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Are firewood preference behaviors influenced by restrictions in access to vegetation, and can they vary over time?

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ABSTRACT

Studies aim to understand the behavior of human populations when selecting certain groups of plants over others. Some plants are chosen for favorable characteristics that justify specific uses. Thus, individuals may exhibit specialized behavior patterns, selecting plants for fuel based on specific biological traits like ignition potential and durability or generalized behavior patterns, depending on species availability or utilitarian redundancy. However, more is needed to know about how the preference for these resources may be shaped by contexts prohibiting resource use. Prohibiting resource use can compel human groups to devise new selection strategies, leading to significant changes in socioecological system dynamics. Hence, this study aims to investigate how preference for plants used as firewood varies in areas with restricted and unrestricted resource use. We conducted semi-structured interviews in two communities. In the past, participants with restricted access to natural resources exhibited specialist behaviors. However, due to imposed restrictions, the community needed to adopt new usage strategies, resulting in generalized behaviors in the present. The use preference at unrestricted areas varied over time, with individuals being generalists in the past and specialists currently. Based on these behavioral patterns, it is possible to infer that these human groups demonstrate adaptive plasticity to cope with the significant impacts of long-term wood resource extraction.

Keywords: Generalists, specialists, timber resources, changes in landscape, ethnobotany.

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SIGNIFICANCE STATEMENT

Human preference for natural resources is influenced by contexts prohibiting using forest resources. This prohibition can lead human groups to create new selection strategies, generating significant changes in the dynamics of local socioecological systems. This study investigated the variation in preference behaviors for plants used as firewood in areas with restricted and unrestricted resource use. We found that these contexts serve as potent mediators of behavioral changes and adaptive strategies in the selection and preference of woody species. Our results enable a deeper understanding of how preferences become indicators to measure the impact of resource extraction and explore the behavior of communities near protected areas in the face of restrictive measures.

INTRODUCTION

Firewood has been considered an important source of fuel for several human populations, especially in developing countries (Tabuti et al. 2003; Top et al. 2004; Ramos et al. 2008; Ramos and Albuquerque 2012; Silva et al. 2019). Considering the importance of wood resources for people's subsistence, it is essential to know the behaviors related to the selection of species used for this purpose. Studies on these relationships demonstrate that human communities tend to select plants because they perceive the presence of characteristics that are more appropriate for the different functions that these resources have within socioecological systems and are treated in ethnobiological literature as behavioral patterns of preference (see Ramos et al. 2008; Medeiros et al. 2012; Ramos and Albuquerque 2012; Silva et al. 2019; Hora et al. 2021).

These behavior patterns can be specialists when people select plants for fuel purposes based on the perception of biological characteristics that are intrinsic to the species, such as ignition potential and ember durability (See Ramos et al. 2008; Medeiros et al. 2012; Nascimento et al. 2019; Hora et al. 2021). On the other hand, they can be a generalist when resource selection is based on the perception of the ecological availability of species that are used for fuel purposes (Ramos et al. 2008; Medeiros et al. 2012), or people may prefer species also used for other purposes, that is, redundant species (Tabuti et al. 2003; Top et al. 2004; Hora et al. 2021).

The classification of human behavioral patterns related to the preference of species for fuel purposes is an analogy to the behaviors already described by Ricklefs (1996) concerning the foraging of resources carried out by other animals. According to this author, animals with specialist behavior present a more complex and specific resource selection process, prioritizing quality and biological characteristics. On the other hand, animals with generalist behavior can select a greater diversity of resources (e.g., food) without these presenting specific biological characteristics, which may occur, depending on their availability.

In the case of humans, understanding behavioral patterns of preference for natural resources is critical, as it has direct implications for biodiversity conservation. These studies are important in scenarios of restricted access to forest areas when human populations are near Conservation Units and depend on forest resources for subsistence. Some studies show that forest resources in these areas continue being used by surrounding populations, mainly when the populations are low-income (Campos et al. 2015), demonstrating that the behavioral pattern of preference can remain stable over time.

Since the availability of forest resources in Conservation Units remains more constant than in areas of common use, the people conditioned to this regime assume the risks of carrying out a prohibited activity when collecting forest resources. Cognitive and cultural processes can lead to adopting strategies to maximize benefits (see assumptions from the Social-Ecological Theory of Maximization in Albuquerque et al. 2019). This maximization can be reflected in the specialist behavior of preference for wood species used as fuel since the risk of collection would be "compensated" by the quality of the foraged resource (Madubansi and Shackleton 2007).

In areas of common use, where extraction of natural resources does not have any restrictions, we believe that human groups can initially select species based on their intrinsic biological characteristics. However, over time, the scarcity of these species can force people to adopt collection strategies based on species availability. According to the theory of the Tragedy of the Commons, proposed by Hardin (1968), the scarcity of resources in areas of common use occurs at an accelerated rate, as there is no limitation on their use and behaviors tend to be selfish. Thus, we can speculate that people would initially behave expertly, focusing on foraging plants with specific biological characteristics, such as better fuel potential and a posteriori; with the scarcity of these resources, people would prefer the more easily found collection locations. Therefore, the species that would have a greater chance of being collected and included in the biocultural system would be those more "apparent", that is, the species that would be most available and abundant in the environment (Albuquerque 2006).

