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One health approch: Diversity of domestic larval habitats and human responsibility in mosquito proliferation in Bobo-Dioulasso (Burkina Faso)

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ABSTRACT

Larval control strategies recommended by the World Health Organization (WHO) require a comprehensive understanding of the distribution and typology of mosquito larval habitats. This study aimed to characterize larval breeding sites of vector-borne diseases and to assess key entomological parameters in Bobo-Dioulasso, Burkina Faso. Larval surveys were conducted in domestic environments across five districts of the city between 2022 and 2023, encompassing both the rainy and dry seasons. Standard entomological indices were calculated, and physicochemical characteristics of breeding sites, including pH and temperature, were measured to support the prediction and mitigation of potential epidemic risks. A total of 2,802 larval breeding sites were identified and classified into six habitat types, predominantly of anthropogenic origin, and were found to harbor *Aedes*, *Anopheles*, and *Culex* species. Larval density and species composition varied significantly across breeding site types. The widespread occurrence of larval habitats and the high level of mosquito proliferation appear to be driven primarily by inadequate environmental sanitation and human activities that create and maintain suitable breeding conditions. Monitoring mosquito density and entomological indicators is essential for tracking the spatiotemporal dynamics of vector-borne diseases. Overall, these findings provide critical evidence to inform and strengthen integrated vector control strategies in Burkina Faso.

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INTRODUCTION

Mosquitoes are major vectors of human pathogens and represent a substantial global public health concern. Among them, species of the genus *Aedes* are responsible for the transmission of several medically significant arboviruses, including yellow fever, dengue, Zika, and chikungunya viruses (Serge *et al.*, 2024). Dengue fever is currently the most widespread arboviral disease worldwide and is caused by four antigenically distinct serotypes (DENV-1, DENV-2, DENV-3, and DENV-4), all capable of infecting humans (Madewell, 2020).

Dengue virus transmission occurs predominantly in tropical and subtropical regions, with a strong predominance in urban and peri-urban environments (Sanou *et al.*, 2025).

Over recent decades, the global incidence of dengue has increased markedly. It is estimated that approximately 3.9 billion people living in 128 countries—nearly half of the world's population—are at risk of infection, with an estimated 390 million infections occurring annually across Africa, the Americas, the Eastern Mediterranean, Southeast Asia, and the Western Pacific regions (Miot *et al.*, 2020). The African region has experienced a growing epidemiological burden, with more than 220,000 dengue cases reported in 2020 alone (Madewell, 2020). Historically characterized by sporadic outbreaks in rural areas of sub-Saharan Africa (Nemg Simo *et al.*, 2018), dengue has increasingly emerged in urban centers, reflecting a notable shift in its epidemiological profile (Biré *et al.*, 2025). Consequently, large-scale outbreaks have been reported in several West and Central African countries, including Senegal, Burkina Faso, and Côte d'Ivoire, underscoring the rising public health importance of arboviral diseases in the region (Otshudiema *et al.*, 2025).

Burkina Faso has experienced recurrent dengue outbreaks, notably during the major epidemics of 2016 and 2017, which predominantly affected large urban centers such as Ouagadougou and Bobo-Dioulasso (Badolo *et al.*, 2022). Despite ongoing efforts to strengthen surveillance and response systems, several factors—including limited case management capacity, insufficient epidemiological and entomological surveillance, inadequate risk communication, and poor environmental sanitation—have contributed to the resurgence of dengue in 2023. Between January and October 2023, nearly 80,000 suspected cases and 349 deaths were reported nationwide. The Hauts-Bassins region, particularly the city of Bobo-Dioulasso, was the most affected, accounting for over 88% of probable cases reported during this period (Ministère de la Santé du Burkina Faso, 2023). In addition to dengue, sporadic cases of yellow fever persist despite vaccination efforts, and chikungunya virus circulation has been confirmed in both human populations and *Aedes* vectors in several localities.

Bobo-Dioulasso, the second-largest city in Burkina Faso, is undergoing rapid urbanization accompanied by profound environmental changes that favor mosquito proliferation (Ouattara *et al.*, 2019). Human activities such as inadequate water storage practices, poor solid waste management, and unplanned urban expansion generate numerous artificial larval habitats that facilitate the development of *Aedes* spp. Consequently, effective vector control requires not only improvements in environmental sanitation but also a detailed understanding of the ecological characteristics of larval breeding sites and the factors shaping vector distribution (Serge *et al.*, 2024).

