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Types of homes and ways of life: a territorial analysis of the environmental determinants that factor into the proliferation of malaria vectors in the rural region of Allada in Benin

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ABSTRACT

Introduction: Anthropogenic factors, as well as environmental factors, can explain fine-scale spatial differences in vector densities and seasonal variations in malaria. In this pilot study, numbers of *Anopheles gambiae* were quantified in concessions in a rural area of southern Benin, West Africa, in order to establish whether vector number and human factors, such as habitat and living practices, are related.
Methods: The courtyard homes of 64 concessions (houses and private yards) were systematically and similarly photographed. Predefined features in the photographed items were extracted by applying an analysis grid that listed vector resting sites or potential breeding sites and also more general information about the building materials used. These data were analysed with respect to entomological data (number of mosquitoes caught per night) using the Kruskal–Wallis test, Pearson correlation coefficients, and analysis of covariance (ANCOVA).

Results: Three recurrent habitat/household types and living practices were identified that corresponded to different standards of living. These were related to the average number of mosquitoes captured per night: type I=0.88 anopheles/night; type II=0.85; and type III 0.55, but this was not statistically significant (Kruskal–Wallis test; p=0.41). There were no significant relationships between the number of potential breeding sites and number of mosquitoes caught (Pearson's correlation coefficient=-0.09, p=0.53). ANCOVA analysis of building materials and numbers of openings did not explain variation in the number of mosquitoes caught.
Conclusions: Three dwelling types were identified by using predetermined socio-environmental characteristics but there was no association found in this study between vector number and habitat characteristics as was suspected.

Key words: Anopheles gambiae, Benin, housing, infectious disease vectors, malaria.

Introduction

Background

Natural conditions play a decisive role in the development of malaria[1,2]. Annual average temperatures of at least 18°C (64.4°F), which promote *Plasmodium*'s parasitic cycle within the mosquito[3], and frequent and sufficient rainfall, which rejuvenates stagnant waters and provides preferential larval breeding grounds for *Anopheles*, both have a significant impact on incidence. These characteristics are present in large areas of the tropics, suggesting that malaria risk within the same zone is not spatially equidistributed. Predictive models of high-risk malarial areas have mainly been developed on the basis of climatic variables. The seasonality of rainfall, minimum temperature, and type of irrigation allow the seasonality of the entomological inoculation rate (EIR) to be determined[4]. However, since temperatures are consistently high (an average of 25°C (77°F)) in tropical regions, rainfall is the most significant determinant of the seasonality of malaria. Nevertheless, analysis at the local (or even micro-local) scale is essential to accurately determine the distribution of malaria risk; important differences in the intensity of transmission exist even at very small scales[5].

More recently, Cottrell et al[6]. have highlighted that local environmental factors are important in determining malarial transmission on a small scale. However, few models account for spatial heterogeneity of malaria risk within and between the impacted territories and the characteristics of the populations living in these areas. Most of the existing literature links malaria to the environment by way of natural factors, often exclusively climatic, capable of generating the existence of biota favourable to the larval development, such as the presence of stagnant water. However, since the early 2000s, the focus has shifted to the analysis of the land cover in the immediate vicinity of living areas (particularly agricultural practices) using multispectral satellite images and integrating data related to households and housing construction materials into geographic information systems (GISs)[7]. It remains a challenge to make accurate predictions of vector proliferation on the basis of physical and biological environmental factors alone[8]. It is necessary to consider the environment in its totality by looking beyond traditional fragmentation of social and natural characteristics within territories. It has been shown that anthropogenic factors are important for the generation of vector shelters close to areas where people live[9]. Associations between risk of malaria and different types of construction have been highlighted in Sri Lanka, where it has been shown that there is an increased incidence of malaria among residents of more modest homes, where a higher number of anopheles have been recorded[10]. This suggests that a plausible link exists between social factors and vulnerability to malaria, but all the contributing factors are yet to be defined.

