10	0.93
M7	Tepapare	Advanced	*Durani bai*	3.6	113	4.51	0.95
U1	Dayuno	Unmanaged	*Titeiri kewënko*	1.13	107	4.24	0.91
U2	Dayuno	Unmanaged	*Titeiri kewënko*	2.80	73	3.89	0.91
U3	Dayuno	Unmanaged	*Titeiri kewënko*	1.28	79	3.93	0.90
U4	Tepapare	Unmanaged	*Titeiri kewënko*	2.11	110	4.24	0.90
U5	Tepapare	Unmanaged	*Titeiri kewënko*	13.22	72	3.71	0.87

old-growth forest species (Puig 2001) (Table 1). The Waorani classification of succession stages was not used in this research, as it requires additional effort in the study of *Wao-tererö* linguistics.

The composition of plant communities was determined by botanical inventories carried out in managed and unmanaged plots in a radial sampling pattern of 0.05 ha. This sampling extension was representative of current spatial use by the Waorani, their villages, and peri-domestic area: Teparare and Dayuno occupy 0.13 ha and 0.17 ha, respectively, and cultivation sites range between 0.012–1.0 ha. On each plot, a randomly selected tree served as the central point of reference from where five transects of 50 x 2 m each were traced and sampled for all species of trees and palms with a DBH ≥2.5 cm (Cerón 2003; Gentry 1988).

The identification of plant species was conducted in two phases. First, samples were identified *in situ* by Waorani field guides, assigning the name in *Wao-tererö* and their local uses, followed by the identification of samples by a botanist. Second, a total of 2,580 herbarium specimens were collected, classified, and stored at the Herbarium of the Pontificia Universidad Católica del Ecuador, Quito (QCA), and catalogued as "Zurita Benavides et al." The duplicates were stored at the Herbarium of the Universidad San Francisco de Quito (QUSF) (Appendix 1–ESM [Electronic Supplementary Material]). The collection of botanical specimens was authorized by the "Ministerio del Ambiente del Ecuador" (001-2013-IC-FLO-DPAP-MAE).

The uses of plants were categorized according to the Waorani and compared with those uses recorded in scientific literature on the Ecuadorian Amazon (Cerón and Montalvo 1998; Davis and Yost 1983; Rios et al. 2007). The categories were defined as follows (Appendix 1–ESM): human food (Hf); animal food (nutriment for mammals, birds, and fishes) (Af); construction (houses, posts, and thatch) (C); fuel (F); medicine (cure or alleviate illness and body health care) (M); handicrafts (fibers, vines, barks, and seeds) (Hc); and tools (fishing instruments, oars, spears, and blowguns) (T).

Statistical Analysis

The Shannon-Wiener index (H') with natural logarithm was used to describe inter- and intra-sample diversity of inventoried plots. As a complement, Pielou's evenness index (J, as described by Oksanen et al. 2014) measured equitability or homogeneity. A Bray-Curtis dissimilarity matrix was derived from the original abundance matrix and served as the basis for a clustering analysis after a hierarchical agglomeration procedure by UPGMA.

An interpretation of factor scores along the vectors of the principal component analysis (PCA) on the original abundance matrix allowed the establishment of botanical indicator species (Höft et al. 1999). To reconcile botanical features with the history of each plot, these botanical indicator species were compared to species classified as "family landmarks" (Table 2). The projection of scores for both time categories and species were scaled in proportion to eigenvalues on all PCA dimensions through the use of symmetrical scaling (Qin et al. 2015). Quantitative multivariate statistical analyses were performed with Vegan v. 2.2-0 (Oksanen et al. 2014) in the R environment (R Core Team 2014).

Results

Plant Diversity and Waorani Management

A total of 522 species were observed in the 12 plots, of which 499 were assigned by the Waorani as having at least one use (Appendix 1–ESM). Local plant diversity was noted to increase with the progression of each stage of vegetation succession and time categories, with the exception of the *ñowene* where diversity decreased (Table 1, Fig. 2). There is a correspondence among the indexes H', J, and richness, evidenced by Pearson correlations which are J with H' ($r = 0.94$, $p < 0.01$), H' with richness ($r = 0.94$, $p < 0.01$), and richness with J ($r = 0.76$, $p < 0.01$) (Table 1).