Although Burkina Faso's national vector control strategy emphasizes community-based actions aimed at eliminating larval habitats, domestic and peri-domestic breeding sites remain widespread, and many natural habitats are difficult to access, providing *Aedes* mosquitoes with abundant oviposition opportunities (Ouédraogo *et al.*, 2022). In response to these challenges, the World Health Organization advocates for integrated vector management approaches that combine environmental management, improved sanitation, and strengthened entomological surveillance (Baragatti *et al.*, 2009; Inoussa *et al.*, 2025).

Despite these recommendations, significant gaps persist in understanding how environmental factors and larval habitat characteristics interact to influence the vectorial capacity of *Aedes aegypti*, particularly in urban settings that have recently experienced epidemics (Jaquet, 2024). In Bobo-Dioulasso, data on the bioecology and typology of larval habitats remain limited, yet such information is essential for optimizing targeted and sustainable vector control interventions.

Given that effective vector control depends on detailed knowledge of vector bioecology, this study aimed to characterize the typology and dynamics of arbovirus vector larval habitats and to examine human practices contributing to the creation and maintenance of breeding sites in Bobo-Dioulasso. The findings are expected to support evidence-based, integrated vector control strategies and to strengthen arbovirus prevention and control efforts in Burkina Faso.

MATERIALS AND METHODS

Type and duration of the study

This prospective, longitudinal, observational study was conducted within the framework of an entomological surveillance program in Bobo-Dioulasso, Burkina Faso, from August 2022 to July 2023. The study employed a purposive sampling approach and combined descriptive and analytical components to characterize the typology, diversity, and seasonal dynamics of mosquito larval habitats and examine the role of human activities in the creation, maintenance, and control of larval breeding sites.

Study area

The study was conducted in Bobo-Dioulasso (11°11′00″ N, 4°17′00″ W), located in Houet Province in western Burkina Faso. The city is a major cosmopolitan urban center and serves as an important commercial and transportation crossroads linking Burkina Faso with Côte d'Ivoire and Mali. Bobo-Dioulasso is the second-largest city in the country, with an estimated population of 984,603 inhabitants according to the most recent General Population and Housing Census (RGPH 2019).

Burkina Faso spans a gradient of climatic zones, ranging from pre-Sahelian conditions in the northern regions to a tropical climate in the south. Bobo-Dioulasso lies within the Sudanian climatic zone, which is characterized by pronounced seasonal variability. The dry and cool season extends from November to February, with mean temperatures of approximately 25 °C.

This is followed by a hot dry season from March to May, during which temperatures may reach 40–45 °C. The rainy season occurs from June to October and is associated with average temperatures of around 28 °C. These climatic conditions play a critical role in shaping mosquito breeding, survival, and seasonal population dynamics.

Choice of study sites

Five neighborhoods were selected for this study, comprising four urban sectors and one peri-rural site (Fig. 1). Site selection was based on purposive criteria, including high human population density, proximity to major entry points of the city, the presence of unmanaged solid waste, stagnant water bodies, and environmental conditions favorable to mosquito breeding. Within each selected neighborhood, households (concessions) were randomly sampled for larval surveys.

The urban sites included four sectors representing contrasting ecological and urbanization profiles. Sector 9, located in the city center, encompasses the Bobo-Dioulasso railway station (SITARAIL) and is characterized by dense housing and the presence of railway-related materials, abandoned wagons, and a large permanent water pool, all of which constitute potential larval habitats for *Aedes* mosquitoes. Sector 22 includes an informal settlement area with dense vegetation and intense anthropogenic activity. This sector borders the National Culture Week (Semaine Nationale de la Culture, SNC) site, which periodically attracts large numbers of visitors from across Africa and beyond, potentially increasing the risk of arbovirus circulation and underscoring the need for entomological surveillance. Sector 26 is a recently inhabited area undergoing rapid urban expansion, where intense human activities are transforming the local environment and likely influencing mosquito distribution and breeding dynamics. Sector 6 is intersected by the Houet backwater and is characterized by urban gardening activities; however, it also serves as an informal dumping site for solid waste and wastewater runoff, creating favorable conditions for mosquito proliferation.