Several recent studies have renewed interest in measuring the impact of the social determinants that alter a population's vulnerability to the vector. These studies have analysed the importance of socio-environmental malarial risk factors in urban zones[11,12] or highlighted the impact of agricultural practices on vector proliferation in urban areas[13]. According to WHO, the social determinants of health correspond to the conditions in which people are born, grow, live, work and age and are primarily responsible for health inequalities. These conditions are determined by the distribution of money and resources at different scales. With respect to malaria, some Asian studies have proposed a link between malaria risk and poverty indicators: deprived communities in Rajasthan (India), for example, seem to be three times more susceptible than more developed communities in the same sector, possibly because of differential knowledge of risk factors[14]. In the same way, the presence of forest cover and indicators of poverty have been associated with increased malaria incidence rates in Vietnam[15]. More recently, a meta-analysis by Tusting et al[16]. has reiterated the link between low socioeconomic status and malaria at a sub-urban scale. This study highlights that wealth is probably protective against malaria by increasing, for example, housing quality, which leads to a decline in the inflow of potential vectors at the fine scale of the household. When the quality of the household is precarious (small dark homes, straw roofs and earthen walls), the endophilic character of *Anopheles gambiae* is promoted and this impacts on vector densities in and around these constructions[9].

Objectives

The comprehensive characterization of small-scale larval habitats or mosquito resting sites has historically required intensive fieldwork. Here was proposed a photography-based approach to capture quickly the living conditions of a number of concessions. This approach results in a single short visit that is minimally invasive for families participating in a research program. This approach echoes the Photovoice methodology[17], in which people use images or videos to describe and share the characteristics of their environment. Photovoice has led, for example, to the identification of socio-environmental determinants of HIV risk among African–American teenagers[18] or the characterization of behavioural risk factors for diarrhoea in Tanzania[19]. This study shares a common goal with Photovoice, namely the characterization of an environment by photography. However, the methodology is based on a single visit and differs from Photovoice in that the photographs taken are dictated by a set of predefined items in an analysis grid to identify the breeding and resting sites of vectors and classify households in order to establish associations with entomological data.

The focus was primarily on the socio-economic factors determined by habitat types and livelihoods. It is hypothesised that certain habitats, dictated by the housing environment and living practices of its occupants, provide optimal conditions for the completion of the phases of the gonotrophic cycle and will therefore attract more mosquitoes. In other words, is there a link between different living conditions and the abundance of *Anopheles gambiae* in rural Benin? This study, which has to be considered a pilot, is currently limited by the very small study sample; it cannot be claimed that the sample is representative of the whole studied area. Nevertheless, the coded items within the study seem to encompass a large diversity of household/habitat types and modes of living. This pilot work paves the way for the effective study of links between housing environments, ways of life and vector proliferation.

Methods

Overall study design, study area and context

This pilot study is part of a multidisciplinary research program called Tolimmunpal, which involves general practitioners, epidemiologists, biologists, biostatisticians, entomologists, geneticists and geographers. Based on a two-year prospective follow-up cohort study of 400 pregnant women–child pairs, this program aims to establish the determinants (environmental, biological and genetic) involved in the development of immune tolerance to malaria in a rural region in southern Benin. Clinical, parasitological and biological data have been collected together with environmental and entomological information.

In order to successfully identify the biological or genetic determinants related to immune tolerance responsible for variations in susceptibility to malaria, it is also essential to take into account the behavioural and environmental factors that might influence susceptibility. Environmental and health data will eventually be integrated in a GIS to generate a comprehensive predictive model of vector proliferation. However, this study is a first step designed to evaluate the impact of the environment – in its broadest sense – on vector proliferation on 64 equally distributed concessions. Environmental factors are defined as characteristics of small-scale households in order to highlight points of convergence and divergence in livelihoods and living practices. This analysis will eventually be extended to include all homes hosting 'mother–child' couples living in the Allada territory of Benin (30 km by 30 km). Allada is a small town in southern Benin[20], located in the north of the Atlantique department, about 56 km from the economic capital of Benin (Cotonou). In the subequatorial zone, Allada receives an annual average rainfall of 1-1.5 m between April and July and between the middle of September and the end of November. The dry season, from December to March, explains a seasonal decrease in the rate of malaria.

