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Amazonian Forest Peoples' Perceptions of Malaria on the Upper Rio Negro, Brazil, are Shaped by Both Local and Scientific Knowledge

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Abstract. *Malaria is endemic in Brazilian Amazonia, accounting for 99% of national cases. Amazonian forest peoples (both Indigenous and traditional) understand and treat the disease based on their knowledge, rituals, and religion. In recent decades, biomedical health coverage has expanded in the region, with implications for local perceptions and practices to prevent, treat, and recover from malaria. This paper attempts to understand how the expansion of biomedical healthcare among forest peoples interacts with their ethnomedicinal knowledge. Our results clearly indicate that most of our research participants in rural northwest Amazonia believe that malaria has a variety of causes, forms of prevention, and treatment. We also found that these beliefs are shaped by both local knowledge (including Indigenous) and some technical concepts of biomedicine. Consequently, new approaches and practices in healthcare need to be developed which consider forest peoples' perceptions and understanding.*

Keywords: *Indigenous knowledge, tropical disease, epidemic.*

Introduction

This article investigates the perceptions of forest peoples about malaria in order to understand the extent to which they are shaped by Indigenous and local knowledge, and scientific knowledge in a region of the upper River Negro in the Brazilian Amazon. The provisioning of medical services to rural populations in Amazonia ranges from non-existent to precarious (Garnelo et al. 2018, 2020). This is compounded by a general failure of biomedically trained health practitioners to understand how their Amazonian patients' perceptions and comprehension of health and disease are influenced by traditional ethnomedicine, beliefs, and perceptions (Dias-Scopel et al. 2017; Diehl and Langdon 2015; Nogueira 2010; Scopel et al. 2018).

To date, few studies worldwide have explored the coexistence of biomedical and ethnomedical health systems for prevention, treatment, and cure of diseases affecting humans and their domesticated animals. Synthesizing the coherent insights from this research is challenging because studies have adopted heterogenous methodological approaches, reflecting researchers' divergent epistemologies. Moreover, the diverse empirical findings reflect both contextual factors (e.g., cultural, social, economic, political, environmental) and the etiology and ecology of particular diseases.

For example, Mathez-Stiefel et al. (2012) used open interviews and free-listing to examine the coexistence of Andean medicine and biomedical healthcare in rural sites in Peru and Bolivia. They found that, despite

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access to biomedical treatment, the population uses ethnomedicine as a resource for cultural affirmation in its confrontation with the dominant medical system, which generates tensions. Research on malaria in rural Nigeria using structured interviews found that mothers sought out both modern and traditional healthcare for their children (Agu and Nwojiji 2005). Geographic distance from health centers was a major barrier to their utilization, whereas traditional healers were sometimes favored due to low-cost and positive personal experiences. A now-dated study in Botswana reported the resistance of nurses to cooperate with ethnomedical systems, due to a dialectical tension between their traditional beliefs and their knowledge acquired during training in biomedicine (Barbee 1986).

Caudell et al.'s (2017) comparative study in East Africa used cultural consensus methods to quantify veterinary expertise among two ethnic groups. They found that ethno- and modern veterinary medicine coexist differently between the Koore and Maasai ethnic groups, which they attribute to tribe-specific histories of experiences with cattle diseases, and cultural differences in how they pass on their veterinary knowledge.

Those studies highlight the importance of understanding the interaction between these two health systems, highlighting this complex and dynamic relationship (medical pluralism). Most of the studies were developed in poorer countries (Hosseinzadeh et al. 2015; Ragunathan et al. 2010; Williamson et al. 2015). Strengths of ethnomedicine include its incorporation of cultural and ritualistic values, and it is often free or relatively inexpensive. Moreover, in addition to treating diseases, ethnomedicine focuses on strengthening the patient's immune system, and preventing conditions through the use of readily available natural (both wild and cultivated) resources. Conversely, biomedicine is based in the scientific method (i.e., acquiring knowledge by testing falsifiable hypotheses), and relies heavily on modern technology's tools (e.g., for diagnosis) and synthetic drugs for disease prevention and treatment. However, pharmaceutical drugs are, in many cases, inspired by traditional medicine, such as the quinoline anti-malaria medicines that are synthetic analogs of quinine (a compound extracted from the bark of *Cinchona* spp. trees) and the anti-malarial derivatives of artemisinin (a lactone extracted from the plant, *Artemisia annua*) (Mohammadi et al. 2020). Ethnomedicine is particularly important because access to biomedicine is very limited for many poorer populations in the Global South.