M1 and M2 belong to the *ñowene* category, which is an initial stage of vegetation succession with recent management practices, and are the poorest plots in plant richness, diversity, and evenness. Richness increases in both M3 and M4, which correspond to the *pikenani bai* category (i.e., intermediate stage of vegetation succession), with the latter plot the richer of the two.

Maximum diversity is reached in plots M5, M6, and M7, which are grouped in the *durani bai* category (i.e., advanced stage of vegetation succession; social history in these three plots dates back at least to six generations in the past). The social history of each plot suggests that human management is a determinant of richness and diversity. The comparison between managed and unmanaged plots (i.e., *titeiri kewënko* category) reveals that

TABLE 2. FAMILY LANDMARKS OR PLANT SPECIES ASSOCIATED WITH WAORANI PEOPLE HISTORY IN THE WAORANI ETHNIC TERRITORY IN ECUADORIAN AMAZONIA.

Scientific name	Plant use	% PC 1	% PC 2	% PC 3
Ammandra dasyneura (Burret) Barfod	C, Hf, Af	*	*	*
Artocarpus communis J.R. Forst. & G. Forst.	Hf	3	2	2
Astrocaryum chambira Burret	Hc, Hf, Af	1	2	8
Bactris gasipaes Kunth	Hf, Af, C, Hc, T	7	2	5
Bixa orellana L.	M, F	*	*	*
Carludovica palmata Ruiz & Pav.	C, Af	*	*	*
Citrus maxima (Burm.) Merr.	Hf	3	2	2
Crescentia cujete L.	T	2	1	1
Desmoncus giganteus A.J. Hend.	Hf	*	*	*
Eugenia stipitata McVaugh	Hf	*	*	*
Inga capitata Desv.	Hf, Af	2	26	24
Inga edulis Mart.	Hf, Af	6	1	27
Inga edulis var. *edulis*	Hf, Af	*	*	*
Inga spectabilis (Vahl) Willd.	Hf, Af	2	1	1
Iriartea deltoidea Ruiz & Pav.	C, M, Hc, Af	31	100	100
Lonchocarpus utilis A.C.Sm.	T	*	*	*
Manihot esculenta Crantz	Hf, Af	*	*	*
Mauritia flexuosa L. f.	Hf, Af	*	*	*
Musa sp.	Hf, Af	9	5	6
Ocotea quixos (Lam.) Kosterm.	F	*	*	*
Oenocarpus bataua Mart.	C, Hc, Hf	3	4	16
Olyra latifolia L.	Hc, C	0	9	11
Phytelephas tenuicaulis (Barfod) A.J. Hend.	C, Hf, Af	43	14	21
Pourouma bicolor Mart.	Hf, Af, F	8	2	7
Pourouma bicolor subsp. *bicolor*	Hf, Af, F	2	4	10
Pourouma guianensis Aubl.	Hf, Af	1	17	23
Pourouma minor Benoist	Hf, Af	8	2	7
Solanum sessiliflorum Dunal	Hf, Af	*	*	*
Strychnos darienensis Seem.	T	1	21	33
Theobroma bicolor Bonpl.	Hf, Af	*	*	*
Theobroma speciosum Willd. ex Spreng.	Hf, Af	2	1	1
Theobroma subincanum Mart.	Hf, Af	4	2	1
Theobroma sp.	Hf, Af	*	*	*

* = plant species identified *in situ* during participant observation and mentioned in Waorani oral history or related to an event and were not included in the PCA as they were not present at the inventoried plots.
% PC 1–% PC 3 = relative percentage of projected vector scores on all PCA dimensions.

diversity in the forest tends to increase under the influence of Waorani management.

FLORISTIC SIMILARITY

The cluster analysis provides a measure of correspondence between the similarity of plant communities and plots associated with Waorani time categories. The clustering results depicted in the dendrogram exhibit a separation of plots at the five-cluster solution (Fig. 3). The clusters can be explained by shared characteristics in topography, plant communities, Waorani management practices, and presence of plant species. *Iriartea deltoidea* Ruiz & Pav. is the only species found in all 12 plots, followed by *Matisia oblongifolia* Poepp. & Endl. and *Tetrorchidium macrophyllum* Müll. Arg., both found in 10 plots.