Household environment: Coding types of housing and ways of life using an itemised list is reported in an analysis grid. The social determinants that facilitate the presence of mosquitoes in the housing environment were first studied. The presence of *Anopheles* can be explained by two essential needs of the mosquito: feeding and reproduction. This behaviour coincides with the three phases of the gonotrophic cycle. The spatial heterogeneity of host–vector contact depends on the way in which land is used. The presence of humans, the existence of rest sites, and the availability of egg-laying sites are some of the principal reasons why mosquitoes settle in certain places. Human presence can condition vectors' choices[9].

An analysis grid was designed that listed predefined variables relating to lifestyle and other characteristics of the home environment that were potentially related to vector proliferation (Fig1), in connection with the essential needs of the mosquitoes (bite, egg-lay and rest). This grid was designed to support careful and systematic interpretation of the photographs and considers:

- population density ('number of people sleeping in the household' and 'isolated or grouped homes')
- potential egg-laying sites in terms of the availability of stagnant water. Grid variables included latrines, showers, rainwater recycling systems, hollow objects, palm factories, uncontrolled dumpsites, kitchen gardens, tanks and asperities in the ground (Fig2)
- potential resting sites and building materials. The different combination of building materials (Fig3) and potential rest sites (Fig4) were then highlighted and coded.

These items were then searched for in a corpus of photographs taken at each of the 64 concessions. Each concession was analysed using this grid to characterise the presence or absence of these items. These data were then used to characterise each household by calculating the percentage of occurrence of each item.

Taking photographs to interpret reality

The housing environment was investigated by using photography. Usually, vector-borne disease studies focus primarily on biomedical data. Social analyses generally follow as a second step. The development of an indirect method of data acquisition by using photography allows remote batch processing by specialists in the humanities, reduces the number of researchers in the field, and permits the application of both biomedical and human approaches at the same time. Photographs, (5-10, depending on the size of the concession) were only taken at sites where mosquitoes were captured. This facilitates ongoing work aiming to show a possible relationship between household types, their livelihoods, and the proliferation of *Anopheles*.

Characteristics of the house	Presence/absence in the yard
Building materials used in the house of mosquito capture: Nature of roof / Nature of wall / Nature of ground	**Recycling of rainwater:** Tank (how many? / Covered / Permanent or temporary roof) Jars to collect rainwater (How many?)
Number of openings of the house of mosquito capture: Number of windows / Number of doors / Air vents	**Hollow objects to collect rainwater:** Kitchen utensils / Dishpan Hollow objects that could serve as a shelter for larvae
Types of enclosure: Presence of enclosure / Nature of enclosure	**Asperities in the ground:** Use?
Showers: Indoor / Outdoor / In backyard	**Uncontrolled dump site:**
Kitchen: Indoor / Outdoor / In backyard Presence of shelter / Opened or closed shelter Nature of shelter's roof	**Kitchen garden:** Type
Latrines: With or without roof	**Vegetation:** Type
Around the housing environment (30 m)	
Presence or absence of: Tank / Abandoned hollow objects / Cultivated fields / Close vegetation / Uncontrolled dump site / Asperities in the ground / Palm wine factory	**Palm wine factory:** Protected by a shelter? **Abandoned red oil factory:** Protected by a shelter?
Occupation of the housing environment	
Number of persons sleeping in the home: **Animals:** Presence of animals Type of occupation (reserved areas / everywhere but inside the rooms / everywhere)	**Attic:** Nature of the attic?

Figure 1: Types of housing environment and living practices: explanatory variables of small-scale differential vulnerability.