Specifically for malaria, several studies into health knowledge in Africa have demonstrated that contact between the Indigenous and biomedical health systems can lead to either mutual learning (Kimbi et al 2014; Odonne et al. 2021) or competition and tensions (Abdullahi 2011; Beiersmann et al. 2007; Hillenbrand 2006). These studies also highlight the importance of health education in combating malaria and recognizing the importance of local knowledge and ethnomedicinal practices in developing more effective, specific practices for this disease's management and eradication. Focusing on Uganda, Nigeria, and South Africa, Agu and Nwojiji (2005), Iriemenam et al. (2011), Munzhedzi et al. (2021), Nuwaha (2002), and others found a range of anti-malarial treatments being employed by local people, combining traditional and modern medicines, often simultaneously. Hence, even when people have access to biomedical health, many continue to use natural resources for medicinal purposes, such as self-medication with commercial antimalarials (not always medically appropriate); traditional treatments at home and/or using local healers; and treatment in clinics or health agencies (Nuwaha 2002). Injections by untrained, itinerant injectionists are another way of treating malaria which can contaminate needles, increasing risks of HIV and hepatitis transmission (Nuwaha 2002).

Our study region, in the northwest of Amazonas State, Brazil, is known for its cultural diversity, with more than 20 Indigenous ethnic groups from four linguistic families: Tukano-Oriental, Aruak, Maku, and Yanomami (Buchillet 1988; Cabalzar and Ricardo 2006; Emperaire and Eloy 2008; Reichel-Dolmatoff 1997). There is a strong history of traditional medicinal practices among these groups, as well as a high incidence of malaria cases (FVS 2022). Our field survey was conducted in 2013 with eight Indigenous and non-Indigenous (mixed Indigenous, slave descendent, and European heritage) traditional rural riverine communities (see Ethical Approval section below), within the framework of the PRONEX/MALARIA project, which initially resulted in a paper on plants for the treatment of malaria from this region (Frausin et al. 2015). The Indigenous communities we surveyed were mostly multi-ethnic (except for the Yanomami), owing to historical colonization, slave trafficking, exploitation of natural resources (such as rubber), Christian evangelization, and government programs, among other factors (Buchillet 1997). An understanding of how the area's tumultuous history (social, political, economic) has influenced perceptions of malaria could be useful in the development of public policy that could contribute to improved success in future malaria control, as well as to the implementation of educational programs that respect local realities and knowledge (Odonne et al. 2021).

Malaria in the Amazon Region

Like other infectious diseases in the Amazon region, malaria arrived through European colonization and caused a drastic decline in the Indigenous populations. As shown by Buchillet (2002), epidemics, including malaria, have had a strong impact on Amazonian rural populations, especially because these epidemics are rooted in colonial expansion. Whether malaria was introduced to the Indigenous peoples of the upper Rio Negro pre- or post-contact with Europeans remains contested but, irrefutably, infectious outbreaks in particular rural locations were (and are) strongly influenced by the arrival of outsiders. For instance, in the eighteenth century, Portuguese expeditions explored the upper Rio Negro, devastating Indigenous communities through epidemics of smallpox, measles, and intermittent fevers, which may have been malaria (Buchillet 2018). Certainly, malaria was present in the early twentieth century, when the Catholic Salesian missionaries settled in the area (Buchillet 2013).

Amazonian societies, like others, have developed a vast and complex group of beliefs, practices, norms, and rituals that make up ethnomedical systems through social interaction that influences perceptions and cognition (Bussalleu et al. 2021). During the centuries following the introduction of malaria, native Amazonian populations developed knowledge associated with the disease and therapeutic strategies for its treatment and control, mainly using plants and animals. In some cases, Indigenous peoples associated seasonal events, such as the phenology of plants and hydrologic cycles, with outbreaks of malaria (Buchillet 2013).

Data have already been recorded in studies among traditional river-dwelling peoples known in Brazilian Portuguese as *ribeirinhos* (Hidalgo 2003; Nogueira 2010), and of shamanic representations of infections among the Desana Indigenous people (western Tukano linguistic family) on the Rio Negro (Buchillet 1988, 2002). Research by Garnelo and Wright (2001) describes the myths of the origin of malaria among Indigenous Baniwa people (Aruak linguistic family). Further work in Amazonia has explored the perceptions, knowledge, and therapeutic strategies to treat malaria between traditional river-dwellers (non-Indigenous) and Indigenous populations (Athias 1998; Botsaris 2007; Frausin et al. 2015; Oliveira et al. 2015; Tomchinsky et al. 2017; Trivellato 2015), as well as on the Yanomami and Luso-Brazilian populations (Milliken 1997;

Milliken and Albert 1996, 1997; Milliken et al. 1999).

According to the World Malaria Report (WHO 2021), the majority of malaria cases in the Americas are from the Amazon regions of Venezuela, Brazil, and Colombia, which accounted for 77% of all cases in this region, with predominance of *Plasmodium vivax* (68%). In Brazil, 99% of malaria cases are registered in the Amazon region, mainly as a consequence of social, environmental, and demographic conditions that facilitate the maintenance of the transmission cycle of the parasite (FVS 2022). However, the proportion of the more lethal *Plasmodium falciparum* has diminished in recent years, relative to *P. vivax* (Almeida et al. 2018; WHO 2020). This paper assesses local communities' understanding of the supernatural and natural causes of malarial disease, the perceived and symbolic reality and cultural context of each ethnic group, and the traditional malaria treatments (prophylactic or preventative) on the upper Rio Negro, used alongside biomedicine. An improved understanding of the knowledge and perceptions among these communities could assist with the development of better healthcare and control of malaria in the upper Rio Negro.