Given the above, the study sought to answer the following question: do local preference behaviors for plants used for fuel vary in the context of prohibiting the use of resources over time? To answer this question, we tried to test two hypotheses: a) In the community using protected forest resources, local preference behaviors for plants used as firewood do not vary over time. We expect that preference behaviors are specialists in the past and the present; b) In the community that uses forest resources in an unprotected area, the behaviors of preferences for plants used as firewood vary over time. We expect that in the past, the behaviors were specialists, and, in the present, the preference behaviors were generalists.

MATERIAL AND METHODS

Study area

The study was conducted in two rural communities (Figure 1) belonging to two distinct counties in Alagoas and Pernambuco. The community Serrote do Amparo is in Santana of Ipanema County. It is classified as a community with vegetation of common use since it is not within any conservation unit (CU) and has a history of extracting woody resources. The second area is the Serra Grande community, belonging to the municipality of Lagoa do Ouro, PE, and is located surrounding the Pedra Talhada Biological Reserve, established on May 20, 1992, by decree N°. 528. In this type of CU, the use of natural resources is prohibited; however, Porfírio et al. (2020) reports that the area has a history of forest resource extraction, mainly timber, which was fundamental in choosing the community.

Serra Grande Community – Pernambuco

This rural community is located around the Biological Reserve of Pedra Talhada (RBPT) in Lagoa do Ouro, Pernambuco. According to the 2021 census, this municipality encompasses an area of 198.762 km^2 and has 13,300 inhabitants. The community's population density is 61.04 per km^2 in the county territory (IBGE 2021).

The region has a bumpy topography, with 70% being wavy to mountainous, and in some parts, the landform is flat and lightly wavy. It is characterized by a tropical rainy climate with two well-defined seasons: a dry summer (October to April) and a rainy winter (May to September). The average annual rainfall is 1,250 to 1,500 mm, and average annual temperatures are around 25°C.

The area of the biological reserve is a fragment of the Mata Atlântica (Atlantic Forest) in high-altitude swamp conditions, located on top of the Borborema highlands, on steep land above 800 meters in altitude in the states of Pernambuco and Alagoas, specifically in the cities in Lagoa do Ouro, PE, Correntes, PE and Quebrangulo, AL (Porfírio et al. 2020). It was created on May 20, 1992, by Decree N°. 528.

The Pedra Talhada Biological Reserve (RBPT) forest is classified as a montane swamp, characterized as an ombrophilous forest composed of numerous taxa typical of humid regions, both endemic and common to the Amazon Rainforest. At first glance, the RBPT appears composed of dense and uniform vegetation. However, in reality, it does not exhibit the characteristics of a homogeneous forest. On the contrary, it juxtaposes various biotopes, ranging from shrubs to trees, occupying various ecological niches.

Its biodiversity is remarkable, with some species found in several or all vegetation units. For example, the Camboatã (*Cupania impressinervia* Acev. Rodr., Sapindaceae), and the Murici (*Byrsonima sericea* DC, Malpighiaceae).

The community of Serra Grande has a total of 50 resident families and one municipal school for students from kindergarten through elementary years. The community has religious temples (Catholic Church and Assembly of God). We found that the activities of extraction and use of woody resources by residents of the Serra Grande community took place for many years before the implementation of the RBPT, and the main source of income is the sale of native species to small and medium businesses.

Regarding the history of forest resource utilization, reports described by Porfírio et al. (2020) demonstrate that the RBPT has undergone periods of intense exploitation of natural resources, facing challenges and difficulties until its legalization. The attractive attributes of biodiversity in the region attracted loggers and hunters responsible for exploiting flora and fauna.

In this study, as highlighted by Porfírio et al. (2020), observations made by residents near the Reserve indicated a 90% reduction in deforestation. This means that the area is no longer significantly affected by this process, and the remaining cases occur less frequently. Previously, people used to extract large quantities of wood from the forest for sale, but now illegal deforestation is carried out through clandestine trails using ox-drawn carts. This wood is used by residents or from the region in their daily activities, such as building roofs, obtaining firewood, and building enclosures.

Currently, the community survives from subsistence agriculture and the commercialization of tubers, especially sweet potato. Its average monthly income is one minimum wage salary. In the past, the community only used wood stoves to cook food. Currently, the community uses liquefied petroleum gas (LPG)

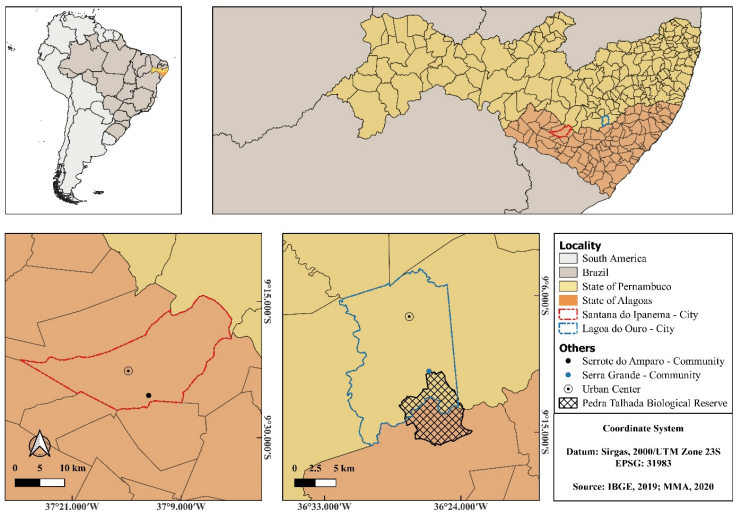

Figure 1. Representation of the geographic locations of the research communities distributed in the states of Alagoas and Pernambuco.

stoves in most of its homes and firewood for cooking food.