The photographer first took a general panoramic photograph of the courtyard home before taking close-up photographs of every element related to the predefined study variables. It was also important to photograph all the sides of the house in order to collect comprehensive information about the building materials used in the walls and roofs and the number of openings such as windows, doors and air vents. The close neighbourhood of the houses was also photographed in order to assess the immediate surrounding environment. Photos were taken in landscape format to better represent the human field of view and highlight small objects. Lastly, the field researchers noted the geographical coordinates of the concession for possible future integration using a GIS, where these photographs could also be imported for a diachronic survey. In this way, characterization of the presence or absence of predefined items in each concession was used to determine household profiles that could be linked to entomological data according to hypothetical-deductive reasoning.

Entomological data

The entomological data relied on mosquito catches in 180 of the 400 children's bedrooms assessed in the program. It was physically impossible to follow the 400 houses. A selection of 180 bedrooms was made on the basis of geographical equidistribution criteria. CDC (Center for Disease Control) light traps were used on two consecutive nights per month between April 2011 and February 2013. The traps were installed at dark and collected at dusk. All mosquitoes were brought to the laboratory for identification (genus and species) and all *Anopheles* mosquitoes were kept individually for further analysis. Of the 64 concessions included in this study, the final focus was on the 51 concessions for which at least 22 nights of catches were available over a full year (a loss of two nights per year was allowed in order to maintain a sufficient number of homes for analysis). For each of these 51 concessions, the average number of *Anopheles gambiae* captured per night was calculated.

Statistics

A statistical analysis of habitat elements or livelihoods was carried out for the 64 concessions. First, an exhaustive survey of the presence or absence of each item listed in the grid was conducted. Then, the most frequent items in the territory studied were calculated using percentages to highlight the most discriminating elements. An overview of the coded concessions led to three classes of household being distinguished.

The average number of *Anopheles gambiae* captured per concession type was calculated. The association between these household types and the average number of *Anopheles* was analysed by the Kruskal–Wallis test, and analysis of covariance (ANCOVA) was performed to highlight relationships between the average number of *Anopheles* captured per night and the building materials used. Finally, the Pearson correlation coefficient was used to correlate the number of potential breeding sites and the average number of *Anopheles* caught. All analyses were carried out using XLSTAT v7.5 (Addinsoft, 2012, www.xlstat.com/en).

Ethics approval

The protocol was approved by the Beninese Ethical Committee of the Faculté des Sciences de la Santé (FSS) and the IRD Consultative Committee on Professional Conduct and Ethics (CCDE).

Results

General characterization of the analysed concessions and elements for typology

The detailed analysis of the photographic corpus using the items in the analysis grid revealed both shared and dissimilar elements between the concessions. This preliminary analysis allowed us to highlight the most discriminating features of the study area.

The most shared habitat elements in the 64 concessions were: the presence of a metal roof on the house (93.8%), absence of an enclosure (70.3%), a low number of discharges (uncontrolled dumpsites) (21.9%), the presence of attics (18.7%) and a low proportion of palm wine factories (1.6%) or palm oil factories (4.7%) (Tables 1,2). Similarly, certain living practices were quite common. Over two-thirds of the families left their kitchen utensils in the courtyard, which was unsurprising since the courtyard outside the home was generally used for cooking. Simple agricultural practice was rare in domestic areas. Only 6.3% of households had a kitchen garden. Crops were mainly found in the immediate surroundings around the homes but only 10% of households had cultivated fields immediately around their house. Over half of the families left the vegetation growing in their yard. The presence of banana trees in residential areas, in almost half of the households that had a garden, was particularly noted. The trees were generally found in isolated clumps and even when the household did not have a tree in their yard, it was very rare not to find at least a few banana trees in the vicinity of the house. It was common practice (92.2%) to cook outside in the courtyard with fire. When it rained, those without a shelter cooked inside their home. Open shelters with straw roofs were the most common. The showers were located outside in the courtyard, and were mostly roofless (93.1%) and made of palm leaves (37.9%).