Methods

Study Area

Santa Isabel do Rio Negro (Figure 1) is in northern Amazonas State in Brazil (00º 25.000′ S, 65º 01.179′ W) with a population in 2021 of 26,566 inhabitants (IBGE 2021). The sociocultural diversity of the municipality is characterized by more than 20 ethnic groups that include, but are not restricted to, the Baniwa, Baré, Desana, Piratapuia, Tariana, Tukano, Tuyuca, and Yanomami, as well as riparian peoples (*ribeirinhos*) and others who live in a small town. Most people in these communities produce swiddens (where cassava root [*Manihot esculenta*] is the main food staple), alongside fishing, hunting, and gathering of forest products such as fruits and nuts (*açaí* [*Euterpe* sp.], *bacaba* [*Oeno-carpus bacaba*], *patauá* [*O. bataua*], Brazil nut [*castanha*] [*Bertholletia excelsa*], *tucumã* [*Astrocaryum* spp.]) and vegetable fibers (e.g., *arumã* [*Ischnosiphon* spp.]). Among other sources of livelihood are federal retirement pensions and/or *bolsa família*, a federal stipend paid to families (Campello and Neri 2014). For heuristic purposes, we divide the peoples in this study into three groupings:

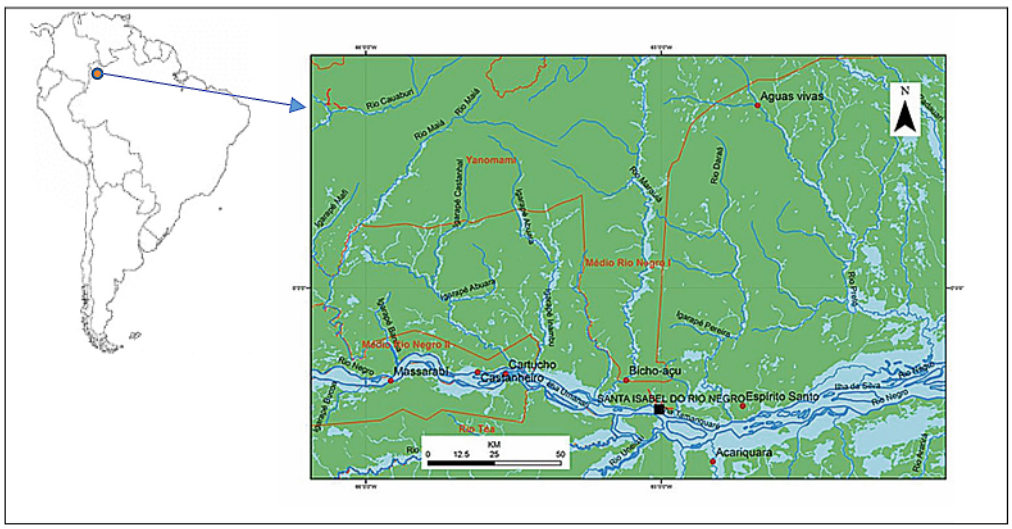

Figure 1. Study area, Santa Isabel do Rio Negro, Amazonas State, Brazil.

Yanomami, other Indigenous peoples living in multi-ethnic communities, and *ribeirinhos*.

Data Collection

This study was conducted in 2013 in eight communities in the Santa Isabel municipality of the upper Rio Negro region, as part of a larger study (PRONEX/MALARIA). In total we interviewed 146 people between the ages of 18 and 85 (in some cases, the age was not known): 66 women (45%) and 80 men (55%) from the Baniwa, Baré, Desana, Piratapuia, Tariana, Tukano, Tuyuca, and Yanomami ethnic groups, as well as *ribeirinhos*. On arrival in the municipal capital of Santa Isabel, we visited the health center (Fundação de Vigilância em Saúde-FVS-SIRN) and the Association of the Indigenous Communities of the Middle Rio Negro (ACIMRN) and enquired about the situation regarding malaria in the region. They helped us select some of the communities to visit. On arrival in each community in 2010, we sought out the leader to explain and get permission to conduct our research. We returned in 2013 to conduct the survey.

Structured interviews were performed and accompanied by informal conversations to understand the interviewee´s knowledge of malaria. The interviewees were asked the following questions:

> Perception: what is malaria (*maleita*, *maleta*, *hura*) for you; do you use other names for malaria?
>
> Causes: what are the causes of malaria?
>
> Prevention: do you know how to prevent malaria?
>
> Therapeutic diets: are there any foods that should not be consumed by a patient with malaria; do you know any food that helps with the treatment of malaria; which ones (fruits, animals, fish); why; do you know foods or drinks that should not be consumed by people who have malaria; which ones; why?

When permitted by the interviewee, this dialogue was recorded. Some of the interviews were conducted in the Yanomami language and, in those cases, we had the help of translators. This was not necessary with the other Indigenous ethnic groups because the vast majority are bilingual (i.e., speak both their native tongue and Portuguese). Also, concomitantly, we followed the progress in the treatment and cure of some local malaria patients. The field information was processed and analyzed using descriptive statistics in MS Excel.