Serrote do Amparo Community – Alagoas

The rural community Serrote do Amparo (Figure 1) is in the municipality of Santana do Ipanema, state of Alagoas. This municipality extends over 473.9 km^2 and has a population of 47,910, according to the 2021 Census. The demographic density is 102.7 inhabitants per km^2 in the municipal territory. This municipality has an average annual temperature of 25.2°C, with an average annual rainfall of 110mm. Situated 272 meters in altitude, Santana do Ipanema has the following geographical coordinates: Latitude: 9°21'49" South, Longitude: 37°14'55" West. A dry tropical climate characterizes the region; the summer is long from October to March, and winter is from April to September. Throughout the year, the weather is muggy and windy. In general, the temperature varies from 18°C to 36°C and is rarely below 16°C or above 38°C (IBGE 2021).

The region where the Serrote does Amparo community is located is classified as hypoxerophytic caatinga. It is characterized by species resistant to long periods of drought and adapted to high temperatures and water deficit. Its biodiversity includes a variety of species, ranging from shrubs to trees, occupying diverse ecological niches (IBGE 2021).

The species diversity is remarkable, with some found throughout the vegetation extent. For example, the Catingueira (*Cenostigma pyramidalis* (Tul.) Gagnon G.P. Lewis, Fabaceae), the Marmeleiro (*Croton macrobothrys* Baill, Euphorbiaceae), and the Braúna (*Schinopsis brasiliensis* Engl, Anacardiaceae) are native species of the ecosystem. An important characteristic of the region is the presence of the invasive species Algaroba (*Prosopis juliflora* (Sw.) DC, Fabaceae), which has favorable characteristics for various uses, including fodder (Pinto et al. 2020).

Regarding the history of forest resource utilization, reports from residents demonstrate that extraction and use of woody resources have been occurring since the beginning of the urbanization process and implementation of fixed dwellings in the area, starting in 1970 (when the exclusive use of wood stoves was common), and establishing itself over the decades. Currently, the community primarily uses liquefied petroleum gas (LPG) stoves in most residences, occasionally using firewood for cooking. The community primarily survives through subsistence agriculture and domestic animal husbandry, such as cattle, poultry, goats, and pigs.

The community has a municipal school serving 329 students at all levels of education and a public health center that provided logistical and informational support for the research conducted in the area. With 60 local families, the average monthly income of residents in the Serrote do Amparo community is one minimum wage.

Ethical and legal aspects of informant selection

Initially, the project was submitted and approved by the Research Ethics Committee (CEP) from the

Universidade Federal Rural de Pernambuco (UFRPE) in the *Plataforma Brasil* the *Comissão Nacional de Ética em Pesquisa* (CONEP) under the registration number CAAE: 58914021.1.0000.9547. It was also submitted to the *Sistema de Autorização e Informação em Biodiversidade* (SISBIO), in order to obtain the licenses required to conduct this research. The first contact with the communities was made through periodic visits, conducting door-to-door conversations accompanied by the local health agent. The justifications, objectives, and contributions to the research were presented to the community on this occasion. All the heads of household (male or female) aged 18 or over and residents of communities who accepted to participate in the research signed the Free and Informed Consent Form (TCLE), which authorizes the collection, use, and publication of information obtained during the interviews (Resolution N°. 466 in 2012, National Council in Health).

Informant profiles

Semi-structured interviews were conducted to collect data regarding the use and extraction of woody resources throughout time (Albuquerque et al. 2014a).

A total of 36 interviews were conducted with heads of households aged over 18 years in the Serra Grande community. This corresponds to 72% of the total sample, which consists of 50 families who agreed to participate in the research and signed the Free and Informed Form (TCLE). There were 14 refusals, possibly due to the ban on natural resource use in the region, which is protected by law. Of those interviewed, 27 (75%) were women between 25 and 85 years old, while 9 (25%) were men between 28 and 76 years old.

27 semi-structured interviews were conducted with heads of families aged over 18 years in the community of Serrote do Amparo. This represents 45% of the families (60) who agreed to participate in the research and signed the Free and Informed Consent Form (TCLE). There were 16 refusals, and 17 residences were empty during the visits, making participation in the research impossible. Of the informants, 15 (55.5%) were women between 25 and 74 years old, while 12 (44.5%) were men between 29 and 74 years old.

Data collection

Semi-structured interviews

The semi-structured interviews were divided into two stages: the first stage aimed to obtain socioeconomic information, such as name, gender, number of residents in the household, age, education, and income. In the second part of the interview, participants were invited to provide information through a free list (Albuquerque et al. 2014b).

At the beginning of this study, we emphasized the importance of understanding local communities' knowledge of wood species used as firewood. Thus, we adopted the method proposed by Silva et al. (2019). This method considers the degree of knowledge on woody plants obtained through free lists, divided into three groups: a) known plants, which make up the informants' general knowledge about firewood; b) plants used (past and present), which are the species present in the list of known plants that the informants use; and c) preferred plants (past and present), which are the plants chosen by the informants due to their unique chemical/physical characteristics and favorable ecological characteristics, such as a greater abundance in the collection sites to the detriment of other species.