In contrast to these widely shared characteristics, other household elements and living practices differed. Differences in the equipment level and the quality of the materials could potentially reflect the income level of the residents. For example, there was a clear distinction between concessions equipped with tanks (45.3%) and others. In the absence of an individual water supply in the concession, inhabitants had strategies to keep the rainwater but this kind of equipment is expensive and must therefore frequently be mutualized. In the same way, the construction materials used for the walls had variable characteristics. Houses made out of cement or brick were slightly better represented in the sample than those made of earth: 35.7% of walls were made of cement, 17.2% of brick and 37.5% of earth. Finally, two major types of dwelling were present in Allada: cement/brick or earthen houses, with cement or brick walls potentially reflecting less precarious households.

Figure 2: Examples of hollow objects likely to serve as vector-breeding sites.

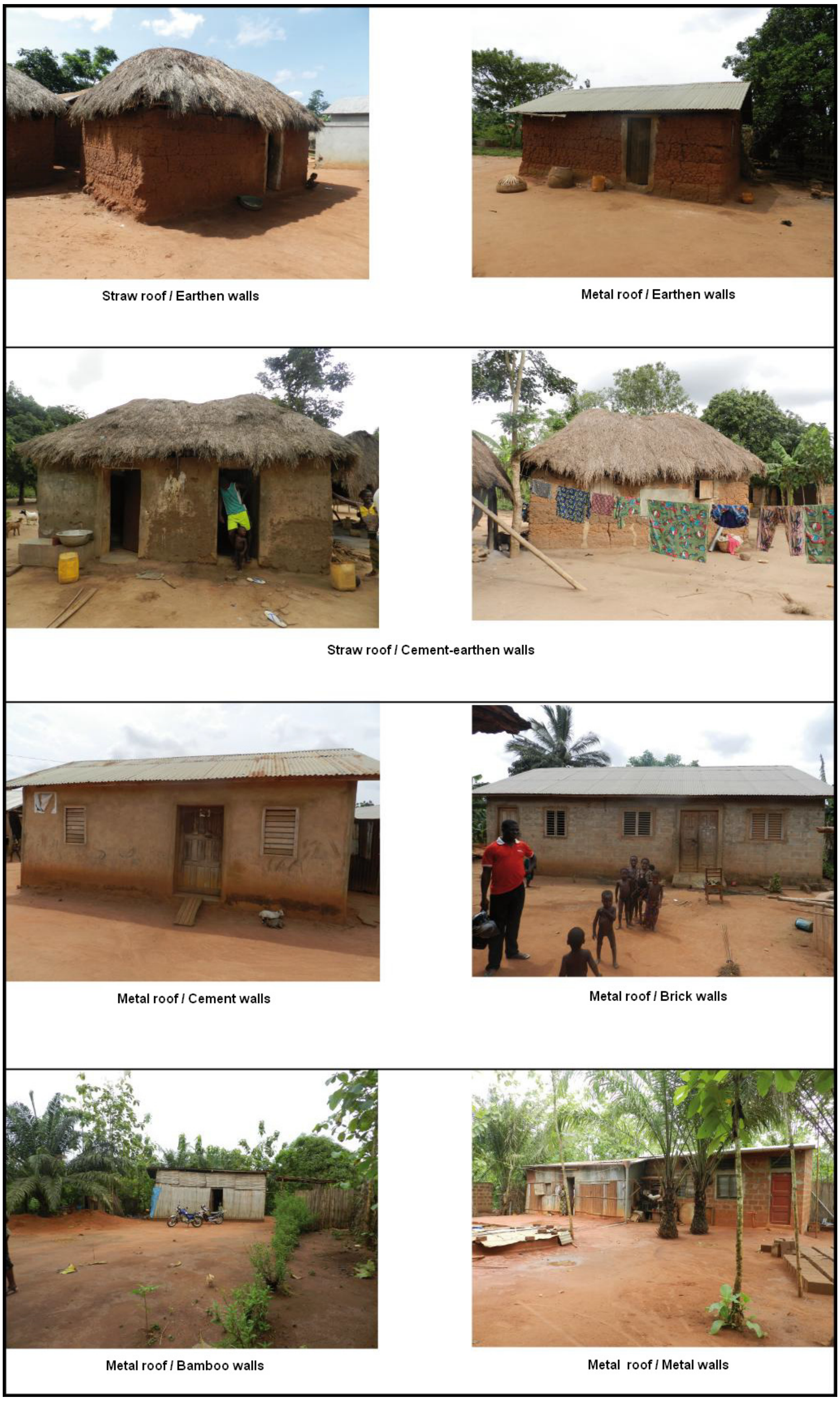

Figure 3: Diversity of the building materials used in the houses where mosquitoes were captured in the region of Allada.

Figure 4: Potential rest sites for mosquitoes in the yards of homes.

The different level of equipment led to three major habitat types being distinguished in the study area. Two extreme types could clearly be distinguished: type 1, very precarious with modest construction materials; and type 3, with hard construction materials, enclosed spaces, and covered water points. An intermediate type (type 2) was also apparent, which possessed a combination of several types of modest materials such as straw or hard (such as brick), with open spaces and uncovered water points.

Table 1: Descriptive statistics of variables related to the households

House of capture	%	Enclosure	%
Nature of walls		Enclosure present	
Earth	37.5	Yes	29.7
Cement and earth	6.2	No	70.3
Cement	35.7	Nature of enclosure	
Brick	17.2	Palm leaf	31.6
Bamboo	1.7	Cement	5.3
Metal	1.7	Brick	52.53
Nature of roof		Hedge	5.3
Straw	6.2	Bamboo	5.3
Metal	93.8	Shower	
Kitchen		With roof	6.9
Location		Without roof	93.1
Inside	6.2	Nature of walls	