Compliance with Ethical Standards/Ethics Approval and Consent to Participate

Ethical clearance for this study was obtained from the National Indian Foundation (FUNAI) and the Association of the Indigenous Communities of the Middle Rio Negro (ACIMRN). Consent was granted by the household, which was integrated into the survey instrument, and by local leaders through the PRONEX/MALARIA project team. We complied with the legal requirements of the Brazilian National Council for the Management of Genetic Heritage (CGEN, process number 02000.001373/2010-11) and the Brazilian National Ethics in Research Committee (process number CEP:3425-2010), and the Medical School at the State University of São Paulo (UNESP) at Botucatu (CEP, resolution number 196/96, National-Health-Council). No species-specific treatments with plants or other natural resources were presented in the present survey.

Results

Perception of the Origins and Causes of Malaria

The local population appear not to recognize differences in the symptoms caused by *Plasmodium falciparum* or *P. vivax*. The symptoms for both species have small differences, such as common headache for *P. falciparum* and the period in which fe-

vers appear. The symptoms in both cases are characterized by constant fevers at the beginning, although with a frequency of recurrence of two days for *P. vivax* and three days for *P. falciparum*. However, there is a significant difference in terms of severity and mortality of malaria, with *P. falciparum* being responsible for the greatest mortality (Hay et al. 2004).

In the northwest and central region of Amazonas and Roraima (including the upper Rio Negro), from 2016–2018, *P. falciparum* had a greater prevalence than expected (Ayala et al. 2021). Among Indigenous children in Amazonas, infection with *P. falciparum* and mixed malaria (both species) was more frequent and required special attention (de Aguiar et al. 2021).

FVS health agents and some participants in this research highlight that biomedical knowledge has progressively enriched the shamanic perceptions and traditional knowledge of malaria among the Indigenous groups of the Rio Negro and has resulted in a decrease in the number of cases of malaria treated and cured through traditional magic-religious methods (*recura* and *benzimento*) (see Processes of Treatment and Cure of Malaria below).

Malaria is called *hura* by the Yanomami, *kunãme* or *kooname* by the Baniwa and Takua, and *maleita* (affliction), *sezão* or *tremedeira* (shaking in the body), and *empaludismo* or *paludismo* among other Indigenous and non-Indigenous groups in the region. The term *maleita* is still used by most elderly people. With the exception of Yanomami communities, all those that we visited are multi-ethnic, which means that the perception of the causes, symptoms, and itinerary of the process of malarial cure is the product of diverse socio-cultural influences, and influenced mainly by the formal educational level of each informant. Yet, it is not strictly determined by the ethnic group to which the individual belongs. Despite this, some myths of the origin of malaria are linked to specific Indigenous ethnic groups, e.g., the Baniwa and the Desana (see Discussion).

In the case of the Yanomami on the Rio Marauiá and Rio Preto, malaria (as well as other illnesses, such as measles and filariasis) are derived from more recent contacts and were previously unknown to them. Thus, there is little history on the use of traditional medicine or specific rituals to cure such diseases. The perception of the Yanomami of the origin of this illness is connected in many cases to contact with *nape* (non-Yanomami people), as described in several accounts:

> The ancient Yanomami didn't have malaria...when they went down, they met the *caboclos* and then they ate the food of the *nape* …it was then that we got to know malaria…The Yanomami only ate *balata do mato* [Sapotaceae], *chamarai*, *inajá* [*Attalea* spp.], palm hearts; they drank honey juice, *buriti* [*Mauritia flexuosa*]... so for that reason they didn't have disease. Why not? Because this natural food, *tucunuí* and *cabarí* they ate during their meal… Because it was natural … For this reason, at this time, after they met *nape*, after *nape* created *hura*. (Male participant, Yanomami, Bicho Açu Community)

We found that most of those interviewed believe that malaria has more than one origin, and, in many cases, a mixture of causes that evolved from traditional knowledge and technical concepts of biomedicine, the latter often transmitted during treatment by health workers. Nevertheless, these biomedical concepts are not completely accepted. For example, we heard different accounts of how the mosquito spreads the disease. Among these accounts, malaria transmission was through the bite of the insect or through drinking dirty water that was contaminated by the eggs of the mosquito, as explained in this account:

> My mother used to say that it was *maleita*/ malaria, because the mosquito lays eggs

> in the water, where we drink and so we drink it and it's inside us. I've no idea what it does inside us. And then when it bursts inside us and then causes that fever, until one takes bitter medicine. We would take that bitter medicine, then a bath, then emetic [*Guarea pubescens*] for us to vomit and for [the malaria] to leave us. (Male participant, Santa Isabel do Rio Negro Municipality)

As seen in the examples above and our broader data, contamination of water by flies, dead animals, and fruit (in some cases poisonous) widely permeates the belief system of the people in the region as the cause of malaria. From our data, water can be seen as the medium in which malaria is generated and transmitted through "contamination" of fruit that falls and stains the ground near *igarapés* (small rivers), rivers, and wells, and by animals that died there. Though some of the informants believe that malaria did not originate directly from a mosquito bite, they recognize the insect as the vector of malaria. However, they describe measures that prevent malaria transmission through improved care of the water they consume.