At this interview stage, participants were asked to provide a free list of plant species used as firewood, using the question: "What plants do you know that can be used as firewood?" to obtain greater species diversity. Then, the informants were asked to identify which of the species known to them were effectively used in the past (defined as the initial period of extraction and use of resources, individual for each informant) and which were used in the present (representing the current year).

After collecting information on species used during different periods, respondents were asked about their preferences for previously identified species that were "effectively used" in both the past and present. They were asked to explain their preferences, indicating the quality criteria that influenced them. These criteria were represented by variables of ecological availability, such as perception of abundance, and intrinsic biological quality, such as fire ignition potential and ember durability, as described in Ramos et al. (2008), Medeiros et al. (2012) and Hora et al. (2021).

All botanical materials cited by interviewees in the Serra Grande community (restricted area) were identified using the floral biodiversity inventory of the Pedra Talhada Biological Reserve – RBPT, published by Studer et al. (2015), in addition to the use of material identification by REFLORA (available at: `reflora.jbrj.gov.br`). The botanical materials cited by Serrote do Amparo community residents were collected and deposited in the herbarium of *IMA/AL – Instituto do Meio Ambiente de Alagoas*. Botanical materials not identified due to the absence of floral material were identified by their vernacular name, using *REFLORA* (available at `reflora.jbrj.gov.br`).

Direct observation

This method fosters community engagement, albeit without requiring the same level of immersion as the "participant observation" method (Albuquerque et al. 2014b). The selection of this approach stemmed from the need to comprehend the qualitative and behavioral aspects occurring during interviews and interactions with participants, aspects often overlooked during quantitative data collection (Albuquerque et al. 2014b). It enabled us to conduct direct observations with the participants, gaining detailed insights into their routines and activities. The aim was to mitigate biases inherent in research addressing sensitive topics, such as, in this specific case, the use of firewood in various prohibition and usage contexts.

Classification of preference behaviors

We adopted the ethical definitions proposed by Medeiros et al. (2012) and Hora et al. (2021) to classify preference behaviors while also considering the emic classifications and perceptions that motivated these behaviors. In this regard, we analyzed the following justifications for each behavior: a) specialist, which is based on criteria related to intrinsic biological factors perceived in the species, such as rapid ignition, low levels of spark and smoke, long-lasting fire, and ember production (Ramos et al. 2008; Hora et al. 2021); b) generalist, which takes into account environmental factors as justifications for preference, such as the perception of abundance and resource availability, including abundant availability or the only viable option for use (Medeiros et al. 2012; Hora et al. 2021).

Defining time frames

The data related to the time frames of extraction of species used as fuel were recorded on an annual scale, considering the initial extraction activity done by the individual until the present day. These data were collected individually, and each head of the household was interviewed. The years mentioned were divided into two groups, considering the individual nature of the data, called "past" (initial year of collection of resources for fuel purposes by the individual) and "present" (current year). The objective was to obtain continuous data on forest resource use.

Data Analysis

The dataset underwent statistical analysis using the R Studio software, aimed at empirically investigating and verifying the two hypotheses proposed in the study. The statistical test Generalized Linear Mixed Models (GLMM) was used with a binomial effect. We sought to understand the variation trend of preference behaviors, the dependent variable, on woody resources used for firewood over time (timeframes), an independent variable, and type of use restriction (restricted and non-restricted areas), an independent variable. Furthermore, an analysis of variance (ANOVA) was performed to compare the variances between citation means of each preference behavior mentioned by the informants in their respective timeframes (past and present).

RESULTS

Species used and preferred for firewood

In the community with restricted access to forest resources, 61 citations of species effectively used as firewood in the past were registered, of which 25 species were mentioned as preferred for firewood (Table 1). Currently, the richness of used species has decreased, with a total of only 17 species (Table 1). Of these, three species were mentioned as preferred for firewood. It is important to emphasize the emergence of coal as fuel for cooking in the present, a fact not present in the snapshot of the past.

In the community with areas of common use, we recorded a total of 19 species cited as firewood in the past, of which a total of 8 species were classified as preferred in the past (Table **??**). There is a decrease in the richness of used species, with a total of only nine species used. Of these, a total of 6 species were mentioned as preferred for firewood (Table **??**).

Table 1. Species cited as used and preferred in both time frames by the residents from the Serra Grande community in the restricted use area, Lagoa do Ouro, PE.