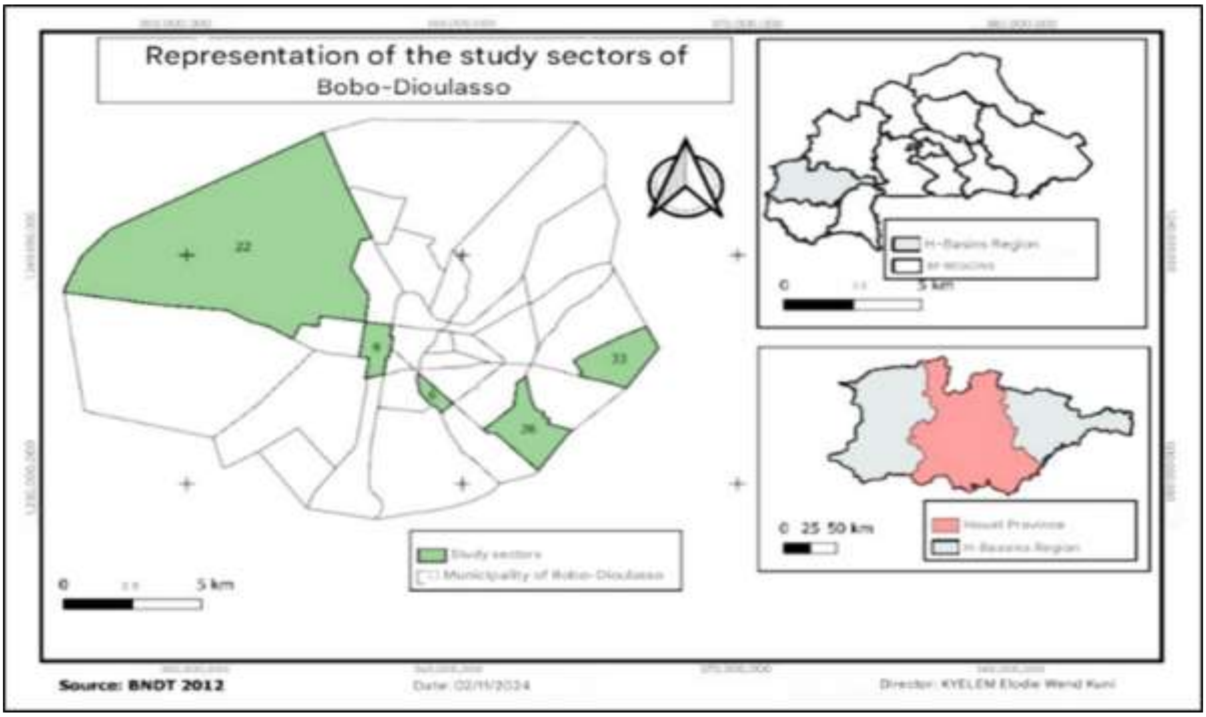

Fig. 1. Study sites

Aedes aegypti, the primary urban arbovirus vector, breeds throughout the year mainly in domestic water storage containers (e.g., jars, basins, flower pots) and peridomestic habitats (e.g., discarded containers, used tires, and anthropogenic waste). Its population density typically increases during the rainy season and in densely populated central neighborhoods, making these urban sectors particularly relevant for surveillance.

The peri-rural site corresponded to Sector 33 (Fig. 1), the first settlement located approximately 15 km from Bobo-Dioulasso along the Bobo-Dioulasso-Ouagadougou road.

This site was selected to capture the urban–rural gradient in environmental conditions and vector ecology. As in other West African cities, Bobo-Dioulasso exhibits marked contrasts between planned (subdivided) neighborhoods, characterized by regular road networks and access to basic urban services, and unplanned or informal areas, which lack formal infrastructure and urban planning. Housing construction also differs between these settings, with cement-built houses predominating in planned areas and mud-built houses more common in informal settlements, potentially influencing water storage practices and the availability of larval habitats.

Data collection

Household survey

From August 2022 to July 2023, six bi-monthly entomological field missions were conducted in the selected study sites. Each mission included community sensitization activities focusing on personal protection against mosquito bites and environmental management practices aimed at reducing larval breeding sites. These activities were followed by structured household surveys and data collection using standardized questionnaires administered via electronic tablets.

Household surveys were carried out in a total of 1,413 households across the five study sectors, representing 3,753 sleeping spaces and an estimated population of 402,753 inhabitants. Data collected included household characteristics, water storage practices, environmental sanitation conditions, and potential mosquito breeding sites. The number of households surveyed varied according to the study site and the survey period, reflecting differences in accessibility and seasonal dynamics.