> Malaria...comes from water. It is created in *apui* [*Clusia* sp.] fruit... I lived in the Yanomami Indigenous area. One day, a chief of theirs there...picked up [*apui*], opened it and inside there are small popcorn-like grains...the mosquitos were there, right? He said it was this that creates malaria...it does not originate only in mosquitos…where I got malaria or it got me, I don't know… I got sick. People were providing treatment and there were no mosquitos. There was only that muddy water. And I didn't leave the woods and when I felt the symptoms... eating a dirty thing causes malaria... Already we want to only drink the white man's medicine. (Female participant, Cabocla, Santa Isabel do Rio Negro Municipality)

Fruiting trees, such as *apuí* (*Clusia* sp.) or *umarí* (*Poraqueiba sericea*), are associated with malaria outbreaks, which coincide with seasonal changes resulting in the formation of ponds and the proliferation of mosquitos. As can be observed in the interview above, according to local knowledge, the fruit that falls on the ground and later ends up in the water "contaminates" it and generates malaria. We also found evidence of the introduction of scientific and/or technical information in the cultural universe of the Rio Negro communities. This information is being slowly assimilated and reconfigured, especially by the older generations. Others believe that malaria originates in animals, such as the snake, but is transmitted by the mosquito:

> The mosquitos will fly… they will bite a snake and then the mosquito comes from the bush to bite us and generate the illness [malaria]. (Female participant, Santa Isabel do Rio Negro Municipality)

Others believe that malaria is transmitted by spirits or energy that live in the forest, or that its origin could be a wild animal from the forest.

> If where you go, it seems that it is walking around there, right? *Hura* [malaria], right? It walks around out there, it seems that you crashed up against it…with *hura* there you feel it already, right there and then. (Participant Yanomami, Bicho Açu Community)

Most of the participants indicated that the number of cases of malaria increases during the rainy season (March and April in this region), decreasing during the dry period or during the transition between these two seasons. In fact, during these periods of seasonal transition, dry to flooded and flooded to dry, pools of water are produced where female *Anopheles* can lay their eggs after blood meals, increasing the numbers of vectors and the incidence of malaria

(personal conversation with health care agents in the area, and da Silva [2014]).

Food Preference for Malaria

Among the other perceptions of the causes of malaria are the consumption of some animals and oily fruits, such as *umarí* (*Poraqueiba sericea*), *bacaba* (*Oenocarpus bacaba*), and *buriti* (*Mauritia flexuosa*). If they are eaten, they cause malaria, according to several informants interviewed in this study. The intuitive relationship between ingesting high fat food, fruit, and the progression and evolution of malaria is not completely clear. Malaria patients often have debilitated livers due to the invasion of liver cells by malaria parasites during infections and dormant forms (hypnozoites) of *Plasmodium vivax*.

In the present study, other causes of malaria were water from unprotected wells and exposure to morning dew or the consumption of alcohol. It may be that people have malaria symptoms coincidentally after ingesting *caxirí* - a fermented mixture of *cará* (*Ipomoea* sp. or *Dioscorea* sp.) and *cana de açúcar* (sugar cane; *Saccharum officinarum*)—or perhaps there was recrudescence caused by alcohol consumption.

In our study, several accounts recommend consumption of light and easily digested foods for malaria patients, low in salt and fat, such as meals based on bananas or *mingão* (cassava porridge), soups and birds, such as chicken, parrot, and *inambú* (*Crypturellus* sp.), as well as natural juices and fresh fish. We found that *reimoso* (a Brazilian popular cultural term for foods that harm patients [mainly rich in fat], however, this classification is diverse and can vary according to each region) is the most common restriction, and avoidance of the consumption of oil-rich fruits, such as palms, certain fish (particularly non-scaled), peccaries (*Pecari tajacu*, *Tayassu pecari*), *paca* (*Cuniculus paca*), and old food. Another relevant requirement is for patients with malaria to rest for some days (*resguardo*).

Despite this, we found in the Rio Negro communities that, in most cases, there is a difficulty in the adoption of adequate malaria prevention measures because of an incomplete comprehension of the role and mode of action of the vector, host, and environment. This is accompanied by a large human migration in the Rio Negro region during the eighteenth to twentieth century, environmental changes, and, in some cases, influenza or infections of the throat and gastrointestinal tract that are confused with symptoms of malaria. These and other factors have complicated and thwarted malaria eradication efforts for decades in this region of the Rio Negro.

Processes of Treatment and Cure of Malaria

The local health clinic in the communities (community health agents) and epidemic control agents were the most common channels used by community members when treating malaria in the urban and rural areas covered in our study. This is a sign of confidence in the formal health system and the treatment received by their professionals. Notwithstanding, it is common to find diverse opinions regarding the performance of these agents. In some cases, the evaluation is negative, with the claim of precariousness in the service provided by the state and lack of investments in equipment.