The first cluster includes unmanaged plots U1 and U4, which represent the time category *titeiri kewënko*. Both occur in primary forest located on hills of the interfluvial area (Fig. 1), which is characterized by changes in vegetation along the downhill. The most dominant species in this cluster is the *Heliconia episcopalis* Vell., found most commonly on the edge of hills beside secondary streams. Other abundant species include *Brosimum utile* subsp. *ovatifolium* (Ducke) C.C. Berg, *Warszewiczia*

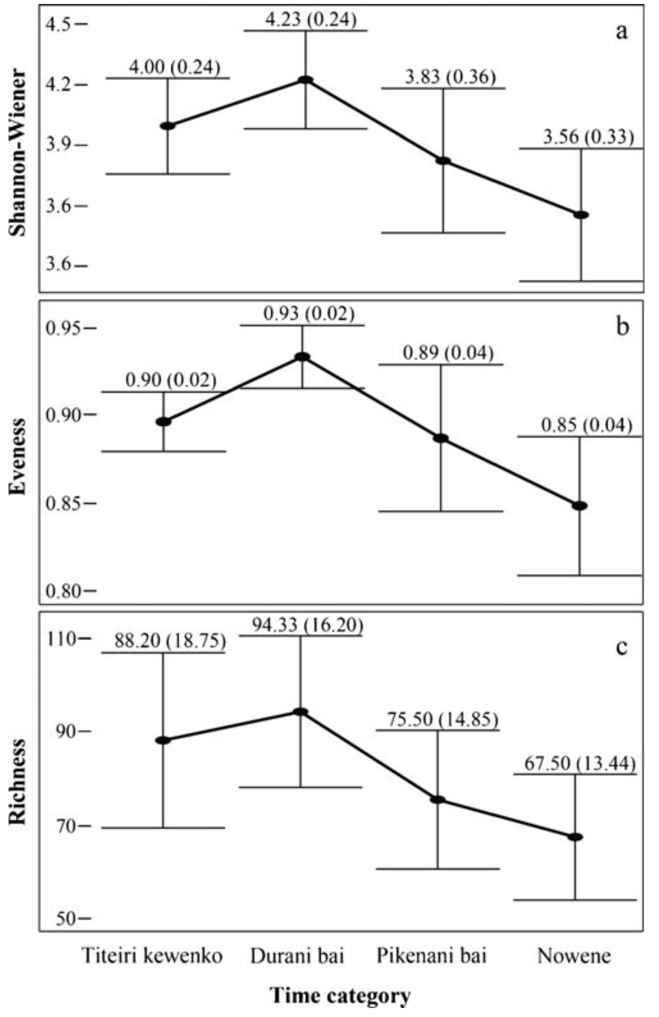

Fig. 2. Plant diversity and Waorani time categories in Ecuadorian Amazon. Black circles represent the mean and bars represent the standard deviation. Values corresponding to mean and standard deviation (in parentheses) are included above bars.

coccinea (Vahl) Klotzsch, and *Himatanthus sucuuba* (Spruce ex Müll. Arg.) Woodson, which occur on summits.

The second cluster is formed by managed plots M2 and M5, corresponding to the time categories *ñowene* and *pikenani bai*. Both are fallows of ancient settlements at Tepapare and Dayuno, and were established 6 and 50 years ago, respectively. The plot M5 had individuals of *Pourouma bicolor* Mart. that were associated with Waorani management dating back to over 6 generations in the past, and their existence has been prolonged to the present. At these two plots the most abundant species are *Sanchezia oblonga* Ruiz & Pav., *Guarea guentheri* Harms, *Brosimum guianense* (Aubl.) Huber, *Pentagonia spathicalix* K. Schum., and *Staphylea occidentalis* Sw.

The third cluster includes managed plot M1 (*ñowene* category) and unmanaged plot U5 (*titeiri kewënko* category), both located at seasonally flooded plains and traversed by hunting paths. The most abundant species are *Urera caracasana* (Jacq.) Gaudich. ex Griseb., *Tetrorchidium macrophyllum, Piper arboreum* Aubl., *P. crassinervium* Kunth, and *Otoba parvifolia* (Markgr.) A.H. Gentry, the presence of which is determined by these hydrogeographic characteristics.