Common name	Scientific name	Family	Used		Preference	
			Past	Present	Past	Present
Açoita Cavalo	*Luehea ochrophylla* Mart	Malvaceae	1	-	1	-
Aroeira	*Schinopsis brasiliensis* Engl	Anacardiaceae	2	-	1	-
Azeitona	Unidentified	Unidentified	1	1	-	-
Bafo de boi	*Couepia impressa* Prance	Chrysobalanaceae	1	-	-	-
Banana de papagaio	*Himatanthus bracteatus* A. DC. Woodson	Apocynaceae	3	-	-	-
Batinga	*Marlierea eugenioides* Cambess. D. Legrand	Myrtaceae	1	-	-	-
Braúna	Unidentified	Unidentified	1	-	1	-
Burra Leiteira	Unidentified	Unidentified	1	-	-	-
Caboatã	*Cupania impressinervia* Acev.-Rodr	Sapindaceae	5	-	1	-
Cachão	Unidentified	Unidentified	1	-	-	-
Cajueiro	Unidentified	Unidentified	4	1	1	-
Catingueira	Unidentified	Unidentified	1	-	1	-
Coentro	Unidentified	Unidentified	2	-	1	-
Canzenzo	*Albizia polycephala* (Benth.) Killip ex Record	Fabaceae	4	1	2	-
Cupiúva	*Tapirira guianensis* Aubl.	Anacardiaceae	1	-	-	-
Enxudia	*Swartzia macrostachya* Benth. var. *Macrostachya*	Fabaceae	-	-	-	-
Favinha	*Stryphnodendron pulcherrimum* (Willd.) Hochr	Fabaceae	1	-	1	-
Furta-cor	*Colubrina glandulosa* subsp. *reitzii* (M. C. Johnst.) Borhidi	Rhamnaceae	1	-	1	-
Gabiroba	Unidentified	Unidentified	1	1	-	-
Gupiuba	Unidentified	Unidentified	1	-	-	-
Imbaúba	*Cecropia palmata* Willd.	Urticaceae	1	-	-	-
Jaqueira	*Artocarpus heterophyllus* Lam	Moraceae	2	-	-	-
Jaqueira da Mata	Unidentified	Unidentified	1	-	1	-
Jatobá	*Hymenaea courbaril* L	Fabaceae	1	-	-	-
Jucá	Unidentified	Unidentified	1	-	1	-
Jurema	*Mimosa tenuiflora* (Willd.) Poir.	Fabaceae	9	23	5	23
Laque	Unidentified	Unidentified	1	-	1	-
Laranjinha	*Zanthoxylum rhoifolium* Lam	Rutaceae	1	-	1	-
Lenha seca	Unidentified	Unidentified	2	2	-	-
Louro	*Pleurothyrium undulatum* (Meisn.) Rohwer	Lauraceae	1	-	-	-
Marmeleiro	*Croton macrobothrys* Bail	Euphorbiaceae	1	-	1	-
Mangueira	Unidentified	Unidentified	3	1	-	-
Mororó	*Bauhinia forficata* Link	Fabaceae	2	-	2	-

Mulungu	*Erythrina velutina* Willd	Fabaceae	1	-	-	-
Murici	*Byrsonima sericea* DC	Malpighiaceae	19	1	22	1
Pau D'arco amarelo	*Tabebuia aurea* (Silva Manso) Benth. & Hook. f. ex S. Moore	Bignoniaceae	1	-	-	-
Pau D'arco roxo	Unidentified	Unidentified	1	-	-	-
Pau Pombo	Unidentified	Unidentified	4	-	1	-
Pau-ferro	*Libidibia ferrea* var. *leiostachya* (Benth.) L. P. Queiroz	Fabaceae	1	-	1	-
Pindaiba	*Xylopia sericea* A. St.Hil	Annonaceae	1	-	-	-
Piranha	*Guapira graciliflora* (Mart. ex Schmidt) Lundell	Nyctaginaceae	6	2	2	1
Pitomba	*Cupania racemosa* (Vell.) Radlk.	Sapindaceae	2	-	-	-
Pororó	*Clusia paralicola* G. Mariz	Clusiaceae	1	-	-	-
Pororoca	*Clusia nemorosa* G. Mey	Clusiaceae	9	-	3	-
Praíba	*Simarouba amara* Aubl	Simaroubaceae	1	-	-	-
Quaiera	Unidentified	Unidentified	2	-		-
Sambacuin	*Schefflera morototoni* (Aubl.) Maguire	Araliaceae	1	-	-	-
Sapucarana	*Lecythis lurida* (Miers) S.A. Mori	Lecythidaceae	1	-	-	-
Sucupira	*Bowdichia virgilioides* Kunth	Fabaceae	5	2	-	-

Legend: "family" – Botanical family; "Past and present" – Time frame; "Used" – Species effectively used in specific time frame; "Preference" – Species effectively preferred in specific time frame.

Table 2. Species cited as used and preferred in both time frames by residents from the Serrote do Amparo community in a common-use area, Santana do Ipanema, AL.

Common name	Scientific name	Family	Used		Preference	
			Past	Present	Past	Present
Algaroba	*Prosopis juliflora* (Sw.) DC	Fabaceae	20	11	18	9
Angico	*Anadenanthera macrocarpa* (Benth.) Brenan	Fabaceae	6	3	1	-
Aroeira	*Astronium urundeuva* (M.Allemão) Engl	Anacardiaceae	1	-	-	-
Avéloz	Unidentified	Unidentified	2	1	-	-
Braúna	*Schinopsis brasiliensis* Engl	Anacardiaceae	2	-	-	-
Cajueiro	*Anacardium occidentale* L	Anacardiaceae	3	-	-	-
Catingueira	*Cenostigma pyramidalis* (Tul.) Gagnon & G.P.Lewis	Fabaceae	26	17	25	18
Craibeira	*Tabebuia aurea* (Manso) Benth. & Hook. f. ex S. Moore	Bignoniaceae	1	-	-	-
Espinheiro	*Piptadenia retusa* (Jacq.) P.G.Ribeiro, Seigler & Ebinger	Fabaceae	11	4	2	1
Goiabeira	*Psidium guajava* L	Myrtaceae	1	-	-	-
Juazeiro	*Sarcomphalus joazeiro* (Mart.) Hauenschild	Rhamnaceae	9	5	8	2
Jurema	*Mimosa tenuiflora* (Willd.) Poir	Fabaceae	21	10	20	5
Labirinto	Unidentified	Unidentified	2	-	-	-
Maçaranduba	Unidentified	Unidentified	1	-		
Marmeleiro	*Croton blanchetianus* Baill.	Euphorbiaceae	17	12	17	7
Pau-Ferro	*Libidibia ferrea* (Mart. ex Tul.) L.P.Queiroz	Fabaceae	1	1	-	-
Pata-de-vaca	*Bauhinia cheilantha* (Bong.) Steud	Fabaceae	1	-	-	-
Pé de Coroba	Unidentified	Unidentified	1	-	-	-
Pereiro	*Aspidosperma pyrifolium* Mart. & Zucc	Apocynaceae	3	1	1	-