Despite the above, individuals with malaria (or symptoms of malaria) have different ways of dealing with this within the family nucleus and/or the community. Children and adolescents, for example, turn first to adults who accompany them at the health post in the search of a diagnosis and treatment. At other times, the representative of the community or *pajé* (shaman) is sought out by malaria patients seeking orientation, medication, radio contact, or transportation to another community with a health agent practicing Western medicine. Nevertheless, we perceived that this dynamic is changing

in the communities that we visited, with the biomedical health service being visited in most cases.

For the Yanomami, malaria is a sickness of the *nape*: "only the *nape* can cure malaria" (Male participant, Yanomami, Bicho Açu Community). In our study, according to several accounts, *recura* is practiced uniquely by the *pajé* of the community with the use of *paricá*, a psychotropic that, according to the Yanomami, acts like a channel to visualize a spiritual world where all the diseases live. *Paricá* is a hallucinogenic snuff used by other tribes in the upper Rio Negro, blown into the nostrils through a tube. It is made from the seeds of *Anadenanthera peregrina* or the resin from the bark of *Virola* spp., mixed with ashes of *Theobroma subincanum* (Schultes 1954). Only the *pajé* cures the illnesses of the Yanomami which cannot be treated through biomedical treatments.

> If one has malaria, true malaria, no one can do anything...we don't perform a ritual when [a Yanomami] has malaria. The *nape* [non-Yanomami people] is here...and so readily he examines the patient… [To see if] he has fever…if those *napes* don't know what is wrong with the patient, then we use *paricá*. We cure. It is called *recura*. It is used when the *nape* don't know what to do... the *paricá* 'image' is rather like television. It opens, and then the singing will appear...Aside from this, you see any little thing, you see everything, right? You see little animals. You...see like a frog also. You see like a spider also. After this ends and people appear, as people. (Male participant, Yanomami, Bicho Açu Community)

Benzimento is a traditional ritual (from the Portuguese *benzer*, to cross or bless oneself). While no longer very common, it is practiced among some ethnic groups for the treatment of diseases. For example, in an account of an Indigenous Tukano, the use of smoke from *breu* (resinous exudate from *Protium* spp.) is mentioned as a treatment for malaria. Nonetheless, these practices continue to be performed for treatment of highly contagious endemic diseases, such as measles and malaria.

Synergies between Ethnomedicine, Biomedicine, and Mythology

In the Rio Negro region, like the Yanomami, some still classify malaria as a *doença dos brancos* (white man's disease) and there are two main treatments: the white man's remedy (biomedicine/pharmaceuticals) or a traditional remedy (ethnomedicine). Biomedicine is presently the most popular. It is often used in parallel with teas and medicinal plant infusions, mainly for treatment of the symptoms of the disease. Home remedies are more commonly used when malaria is suspected and treatment by health professionals is not immediately available. Moreover, we found that prophylaxis is practiced using *saracura-mirá* (*Ampelozizyphus amazonicus*).

Despite the continual health assistance by governmental institutions in the Rio Negro region and intense missionary activity, the use of therapeutic strategies based on plants, animals, and magic-religious rituals continue to be practiced for the treatment and cure of malaria and associated conditions. These practices are mainly performed by adults and the elderly, often speaking two or more languages, including Portuguese and Nheengatu (Indigenous language from the Tupi-Guarani family), that they learned with their parents, grandparents, neighbors, and friends in the home environment or by observation.

We found that news and media transmitted through television and radio have influenced the knowledge of traditional medicines, particularly species of the genus *Plectranthus* (known locally as *boldo*). A common practice is combining pharmaceuticals alongside the use of medicinal plants, e.g., through purgatives for cleaning a "dirty liver" with consumption of teas and infusions

to lessen malaria symptoms. In addition, in Santa Isabel do Rio Negro, some people maintain that they have found a cure for malaria through masses at the Assembly of God evangelical church, with the help of the congregation and the preacher.

> The priest was Padre Afonso...I had that bad malaria. I was there for three days, and he arrived, right? Then he said that I had malaria and asked me whether I had taken any kind of remedy? And I said Padre, I didn't take any kind of remedy. And so, he said that this would end. He took my left hand...and then, he was conversing with me, and I was conversing with him, and he left. This was on a Saturday. Then I waited for the day after Sunday and there was no more malaria. Then, Monday and Tuesday went by and no malaria. I didn't take any kind of medication...But the Padre for sure made the malaria end, without my taking any medicine. (Male participant, lower Rio Negro)

Where malaria is the suspected diagnosis, followed by a treatment and later improvement in the condition of patients, it is impossible to corroborate the effectiveness of these due to the absence of definitive laboratory tests (analysis of a patient blood smear by a trained health professional) to confirm the existence of *Plasmodium* spp. in the blood. In some accounts of the Yanomami, it is presumed that contact with malaria occurred relatively recently through contact with *nape* and the knowledge on the use of some plants, such as *carapanaúba* (*Aspidosperma* spp.) and *saracura-mirá*, for the treatment of this disease was taught by the *ribeirinhos* and other Indigenous groups.