Aedes spp. larvae

Larval surveys were conducted bimonthly from August 2022 to July 2023. During each survey round, thirty (30) households per neighborhood were systematically inspected. In total, one hundred and twenty (120) households were surveyed across the four selected urban neighborhoods of Bobo-Dioulasso (30 households per neighborhood). The peri-rural site (Sector 33) was surveyed using the same protocol, with thirty (30) households sampled, ensuring comparability with urban sites (Fig. 2).

Fig. 2. Collection of larvae in domestic breeding sites in Bobo Dioulasso, June 2023 (Diversity of larval breeding sites discovered around the houses surveyed.)

At each household visit, all potential mosquito breeding sites, including indoor and outdoor water-holding containers, were inspected following World Health Organization (WHO) guidelines for larval surveillance and the Breteau Index protocol. Geographic coordinates and physical and physicochemical parameters of each breeding site were recorded using a Global Positioning System (GPS) device and a water parameter tester (WPT).

Larvae and pupae were collected from all positive containers. Water from each container was sampled using a standard ladle and transferred into labeled jars. For small-volume or narrow containers, the entire water content was collected. Samples were subsequently filtered through a fine mesh sieve, rinsed with distilled water, and transferred into labeled containers. Larvae were counted and classified by genus and developmental stage.

For each household, data were recorded on the number of occupants, sleeping spaces, and water-holding containers. Breeding sites were categorized as natural or artificial, and as positive or negative. A breeding site was considered positive when at least one mosquito larva or pupa was present, and negative when stagnant water was present but no immature stages were detected. The number of positive and negative breeding sites, as well as the total number of larvae and pupae collected, were documented for each survey round.

Laboratory activities

Mosquito larvae rearing and identification

Collected larvae were reared in the insectary using plastic trays (30 × 25 × 5 cm) filled with borehole water to a depth of approximately 4 cm. Averages of 20 larvae were placed in each tray to avoid overcrowding. Larvae were fed daily with finely ground Tetramin® fish food. Pupae were collected daily and transferred into separate containers, then placed in emergence cages until adult eclosion.

Emerging adult mosquitoes were provided with a 10% glucose solution and maintained for subsequent experimental procedures. Larvae were initially identified to the genus level under a stereomicroscope, and larval and pupal densities per breeding site were recorded. Rearing was conducted under controlled insectary conditions, with a temperature of 27 ± 2 °C and relative humidity of 80 ± 10%.

Adult mosquitoes were morphologically identified using standard taxonomic keys, and only specimens confirmed as *Aedes aegypti* were used or kept for other scientific research purposes.

Data management and statistical analysis

Data were collected between August 2022 and June 2023 during field surveys. Household- and entomological-level data were captured electronically using standardized questionnaires developed on the KoboToolbox platform and administered via the ODK KoboCollect application (version 2024.1.3) on Android tablets equipped with integrated GPS (Samsung Galaxy Tab 7.0 Plus). Geographic coordinates of all surveyed households were recorded to enable spatial analyses and mapping of larval habitats.

Environmental and physicochemical parameters of breeding sites, including temperature and pH, were measured in situ using a water parameter tester (WPT). Each household was characterized based on environmental conditions, housing characteristics, water storage practices, and demographic information (number of occupants, number of sleeping spaces).

Photographic documentation of breeding sites was also collected. All data were transmitted via a secure internet connection to a centralized server and protected by access codes.

Entomological indices were calculated according to WHO guidelines (1972, 2012) guidelines ((Djiappi-Tchamen *et al.*, 2021).

Data cleaning, organization, and preliminary analyses were conducted using Microsoft Excel 2019. Statistical analyses were performed using SPSS software, including the calculation of entomological indices and descriptive statistics. Data normality was assessed using appropriate post-hoc tests (Bonferroni or Dunnett tests, where applicable). Multiple statistical comparison (multiple comparisons performed using Duncan's post hoc test) was used after an analysis of variance (ANOVA). Distribution data which contains counts and percentages was not suitable for ANOVA. The approximations of the chi-square test or Fisher's exact test was used.

Spatial distribution maps of larval habitats and survey sites were generated using QGIS software version 3.30. The manuscript was prepared using Microsoft Word 2019.