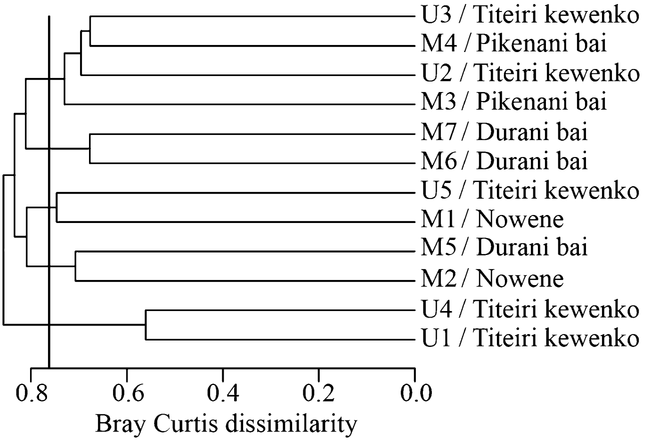

Fig. 3. A dendrogram based on a Bray-Curtis dissimilarity matrix and clustering a total of 12 managed (M) and unmanaged (U) forest plots. The cophenetic correlation coefficient is high ($r = 0.89$) and significant ($p < 0.001$).

The fourth cluster is formed by managed plots M6 and M7, belonging to the time category *durani bai*, dating back to six generations. Both places are situated 3.5 km from the village with management practices often carried out by hunters, gatherers, and fishers. These plots share common characteristics of Waorani management because the ancestors of Tepapare and Dayuno moved cyclically downriver and temporarily settled at these sites. Calabash (*Crescentia cujete* L.) is present at the M6 plot and was mentioned in oral history as the first reproductive tree in Waorani territory. The most abundant species at this cluster are *Pentagonia macrophylla* Benth., *Pseudolmedia laevigata* Trécul, and *Tessmannianthus heterostemon* Markgr., all having definite uses for Waorani people (Appendix 1–ESM).

The last cluster comprises 4 plots M3, M4, U2, and U3. The managed plot M4 and unmanaged plot U3 are relatively more similar in floristic composition than the other two plots in this cluster. M4 was cultivated during the 1970s by a Tepapare family, and the current *Olyra latifolia* L. population is managed for manufacturing quiver. Managed plot M3 (*pikenani bai* category) was also occupied by a Tepapare family 15 years ago and is recognized by the presence of the palm tree *Bactris gasipaes*. Unmanaged plots U2 and U3 (*titeiri kewënko* category) are situated in an interfluvial plain, sporadically inundated and traversed by hunting paths. U3 has a *Dussia tessmannii* Harms tree that produces seeds that attract collared peccary (*Tayassu tajacu*), which further modify understory composition. The similarity among these plots is defined by topography, interfluvial plains, and secondary streams. The most abundant species for this cluster are *Apeiba membranacea* Spruce ex Benth., *Astrocaryum urostachys* Burret, *Inga* sp., *Miconia* sp., and *Phytelephas tenuicaulis* (Barfod) A.J. Hend.

The cluster analysis shows that three of the five clusters are formed due to similarities produced by human management. Hence, clusters of plots influenced by human management activity can be differentiated from clusters with unmanaged plots by their social history and floristic composition. The cluster formed by M2 (*ñowene*) and M5 (*pikenani bai*) represents two consecutive time categories that share common botanical indicator species as evidence of human management. The plots M6 and M7, both belonging to the *durani bai* category, share high diversity and richness, and form a single cluster; this is possibly the result of long-term human management.

Floristic Composition: Structure and Management

The space of the first three principal components displays a distribution pattern of the four "Waorani time categories." The region near the center of the axes is composed of plant species with the lowest variability, and those with the highest abundance are more distant and placed at the extremes of the principal components. PC I is a dimension that distinguishes unmanaged from recently managed forest patches. PC II is important for explaining the role of some family landmarks. Finally, PC III separates intermediate time categories (i.e., *pikenani bai* from *durani bai*).