Discussion

Understanding Malaria and its Causes by Indigenous Groups

Knowledge of malaria among the Indigenous communities may be based on storytelling. For the Baniwa, the origin of the disease is told in a myth that explains the emergence of *timbó* (*Lonchocarpus* spp.—a plant with ichthyotoxic properties). The poison is taken from the shattered body of a venomous being and spread by the rivers and deposited in rock holes. The poison is then mixed in the rivers during the transition between summer and winter (as the water rises) and causes outbreaks of the disease (Garnelo and Wright 2001). Similarly, the Desana have two myths associated with the creation of malaria by *curare* (*Strychnos* spp.), as described by Buchillet (2013). In the first myth, Sĩ Gõamɨ (a demiurge), wounded by a *curare*-poisoned dart, vomited malaria to the four corners of the universe. In the second myth, the shaman Gaye, also wounded by a *curare*-poisoned dart, crashed to the ground and his broken bones were thrown in all directions, spreading malaria throughout the world.

On the other hand, Athias (1998), in his study of medical and representation systems among the Hupdë-Maku, found that these Indigenous groups use the same semantic content in their languages to denominate exogenous or more recently introduced diseases, such as malaria. A wider discussion of the medical systems of Indigenous peoples on the upper Rio Negro showed that the Tukano, Arawak, and Maku all regard novel diseases in their languages as "from white people" and produced mythological explanations for their appearance (Athias et al. 2007).

In addition to the mythological origin of malaria for some Indigenous groups, our survey showed the belief that malaria was partly related to water, which is reflected elsewhere in the world. Such beliefs were found in communities in Africa, India, and Latin America, where water continues to be important in connection with malaria (Agu and Nwojiji 2005; Buchillet 2002; Das et al. 2013; Ibidapo 2005; Paul et al. 2017). Similarly, we found that the relationship between snakes and malaria (in our survey) is recorded for other diseases in Latin America. For example, Shawi understanding of leish-

maniasis transmission in Peru is that snakes (particularly poisonous ones) can pass on the disease when an insect bites the snake and then the humans (Odonne et al. 2009). Snakes and other animals are, in fact, bitten by anopheline mosquitos, and *Plasmodium* spp. are found in Neotropical snakes. However, the *Plasmodium* spp. that cause malaria in humans have not been detected in snakes to our knowledge (Ayala 1978; Ayala et al. 1978; Garnham 1965; Thoisy et al. 2000).

On the other hand, non-human primates are relevant sources and reservoirs of *Plasmodium* spp. that do cause malaria in people. In Southeast Asia, the predominant simian malaria parasite, *Plasmodium knowlesi,* once believed to infect only monkeys, is now known to cause human malaria throughout the region (Hellemond et al. 2009). Very recently, it has been shown that the simian parasite *P. simium* in howler monkeys (*Alouatta* spp.) was responsible for human malaria outbreaks in Rio de Janeiro (Brasil et al. 2017). It is possible that community members are describing the existence of zoonotic *Plasmodium* reservoirs in this region of the Amazon, which should be the subject of further field studies, but the alternative is a hybrid between emic and biomedical etiologies. However, there is no doubt that, in communities where the public health system is older and where malaria control, treatment, and sometimes education programs have been in place for longer, malaria is associated with the bite of a mosquito, as documented in a study by Kimbi et al. (2014).

Food, Drink, and Malaria

The consumption of some foods recorded in this study, either because it is believed that they cause malaria or should not to be eaten by malaria patients, have already been documented in other studies in the Amazon. An example can be seen in Boca do Acre, where da Silva (2014) found that local communities believe that malaria was caused by eating fatty foods such as *jabuti* (*Chelonoidis* spp.), *bacaba*, and *buriti* (*Mauritia flexuosa*). Something similar was registered by Buchillet (2002) in the Rio Negro, where the author found the association of the ingestion of certain foods, like *umarí* and *bacaba*, as being the cause of malaria.

Previous studies have also shown that symbolic aspects of diet are common in therapeutic practices for the prevention, treatment, and cure of various diseases (Canesqui 1994; Kimbi et al. 2014; Shepard 2004). An example can be seen in a review by Odonne et al. (2017), where the authors explore the treatments for leishmaniasis among different groups in Amazonia. These include some perceptions and diet restrictions among Chayahuita (Peru), such as avoiding eating meat from animals that dig like armadillos or tortoises, because the wound would enlarge.

Some recent experiments have explored how host nutritional status and diet influences the development of the *Plasmodium* parasites and their sexual differentiation. Zuzarte et al. (2017) found a new mechanism by which *Plasmodium* are eliminated inside liver cells. Reactive Oxygen Species (ROS) increases in the liver cells in connection with the accumulation of lipids from high-fat diet. This reduces *Plasmodium* survival in liver cells, impacting the progress to the blood stage and diminishing severe malaria. In conclusion, the researchers found that consumption of high-fat foods interferes with the development of *Plasmodium*.