RESULTS

Population density in the study areas

A total of 1,376 households were surveyed across the five study sites, of which 1,283 contained at least one mosquito breeding site (positive) and 93 had none (negative). These households comprised 3,675 sleeping spaces and an estimated population of

377,146 inhabitants. Household occupancy varied by sector and over time, with Sector 33 being the most densely populated (25%), followed by Sector 26 (21%), Sector 6 (20%), and Sectors 9 and 22 (17% each) (Fig. 3).

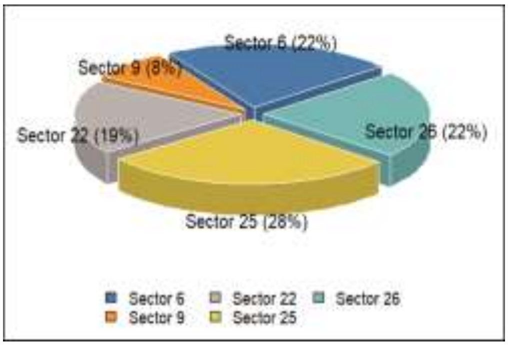

Fig. 3. Percentage of individuals per concession by sector and per month

Larval breeding sites

Bimonthly surveys conducted over a 12-month period resulted in the inspection of 2,802 potential larval breeding sites, including 1,889 during the rainy season and 913 during the dry season, averaging approximately two containers per household. Among these, 558 sites were positive for mosquito immature stages, while 2,244 sites were negative. During the rainy season, 539 of 1,889 surveyed sites were positive, whereas only 19 of 913 sites were positive in the dry season, highlighting the strong seasonal variation in larval habitat occupancy.

Quantitative and qualitative characterization of larval breeding sites

Bimonthly larval surveys conducted over a 12-month period resulted in the inspection of 2,802 potential breeding sites, including 1,889 during the rainy season and 913 during the dry season. Among these, 558 sites were positive for mosquito immature stages, yielding a total of 9,103 larvae and 920 pupae across all study sites. During the rainy season, 539 of 1,889 sites were positive, compared with only 19 of 913 sites during the dry season, highlighting marked seasonal variation in larval habitat occupancy (*F*_value = 16.86; Df = 4; *Pr*(>F) < 0.001). The remaining 2,244 sites were classified as negative.

Larval productivity was influenced by several environmental factors. *Aedes* spp. larvae showed a preference for habitats with slightly alkaline pH values (7.2–8.3) and relatively high temperatures, whereas *Anopheles* larvae were more common in slightly acidic conditions.

Random larval surveys of household containers in each sector revealed that during the dry season, rural households contained 1,783 potential containers compared with an average of 1,580 in urban areas. During the rainy season, these numbers increased to 2,747 containers in rural areas and an average of 1,990 in urban areas, regardless of container type. On average, the larval density was higher in rural areas (2.18 larvae per container) than in urban areas (≤1.977 larvae per container), with statistically significant differences between sectors (*F*_value = 56.25; Df = 4; *Pr*(>F) < 0.001). Seasonal comparisons also indicated a significantly higher larval abundance during the rainy season (2.126 larvae per container) compared with the dry season (1.669 larvae per container) (*F*_value= 250.03; Df = 1; *Pr*(>F) < 0.001) (Table 1).

As shown in Table 2, the total number of larval breeding sites was substantially higher during the rainy season, with a pronounced predominance in urban areas, which accounted for 68.6% of all recorded breeding sites, compared with 31.4% in rural areas. Abandoned household containers constituted the most frequent breeding site type (59.8%), followed by general household waste (17.9%). The distribution of larval breeding site types differed significantly between rural and urban settings (*X*-squared = 17.279, df = 5, *p-value* = 0.004).

This distribution highlights contrasting patterns in habitat availability and use between these two environments.

The high density of breeding sites in urban settings is likely attributable to the accumulation of objects capable of retaining rainwater, thereby creating favorable conditions for mosquito development.

These findings underscore the rainy season as a critical period for mosquito population expansion, particularly in densely populated and highly anthropized environments.

Analysis of Table 3 indicates that the total number of larval breeding sites was lower during the dry season than during the rainy season, although the spatial distribution across study areas remained largely unchanged (Fisher's Exact Test; *p-value* = 0.002). Urban areas continued to account for the majority of breeding sites (68.5%), highlighting the persistence of artificial habitats that are not directly dependent on rainfall.