Legend: "family" – Botanical family; "Past and present" – Time frame; "Used" – Species effectively used in specific time frame; "Preference" – Species effectively preferred in specific time frame.

Preference behaviors in restricted use areas vary over time (H1)

The GLMM analysis showed a trend of specialist behavior in the past, in relation to the preference for wood resources for fuel purposes, in the restricted use community (*Serra Grande*) (Figure 2), with a significant result ($p < 0.000849$), that is, the species were selected because they presented a combination of characteristics perceived biological and physical characteristics, such as strong wood, rapid fire ignition, production of little smoke, production in lasting ember and others.

The data regarding preferred behaviors in the present demonstrate that they showed a tendency to change in relation to the behaviors described in the past, presenting a tendency towards mostly generalist behavior in the present ($p > 0.6489$) (Table 3). We found that the justifications and criteria for the preference of the species group were based on the ecological characteristics of the plants in the extraction sites, such as abundance, which refutes our hypothesis, given the change in the behavioral pattern over time.

Preference behaviors in areas of unrestricted use vary over time (H2)

There was a tendency towards mostly generalist behaviors in the preference of species for fuel purposes in the past in the community with unrestricted resource use, although not significant ($p < 0.4675$) (Figure 2). In other words, the informants selected the species because they had a high abundance in their perceptions, presenting the justification that "there were many." Regarding the behaviors of preference in the present, they presented a trend in variation in relationship to those in the past; criteria such as flame durability, no production in smoke, and fast ignition had a greater representation in the justifications. Such characteristics are intrinsic to the species, which indicates that the local population tends to have specialist behavior ($p < 0.2074$) (Figure 2). Therefore, these results confirm our hypothesis.

Regarding preference behaviors in the present, there was a tendency to vary in relation to those in the past; criteria such as flame durability, non-production of smoke, and rapid ignition had a greater representation in justifications for use. Such characteristics are intrinsic to the species, which indicates that the local population tends to exhibit specialist behavior ($p < 0.2074$) (Figure 2). Therefore, these results confirm our hypothesis.

DISCUSSION

The diversity of species used and preferred as firewood in the protected area, and preference behaviors for firewood varied over time (H1).

The results did not confirm our hypothesis. The analyses indicate that preference behaviors in this type of area vary over time, presenting a result contrary to our prediction. We expected to observe a prevalence of specialist plant preference behaviors based on intrinsic biological characteristics, such as strong timber, rapid ignition, non-smoke production, high ember production, and long-lasting fire, most of which are characteristics observed in native and local species (Martínez 2015). Preference behaviors for firewood species by the community in the past have established themselves with specialist standards; that is, the selection and use of preferred species considered the possible intrinsic biological characteristics, demonstrating their physical/chemical aspects were considered as justification for use. These results were similar to those found by Hora et al. (2021) when they observed the presence of these characteristics in wood species, which was the main justification for such use (cooking food).

Therefore, the results found specifically during this time frame (i.e., the past) are contrary to those reported by Ramos et al. (2008). The authors show that the species cited with a greater probability of being extracted by the local population are mostly species with a greater abundance of individuals at the collection sites and not those with better biological qualities ("hard" or "strong" wood).

The study by Martínez (2015), conducted with communities close to a protected area in Argentina, observed that the human community, which already had a history of using wood resources, tended to select a greater variety of exotic species more frequently as a source of firewood/fuel. According to Martínez, this demonstrates an approach that prioritizes sustainable selection criteria. It is believed that this behavior is contributing to the conservation of native species, in addition to representing a strategy to reduce the need for intensive use of wood resources for their subsistence.

Such behaviors described by Martínez (2015) demonstrate a trend observed in this study regarding behavioral strategies and the adaptive plasticity that human communities present to circumvent the prohibitive processes imposed by the implementation of conservation units, especially in areas that have historical experiences and human communities' extraction of natural resources.

The observations found in this study show that

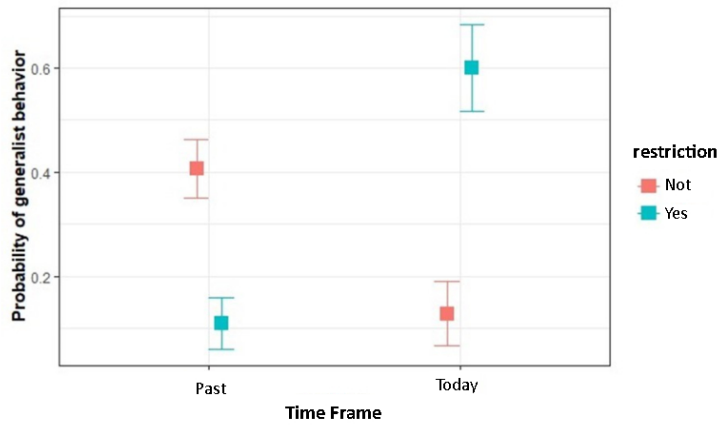

Figure 2. Representation of the probability of variation in the behaviors of preference for timber species in the Serrote do Amparo communities (non-restricted use) and Serra Grande (restricted use) over time frames (past and present).