Outside	92.2	Palm leaf	37.9
In backyard	1.6	Bamboo	10.3
Kitchen shelter		Cement	6.9
Present	76.6	Brick	8.6
Absent	23.4	Metal	3.4
Nature of kitchen shelter		Cloth	3.4
Open	71.7	Without structure	29.5
Closed	28.3	Latrines	
Nature of shelter roof		Present	27
Straw	6.5	Absent	73
Palm leaf	76.1	With roof	29.4
Metal	17.4	Without roof	70.6

Detailed analysis of the three types of concessions

The frequencies of each type of equipment per household type were summarized (Table 3). The first household type (*n*=28) is most precarious in terms of habitat type and lifestyle. It is generally defined by the combination of an earthen house with a metal roof, a shower without walls, and a shelter for cooking. The main building materials are palm leaves for the fence and straw for the roof of the kitchen's shelter. This type is also characterized by the opening up of living spaces, which can increase vulnerability to mosquito bites. The courtyard home has very few amenities: rarely a tank (29%), no visible latrines and jars being used to recycle rainwater. This type seems to be a fertile ground for the growth of mosquito larvae, but there are a smaller number of egg-laying sites due to the absence of certain kinds of equipment, such as a tank or a latrine. In contrast, there are resting sites, since the most commonly used building materials are earth, palm leaves and straw. Palm-leaf shower walls, a home's earthen walls and the kitchen's straw roof can be good repositories for mosquitoes.

The second household type (*n*=25) tends to be associated with wealthier families; 68% of the concessions are fenced by walls or hedges. Houses with hard wall materials (92%) are all covered with metal roof. A total of 60% of these concessions have tanks, the majority uncovered (64%). A small majority of these concessions are visibly equipped with latrines (52%). Type 2 appears to be the household type that is more conducive to the development of vectors. The presence of open tanks, latrines, roofless showers and kitchen utensils in the courtyard leads to an abundance of mosquito resting sites. Families living here would be more vulnerable to vector bites because the majority of living places (eg kitchen, shower, toilet) are open.