In addition, Leme da Silva (2007), in his study among the riverine population of the Rio Negro, found that behavior and physical appearance are important aspects to categorize an animal as *reimoso* (slimy, mucous) or not. According to the same author, animals with hybrid characteristics of difficult categorization, such as smooth (non-scaled) fish and animals of a generalist diet, such as *piranhas* (*Serrasalmus* spp.) and *queixadas* (peccaries), are considered impure and therefore not recommended for malaria patients.

On the other hand, in several accounts in this study, people believe that the consumption of alcohol can cause malaria or perhaps can produce recrudescence. Indeed, recent research on alcohol/mosquito interactions demonstrated that intake of alcohol (beer) increased the likelihood of mosquitos landing on the skin (Shirai 2002). Likewise, Lefèvre et al. (2010), in an experiment in Burkina Faso, showed that beer consumption is a risk factor associated with increased numbers of *Anopheles gambiae* mosquito bites (the main vector of malaria in Africa), due to body odor and breath. However, more research is needed to determine whether alcohol or other compounds in beer attract the mosquitoes, considering this information is important in preventing malaria which, according to Lefèvre et al. (2010), needs to be integrated into public health and disease control policy programs.

Management of Malaria in Indigenous Groups

According to Athias (1998), despite the significant differences among the processes of treatment of the Tukano, Aruak, and Maku of the Rio Negro, there are common elements in the way that the *pajés* operate as a mediating agent that can offer a diagnosis and a cure. This categorization system of diseases is common in diverse groups in the world. For example, a study by da Mata et al. (2012:7) shows that the female Indigenous Wajãpi (Amapá/Brazil) informants believe that the shamans (traditional healers) cannot treat malaria or other diseases, like diarrhoea, "but only illness from a python; if your head becomes dizzy, the shaman treats it." In addition, other research in the Andes with two Indigenous groups shows the preference of biomedical treatment when diseases are considered "serious" and where medicinal plants are ineffective (Mathez-Stiefel et al. 2012).

Historical documents and some Indigenous peoples agree that different rituals, such as healing practices, were very common in various Indigenous ethnic groups before the arrival of Europeans (that brought foreign diseases). These rituals were prohibited and penalized in colonial times as practices of the devil (Gruzinski 2006). However, the use of *benzimento* rituals to treat diseases, such as malaria, is currently practiced (although less common) in the Amazon and has already been described in previous studies on Indigenous communities of the Rio Negro (Azevedo 2009; Dutra 2011). The same happens with the use of home remedies to cure malaria in parallel with biomedical remedies or alone, when there are no health professionals available (Hidalgo 2003; Kffuri et al. 2016; Nogueira 2010; Tomchinsky 2014). In this context, Milliken et al. (1999) found that among the 198 medicinal species used by the Yanomami of the state of Amazonas, Brazil, ten were used specifically for the treatment of malaria, seven internally and three externally.

In our study, we found that *carapanaúba* (*Aspidosperma* spp.) and *saracura-mirá* (*A. amazonicus*) plants were the most popular among Indigenous communities in the Upper Río Negro territories, as well as other communities in the Amazon region. Experimental studies have demonstrated the antimalarial activity of extracts and substances isolated from these plants (Andrade-Neto et al. 2007, 2008; Henrique et al. 2010; Montoia et al. 2014; Oliveira et al. 2015; Rocha e Silva et al. 2012). The use of *A. amazonicus* is known as a prophylactic for malaria more widely in the Amazon region (Andrade-Neto et al. 2008; Frausin et al. 2015; Oliveira et al. 2015).

Despite the accounts of treatments involving pharmaceuticals and home remedies, the systems in place are more complex than either system separately or simply combined. This corresponds to a survey of malarial remedies in French Guiana, where biomedicine and phytotherapies are used together (Odonne et al. 2021). At the same time, in another study of ethnoveterinary versus contemporary biomedicine in

livestock-dependent areas in East Africa, it was found that the differences between the Maasai and Koore Indigenous peoples were due to cultural transmission (Caudell et al. 2017). The classification of different treatments is not a simple categorization among Indigenous populations, as they are part of the broad set of interpretations and representations which change over the generations (Athias 1998).

Conclusions

This article has revealed a complex diversity of knowledge among forest peoples about malaria in the upper Rio Negro, Brazilian Amazon. The results indicate that most of the Indigenous and *ribeirinho* inhabitants of the area believe that malaria has a variety of forms of prevention and treatment, as well as causes that evolved from traditional knowledge, incorporating some technical concepts of biomedicine.

Biomedical knowledge has complemented shamanic perceptions and traditional knowledge about this disease, resulting in a decrease in the number of cases treated and cured through traditional methods. Prior to the arrival of biomedicine, the use of natural resources and magical-religious rituals were the only source of treatment. We found complex and profound problems of dialogue with asymmetric power relations between these two systems (biomedical and traditional). A reform in the biomedical treatment method is urgent and necessary, focusing and capitalizing on local perceptions of malaria, cultural values, and effective prevention behaviors in the area. The results of this work are important since they help make local perceptions about the disease visible and support contribution to the design of public policies that allow better success in the eradication of malaria.

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