Table 3. Estimated correlation between preference behaviors and time frames.

	Standard estimate value	z of	Error	Pr(>|z|)
Restricted area	0.2074		1	0.6489
Present time frame	0.5279		1	0.4675
Restricted area: PresentTimeFrame	19.2229		1	1.163e-05 ***

the Serra Grande community (restricted use) went through a process of change in their preferences for firewood species over the years, mainly due to the implementation of the Pedra Talhada Biological Reserve (RBTP). This process influenced the community to adjust its preferences, which were previously oriented towards local species in a specialist capacity, justified by the high diversity, proximity of residences to collection areas, and use of species in commercial activities. After implementing the RBPT, these preferences were replaced by more generalized species selection. To circumvent laws prohibiting the use and to fulfill the local need for the subsistence of natural resources, residents used the strategy of cultivating *Mimosa tenuiflora* (Willd.) Poir is a species that is not protected by the native species conservation laws established by the RBPT. In essence, implementing the Biological Reserve led to a reorientation of community behavior in relation to species used as firewood.

This change may be closely related to the cultural aspect of resource use. It was observed (through the participant observation method) that local practices of utilizing native species have been reduced in the present, with few signs of their use. This reduction appears to be more directed towards species found on the private property of the informants, which, for some reason, were felled and ended up being used in household activities, highlighting that cultural practices can establish changes. However, their motivation may be rooted in the memory and daily life of human communities. Therefore, Silva et al. (2020) demonstrated the high probability that important information about how to deal with recurrent challenges in nature (e.g., prohibition of use) could be favored in human memory, whereas adaptive information (e.g., insertion of *M. tenuiflora*) is favored in cultures when the event becomes recurrent and continuous in nature, which is the case with the implementation of REBIO (Silva et al. 2020). Considering how the human mind can recover favorable information from the past and that the human mind has adaptive plasticity to overcome the effects of challenging events for survival (e.g., insertion of new species in sociocultural systems), Santoro et al. (2017) observed that the high incidence of malaria led to greater knowledge about antimalarial medicinal plants in African populations. In other words, the recurrence of adversities in the environment, in this specific case, the prohibition of use, can model adaptive information that will be preferentially remembered about specific resources over others (Silva et al. 2020).

At present, one of the solutions found by the local

population was the planting of *M. tenuiflora* in the areas surrounding the RBPT and in private properties. The choice of this species was established as the main strategy to circumvent the ban's effects, as it was also preferred in the past. This aspect caused the population's cognitive system to retrieve the information that was most useful and reliable about the intrinsic characteristics that the ethnospecies present for use in the form of firewood, providing necessary information to meet local demands. In addition, other intrinsic aspects of may justify this present preference; studies show that this species has a high timber potential for the northeast (Figueirôa et al. 2006; Silva et al. 2011), in addition to being quality wood for charcoal production with high levels of calorific value. These characteristics and the non-presence of this species as a conservation focus of the RBPT reinforces the current choice and permanence of specialist preference behaviors in this community.

In the unprotected area, the behaviors and preferences of firewood vary over time (H2).

The results confirmed our hypothesis; the analyses indicated that the preference behaviors in this type of area (common use area) tend to vary over time, with evidence of generalist and specialist behaviors over the years. In the past, preference behaviors were prevalent for plants perceived with favorable ecological characteristics, such as the abundance of species at collection locations, which is a standard characteristic of generalist behavior in species preference. This specific result confirms existing literature, where studies have pointed out that the use of firewood at first would be redundant and generalist; that is, the use would be directed towards more available and abundant species (Ramos et al. 2008; Medeiros et al. 2012; Cruz et al. 2020).

Thus, the preference behaviors for firewood species reported by informants from the common use community (Serrote do Amparo community) were established as generalist, where the preference was justified only by the environmental and ecological attributes of the plants. This is behavior contrary to those established in arid and semiarid regions since human populations are subject to environmental limitations that can lead to adjustments and restrictions in the use of forest resources, in addition to being exposed to possible structural changes in plant communities, interfering with the abundance of local species (Martínez 2015).

These results corroborate the findings by Marquez-Reynoso (2017), where high rates of ecological aspects (abundance) directly influence the population's decision about which species will be used as firewood. Even though there are groups of species with better biological characteristics, the population tends to use species with greater local abundance (see also Lucena et al. 2012). Therefore, people close to forest areas with common use focus their foraging on plants more easily found in collection sites, as they would have a greater chance of being experimented on, extracted, and included in a cultural system. Thus, the most used species by these human groups correspond precisely to the most "apparent," the most available and abundant (Albuquerque 2006). Using a species because there is more of it can represent the practicality of people in solving their problem of obtaining firewood and spending less time and work. However, the type of preferred resource may be different for them.