The original data matrix produces a total of three principal components (PCs), which account for 100% of the variance. The abundance of 22 botanical indicator species differentiates the four time categories, as they characterized each category in terms of their floristic composition (Fig. 4). Among the 22 botanical indicator species there are two important palms, which also are "family landmarks" (Table 2). The presence of *Iriartea deltoidea* and *Phytelephas tenuicaulis* shows a

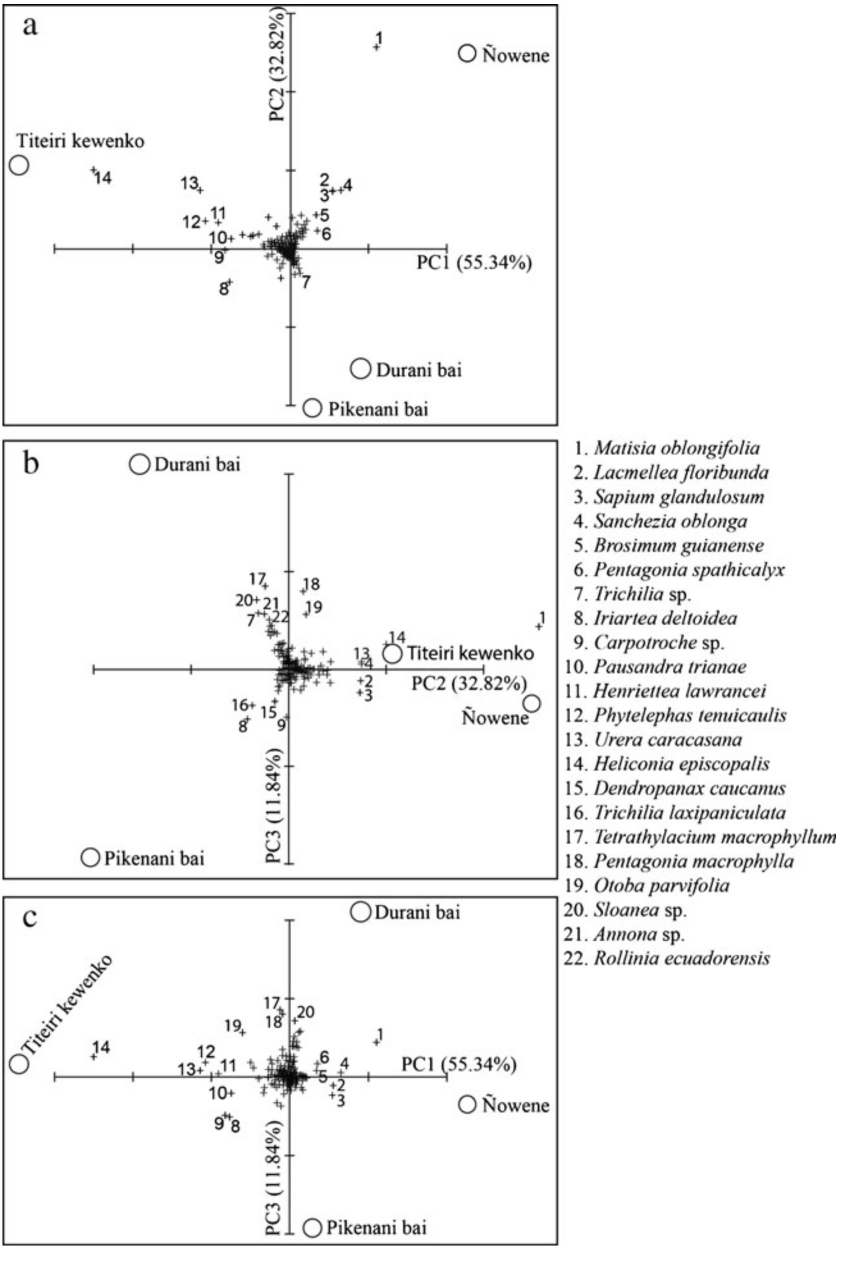

Fig. 4. Space formed by the three first principal components. The biplot displays the plant species pattern of variation for the four time categories in Waorani Ethnic Territory. Both time categories and plant species were projected by symmetrical scaling.

relationship between social history and the Waorani management of plants species.