Table 2: Descriptive statistics of variables related to living practices in the region of Allada

Variable	%	Variable	%
Tank in yard		**Presence of uncontrolled dump site**	
Yes	45.3	Yes	21.9
No	54.7	No	78.1
Number of tanks		**Hollow objects in the yard**	
1	86.2	Kitchen utensils/dishpan	
2	10.3	Yes	68.7
3	3.5	No	31.3
Covered		**Kitchen garden**	
Yes	48.3	Presence of a kitchen garden	
No	51.7	Yes	6.3
Nature of tank roof		No	93.7
Temporary	28.6	**Vegetation in yard**	
Permanent	71.4	Presence of vegetation	
Jar in yard		Yes	54.7
Yes	20.3	No	45.3
No	79.7	**Animals**	
Number of jars		Presence of animals	
1	46.1	Yes	59.4
2	30.8	No	40.6
3	15.4	Location	
4	7.7	Reserved area	7.9
Factory in yard		Free	47.4
Abandoned red oil factory		Both	44.7
Yes	4.7	**Attic in the yard**	
No	95.3	Presence of attic	
Palm wine factory		Yes	18.7
Yes	1.6	No	81.3
No	98.4	Nature of attic	
Asperity in ground		Palm leaf	83.4
Holes in ground		Bamboo	16.6
Yes	20.3		
No	79.7		

The third household type (*n*=11) refers to a higher socioeconomic level of living; 82% of these concessions are enclosed by a fence. These exterior walls insulate the courtyard of the concessions, sometimes planted with ornamental species, from the public space. Houses with metal roofs are mostly made of hard materials (73%). A total of 55% of these households are equipped with one or two tanks covered permanently in 67% of cases. The outdoor showers are mainly walled (55%). Outdoor kitchens are all equipped with metal or straw roofs. Type 3 households seem less favourable to the development of vectors because the possibility of resting or egg-laying sites is smaller. Therefore, the walls of various elements of the home may not be conducive for the vector to rest. The living spaces are also closed off. Showers, latrines and tanks cannot be used as egg-laying sites because they have roofs.

Household types or their components and entomology

A first analysis of the average number of mosquitoes caught per night in each of the household types did not reveal a relationship between the number of mosquitoes and the social and material characteristics of the households. Based on the analysis of 51 concessions, the average number of mosquitoes captured per night was 0.55 in type 3, while the numbers were 0.88 and 0.85 mosquitoes/night for types 1 and 2, respectively, but these differences were not significant (Kruskal–Wallis test; p=0.41). An analysis combining types 1 and 2 (characterized by comparable anopheline densities) does not lead to more significant differences.

As well as categorization into three classes, a number of potential breeding sites were calculated for each concession, which corresponded to the sum of the number of jars, tanks, latrines, showers, and oil or palm wine factories in and around the concession. Analysis of correlation between the average number of *Anopheles gambiae* and the number of these potential breeding areas was not significant (r=-0.09, p=0.5).

Finally, a multivariate linear regression (ANCOVA) was performed to investigate the importance of the household materials and the number of openings on the average number of *Anopheles* captured per night. The results did not show any association between potential explanatory variables and the number of *Anopheles* captured per night (Table 4).

Discussion

This study attempted to identify the contribution of social and environmental factors to the risk of malaria associated with vector proliferation, which an analysis of the natural environment alone only partially explains. The way in which humans occupy the environment has resulted in a more comprehensive definition of 'environment' as 'the natural environment but also the environment built by humans'[21]. Etymologically, 'environment' is what is 'around' or what 'accompanies'. If the physical environment sets the context of what accompanies us, our anthropogenic creations also 'surround' us.

The analysis of living spaces using photography of 64 dwellings revealed three main types of household and living practices near Allada, where there is a diversity of habitat types and lifestyles. Mosquito control campaigns have shown that poorer lifestyles generate a malaria risk, since they tend to contain more areas with stagnant water and potential resting sites. This study, which has to be considered a pilot, is currently limited by the very small study sample; the sample cannot be claimed to be representative of the whole studied area. Nevertheless, the diversity of coded items within the study seems to encompass a large diversity of household/habitat types and modes of living.