Another important factor in understanding the prevalence of this type of (generalist) behavior in the past is the history of wood resources used as fuel by the local population. Ethnobotanical literature demonstrates (Ramos et al. 2008; Medeiros et al. 2012) that the use of woody resources in the form of fuel, naturally, at first, has a redundant use since the plant used as firewood does not necessarily need to present such specific characteristics when compared to other community demands (e.g., building houses, tools), which require resources with specific biological properties (Ramos et al. 2008; Medeiros et al. 2012).

Thus, we show that the use of this type of resource in a community with common use area, at first (past), was established in an ungoverned and redundant manner, without any concern about the decrease of the abundance of a preferred species but aimed at maximizing the gain and decreasing the immediate demands of the community. Since the use of resources by the community is closely linked to the low socioeconomic situation, this vulnerable economic situation forces the use of natural resources with greater frequency and intensity (Albuquerque and Andrade 2002; Lucena et al. 2012; Cardoso et al. 2015; Morales et al. 2017; Hora et al. 2021). Presently, these behaviors varied and presented behavioral patterns directed to the perception of intrinsic biological characteristics in physical/chemical quality (specialist behavior) as the main justification for the preference of plants over others. The ecological indexes of the species in the natural environment have been decreasing over the years through use and extraction due to the community pressure on the extraction of local resources, putting the local forest replacement capacity at risk and possibly causing local extinctions of native species (Hardin 1968; Ramos et al. 2008; Hora et al. 2021).

This result is different from those observed by studies performed in rural communities, which intended to investigate the influence of abundance and availability of resources on the use of firewood for

cooking food. For example, Top et al. (2004) observed that the proximity of natural resources increased the use of this resource, even with its scarcity in forested areas, influencing human communities to seek available species, demonstrating generalist behaviors in this scenario. The species with intrinsic biological characteristics (strong wood, quick ignition, non-smoking) could present a higher scarcity rate among collection sites in relation to species without such characteristics.

Another justification for such results would be studies that show that strong pressure from anthropic actions negatively affects the abundance indices of native species and reduces ecosystem services (see Ribeiro et al. 2019; Silva et al. 2019). We believe that these harmful effects on the vegetation caused over the years by the extraction process may have driven the change in preference behaviors and use of firewood in the community. The low number of citations of preferred species in the present demonstrates that there may have been a decrease in the preferred species over the years of local resource extraction, this decrease being the possible event that culminated in the change in the selection behaviors of the community. Since the species did not present the same abundance rates in the collection sites as in the past, the focus is on using species with intrinsic biological characteristics remaining in that fragment, which is the main reason for using them in the present. Therefore, the high demand for natural resources and the low abundance of resources directed the extraction to species that have, for example, strong wood and fire durability (Hora et al. 2021) since the presence of this characteristic results in a bigger time interval for that the family to expend energy to acquire their daily stock of firewood. Given this scenario, the results found reaffirm the observations by Hora et al. (2021), where the authors state that there is no consensus in the literature regarding the preference behaviors and the collection of plants for fuel purposes in human populations in a scenario of common use of natural resources. In this scenario, the natural environment can suffer more accelerated anthropic degradation, interfering with the ecological rates of native species and consequently in establishing behavioral patterns (Brouwer and Falcão 2001; Brito and Cintra 2004; Cruz et al. 2020). In some cases, people adopt specialized collection behavior (Kituyi et al. 2001; Shah et al. 2007), and in other cases, the adopted behavior is a generalist (Top et al. 2004); the presence of both behaviors is also possible (Cruz et al. 2020).

In this case, our results demonstrate that the behavioral patterns of preference were dynamically and flexibly established across time frames. Sometimes, they are generalists (when abundance is high in the collection sites) in the past (Top et al. 2004), they are specialists in the present (looking for specific qualities for a specific use, such as high production of embers, when the family needs to use a wood stove to cook more foods), or the combination of both (a species with high abundance and rapid ignition) (Ramos and Albuquerque 2012; Silva et al. 2019).

Therefore, the preference behaviors in these communities (common use area) have changed over the years according to the situation in the forest area since the natural environment has constantly changed through the history of local use (sometimes due to anthropic actions, sometimes through natural actions). Therefore, the abundance indicators of species explain the preference for firewood over time, as observed by Cruz et al. (2020), and sometimes the attributes of intrinsic biological quality are prioritized, as observed by Ramos et al. (2008).

CONCLUSION

The preference behaviors in woody species suffer the direct influence of variables tested in this study. However, it was evident that human groups have adaptive plasticity to bypass the drastic effects of the extraction of timber resources in the long term. Communities seek new management strategies and implementation of new species to supply the urgent and basic needs of the community or family.

Our results show that laws preserving local natural resources emerge as an effective strategy for mitigating the adverse effects of unrestrained logging. However, implementing these laws must be sensitive to the specific needs of communities residing in these areas. The local populations faced direct impacts from such bans, resulting in a considerable energy and cultural burden for their continued dependence on timber resources.

It is crucial to consider the difficulty these communities have reconciling their traditional practices with the legal restrictions on protecting natural resources. Therefore, implementing conservation measures must be accompanied by policies that adequately address local needs and realities, ensuring a gradual and smooth transition to compliance with conservation laws.

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DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

CONTRIBUTION STATEMENT

Conceived of the presented idea: CHTM, TCS.
Carried out the experiment: CHTM.
Carried out the data analysis: CHTM, TCS.
Wrote the first draft of the manuscript: CHTM.
Review and final write of the manuscript: CHTM, TCS, MAR.
Supervision: TCS, MAR

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