The first principal component (PC I) represents the effects of management along time. This sharply separates the time category representing unmanaged forests (*titeiri kewënko*) from the most recent time category in managed forests (*ñowene*). It also creates two distinguishable regions, the first consisting of the three time categories of managed forests (*ñowene, pikenani bai* and *durani bai*), and the second containing exclusively unmanaged forest (*titeiri kewënko*) (Fig. 4). The more abundant botanical indicator species on PC1 have multiple uses; for example, *Matisia oblongifolia* and *Phytelephas tenuicaulis* are used as human and animal food and for construction (Appendix 1–ESM). According to oral history, the latter species is also considered an indicator of ancient longhouses.

PC II is the only component highlighting the role of two "family landmarks," *Iriartea deltoidea* and *Phytelephas tenuicaulis*, as abundant species that serve to separate time categories of managed forest patches: *ñowene* from *durani bai* and *pikenani bai* (Fig. 4).

PC III differentiates the time categories *pikenani bai* and *durani bai*, through the abundance of five plant species. Two of these plant species at *pikenani bai* are *Iriartea deltoidea* and *Carpotroche* sp., which are characteristic of secondary forest. The other three at *durani bai* are *Tetrathylacium macrophyllum* Poepp., *Pentagonia macrophylla*, and *Slonea* sp., which are representative of old-growth forest species (Fig. 4c).

Floristic composition in the Waorani Ethnic Reserve has been shaped by both anthropogenic and biophysical factors, and this study provides evidence of the former; PC I reflects the effects of human management. Waorani people, through their daily activities, have dispersed useful plants with cultural value. Thus, the recent transformation of the location of their settlements from the hillside to the riverbanks can be associated to this result. These plants become "family landmarks" in habitats where they are not spontaneously present, and register social history as corroborated by the distribution of both time categories and indicator species in the space formed between PC I and PC III.

Discussion

The correspondence between places with history and floristic composition shows that plant richness and diversity increased with Waorani management. Similarly to other Amazonian peoples, this indigenous group manages the forest as their forebears did (Balée 1994, 2013; Basso 1995; Dean 2009; Posey 2002; Zent and Zent 2006). This is by dispersing useful and symbolic species that subtly create a unique anthropogenic forest patch. Scientists discern these places in Amazonia by the presence of plants that have high use value and become indicator species (Balée 2013:53–69; Posey 2002:200–16).

Similarly to Balée (2010, 2013:53–69), this study shows that Waorani forest management can enhance beta diversity (*durani bai*) above natural alpha diversity (*titeiri kewënko*). Additionally, this research contributes to historical ecology by discerning the time period of first management practices, which established a particular floral composition.

The presence and abundance of certain species suggest that vegetation succession in certain Waorani lands is the product of human management; for example, *Phytelephas tenuicaulis, Iriartea deltoidea, Matisia oblongifolia,* and *Guarea guentheri*, which are present in all time categories. However, their abundance is clearly distinct by category (and by the plots forming them) as shown by vectors in the PCA. The first two species are abundant palms in alluvial plains and slopes of the Ecuadorian Amazon (Montúfar et al. 2013). Moreover, *P. tenuicaulis* is a "family landmark" and their populations occur in ancient longhouses sites. The presence of landmarks enables Waorani to navigate the forest and discern their forbearers' actions. Coupling "family landmarks" with oral narratives allows a reconstruction of social and ecological history, as well as dating landscape periods.

Previous ethnobotanical studies with Waorani people considered them as skilled ecologists because of their thorough understanding of the forest and its natural cycles (Davis and Yost 1983:162). Other research had established ethnobotanical checklists (Cerón and Montalvo 1998; Davis and Yost 1983; Freire Betancout 2006; Macía 2004; Rios et al. 2007). Nevertheless, these former studies do not explain Waorani motivations for forest management.