The use of photography to capture the characteristics of neighbourhoods is not without limitations. The housing environment in Allada is very compact and it was therefore sometimes difficult to take pictures around certain houses since the photographer needed to invade the intimate space of other families whose houses did not form part of the study and who did not sign the initial consent form. It would also be desirable to analyse the elements of the environment close to the home by showing them together with the house, so that the distance separating them can be assessed. The development of the analysis grid is time-saving for research teams, and can be completed by the team in conjunction with the cohort. It can also be completed by geographers remotely who therefore do not necessarily have to be present when the digital photographs are transmitted via the internet. However, this approach can generate some interpretation bias: can the absence of animals in a photograph be generalized? Is a tank always or temporarily covered? Is it a jar or a kitchen utensil? Is it an earthen wall or mixed with cement? Only a subsequent review may help remove some of these potential misinterpretations.

Using local communities to collect photographic data using the Photovoice methodology could also identify other factors that increase malaria risk that the investigators did not consider *a priori*. The involvement of people to characterize their living using Photovoice is not novel. This methodology has, for example, recently been used to study the residential environment of the elderly in Atlanta (USA)[22], and this method of investigation needs further consideration in this context.

Table 3: Percentages of equipment per household type

Equipment	Type 1 (*n*=28) (%)	Type 2 (*n*=25) (%)	Type 3 (*n*=11) (%)
Enclosure	21	68	82
House			
Roof			
Metal	89	100	100
Straw	11	0	0
Walls			
Cement/brick	14	88	73
Earth	82	8	27
Metal	0	4	0
Bamboo	4	0	0
Tanks	29	60	55
Not covered	63	53	33
Covered	37	47	67
Permanent roof	0	57	100
Temporary roof	100	43	0
Outdoor shower	100	100	100
Walls	0	24	55
Metal	0	0	0
Bamboo	75	32	45
No walls	25	44	0
Roof	0	8	72
Latrines	0	52	27
Walls	0	90	100
Outside kitchen	100	100	100
Walls	0	16	36
Roof metal	4	8	45
Roof straw	39	52	55
No shelter	66	40	0
Kitchen garden	7	4	9
Ornamental plants	0	0	27
Animals	46	60	55
Dump sites	0	4	9

Table 4: **Relation between the mean number of collected *Anopheles* and the covariates (multivariate regression)**

Covariables	Value	*P*	95% confidence interval
Number of windows	-0.035	0.841	[-0.383; 0.314]
Number of doors	-0.067	0.694	[-0.407; 0.273]
Material of roof			
Straw	0.133	0.391	[-0.176; 0.442]
Metal	0.000		
Earth	0.449	0.389	[-0.592; 1.490]
Cement and earth	0.369	0.252	[-0.273; 1.011]
Cement	0.344	0.511	[-0.701; 1.388]
Brick	0.245	0.550	[-0.574; 1.064]
Metal	0.000		

The analysis appears to show a trend towards an increased number of mosquitoes, depending on the precariousness of the habitat. The lack of statistical significance may be a result of the small numbers studied. The continuation of this work in terms of more extensively coding habitats and more mosquito catches should lead to more definitive conclusions based on a larger sample size. There was also no correlation detected between potential breeding sites and average numbers of *Anopheles* captured and it is likely to be necessary to consider tanks and single abandoned jars differently using weighting to better consider their contribution to breeding and risk. The creation of a larger database will be of interest and will allow precise characterization of each of the 180 concessions equipped with CDC light traps. The ANCOVA analysis, despite the current lack of a detected relationship between entomological data and habitat characteristics, is a useful methodological start to analysing all the factors collected using the photographic analysis.

Conclusions

This pilot study on a sample of 64 concessions in a rural area of southern Benin has laid the methodological foundation for appraising the living conditions of local populations by using photography. This analysis demonstrates a high level of heterogeneity of amenities between the concessions, reflecting differential socio-economic conditions. Statistical analyses do not currently reveal significant relationships between entomological data and habitat characteristics or livelihoods, but further analysis is needed in a larger dataset.

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