Davis and Yost (1983) registered 148 useful plant species for the Waorani; of those that could provide food for local populations, there were 44 species of wild plants and 19 species of cultivated plants. This is in concordance with the present research that found human food as the most common cultural use. However, Cerón and Montalvo (1998:22) inventoried 625 useful plant species in a forest plot, where human food was the fifth category of use with 150 species, and the first category was fuel, with 409 species. A contribution made by the current research was to interpret plant uses by considering the social history of family clusters. This was possible because knowledge and management practices are transmitted from one generation to another and it is also influenced by the relationship with other human groups.

Another topic analyzed by some of the preceding studies is about how the Waorani named plants, as it is striking how uniquely each person assigned names to plants (Rival 2009). The plant names embodied the following aspects: 1) ecological information on the phase of growth and fructification (Cerón and Montalvo 1998; Macía 2004); 2) habitat and particular uses and users (Cerón and Montalvo 1998; Davis and Yost 1983); and 3) management practices and practitioners. The three aforementioned aspects were combined by Waorani people to name "family landmarks."

The combination of qualitative and quantitative methods in the present study enabled researchers to interpret the salient motivations behind managing a forest patch, the social history attached to a place, as well as a particular relationship between a person or family cluster with a specific plant. The study of indigenous territories needs to encounter socio-spatial elements, as social life creates places through history and actions (Zent and Zent 2006:92).

Oral history is useful to determine the beginning of forest patch anthropization, however further study is necessary on this topic. Posey (2002:33–41) and Thornton (2008:127–133) reported that local knowledge interprets seasonal calendars. These are more or less regular periods that recur cyclically, having an impact on economic and ritual activities. Marques (2013) reconstructed family histories of *sertanejos* (*sertão* dwellers) at the Northeastern hinterlands (*sertão*) of Brazil, and explained the current spatial configuration of a territory, which was determined by the relationship between friends, kin, and other people. The configuration of space and time at the *sertão* is comparable to what happens nowadays with Waorani people across generation spans.

"Waorani time categories" are a contribution to historical ecology and the anthropology of time. In this sense, Gell (2000:260) distinguished between "time-talk" and "time-use." In oral history, time-talk expresses the local strategies to revitalize or keep the past alive. Time-use is used for the material and immaterial construction of space. In the case of Waorani people, time categories articulate time-talk with time-use when events and actions are organized in a patch of forest, because the presence of palms and trees are evidence of previous human management. Briefly, the time-talk is not enclosed in storytelling but is active in everyday life activities, when ecological knowledge and social history are transmitted.

The Waorani have managed their territory for five (Yost 1981) or six generations in the past (at the least), and this is perceivable by the data analyzed in the present study and recorded at sites in the forest with social history. Examples of these sites are hunting paths, cultivations sites, and peridomestic spaces. The survivorship of this group has been extended to the present by their skills to manage and coexist with natural resources (Davis and Yost 1983; Rival 2002; Yost 1981). This is tangible by how they have contributed to forest diversity as well as plant abundance and richness in their territory.

Conclusions

The present research with Waorani people analyzed their indigenous time periods with quantitative analysis and diversity indexes, which provided evidence of a relationship between Waorani time recognition and stages of vegetation succession. In the Waorani Ethnic Reserve, plant diversity increases with time and management practices. This evolution of the floristic composition through time can be approached with the Waorani time categories.

The profound TEK of Waorani people can be studied through their oral history, which manifests in their interpretation of landscape. This research had validated the "Waorani time categories" as an analytical tool to interpret the anthropic impact on floristic composition. Moreover, the "time categories" and the order of vegetation succession can be organized according to Western science for a deep understanding of Amazonian landscape formation.

The temporal dimension is often dismissed in Amazonian studies, so it is important to couple the occurrence of plant species with indigenous time perception. Although time in oral history is measured qualitatively to reconstruct past events, the latter become tangible when supported by quantitative measures of floristic composition, as time is embedded in the ecological dynamics of the Amazonian forest.

For conservation studies, time should be a fundamental dimension when interpreting environmental changes. This study provides initial insights into how historical ecology can be inferred and assessed. Cultural memory brings back relevant elements from the past, particularly through plants with uses and symbolic value. The present study shows that further research is urgently needed in ethnobotany and anthropology of time, especially in a period of rapid sociocultural transformation and accelerated rates of deforestation. To conserve a cultural forest is to keep the cultural memory of indigenous peoples in their landscape alive.

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