Table 1. Number of breeding sites per sector per season

Season	Sector 6	Sector 9	Sector 22	Sector 26	Sector 33	Total
Rainy season	2,145ad	1,969abcd	2,033a	1,803bd	2,747c	2,126a
Dry season	1,644b	1,868ab	1,364	1,447	1,783b	1,669b
Total	1,977ab	1,910ab	1,806b	1,664	2,180a	1,92

The letters (a, b, c, d) appearing next to the values in the table indicate the results of multiple comparisons performed using Duncan's multiple range post hoc test following analysis of variance (ANOVA). Values sharing at least one letter are not significantly different, whereas values with no letters in common differ significantly at the selected significance level (*p*-value < 0.001).

Table 2. Number of larval breeding sites recorded at the study sites during in rainy season

	Vehicle wrecks	Construction equipment	Household waste	Discarded utensils	Animal husbandry equipment	Vegetation	Total	Percentage
Rural	96	11	111	338	30	7	593	31,39%
Urban	168	5	227	792	77	27	1296	68,61%
Total	264	16	338	1130	107	34	1889	100
Percentage	13,98%	0,85%	17,89%	59,82%	5,66%	1,80%	100	

Table 3. Number of breeding sites recorded at the study sites during in dry season

	Vehicle wrecks	Construction equipment	Household waste	Discarded utensils	Animal husbandry equipment	Vegetation	Total	Percentage
Rural	1		25	235	27		288	31,54%
Urban	25	1	78	455	65	1	625	68,46%
Total	26	1	103	690	92	1	913	100
Percentage	2,85%	0,11%	11,28%	75,58%	10,08%	0,11%	100	

Abandoned household containers remained the most prevalent type of breeding site, representing 75.6% of positive sites. This finding suggests that, even in the absence of substantial rainfall, certain containers provide favorable microhabitats for mosquito development. These results underscore the permanent nature of artificial breeding sites, particularly in urban environments, and their role in sustaining mosquito populations throughout the year.

In addition, breeding sites were observed in construction equipment and surrounding vegetation within urban areas, whereas such habitats were scarce or absent in rural settings. A high number of abandoned vehicle wrecks were also recorded in urban sites, further contributing to the availability of larval habitats, in contrast to rural areas where such structures were largely absent.

Among the 558 positive larval habitats identified across all study sites, a total of 9,103 larvae and 920 pupae were collected. *Aedes* spp species were the dominant genus, occurring in 57.1% of positive habitats, followed by *Culex* spp species (30.2%). Mixed breeding sites, containing larvae from multiple genera, accounted for approximately 13% of positive habitats, indicating coexistence of different mosquito genera within certain containers. The distribution of larvae, pupae, and breeding sites showed marked variation among mosquito genus (*Aedes* spp, *Anopheles* spp and *Culex* spp) (Fisher's Exact Test; *p-value* < 0.001), indicating genus-specific patterns in larval abundance and habitat utilization.

The high proportion of larvae (86.0%) relative to pupae reflects active larval development and ongoing mosquito reproduction in the surveyed habitats. The predominance of *Aedes* underscores its major epidemiological significance in the study area and highlights its role as the principal vector of arboviruses (Table 4).

Table 4. Number of positive breeding sites, larvae and pupae by mosquito genus

	Number of larvae	Nomber of pupae	Number of breeding	Total	Percentage
Aedes spp	4998	635	409	6042	57,10%
Culex spp	2930	175	94	3199	30,23%
Mixed (*Aedes* spp + *Culex* spp)	1095	110	50	1255	11,86%
Mixed (*Aedes* spp + *Culex* spp + *Anopheles* spp)	50	0	3	53	0,50%
Mixed (*Culex* spp + *Anopheles* spp)	30	0	2	32	0,30%
Total	9103	920	558	10581	100
Percentage	86,03%	8,69%	5,27%	100	

Table 5. Number of positives breeding site per type and per species

	Vehicle wrecks	Construction equipment	Household waste	Discarded utensils	Animal husbandry equipment	Vegetation	Total	Percentage
Mixed	6	1	2	12	1	0	22	8,91%
Anopheles spp	2	0	0	1	0	0	3	1,21%
Culex spp	12	1	9	30	4	2	58	23,48%
Aedes spp	39	1	22	88	11	3	164	66,40%
Total	59	3	33	131	16	5	247	100
Percentage	23,89%	1,21%	13,36%	53,04%	6,48%	2,02%	100	

Analysis of the data (Table 5) showed that positive larval breeding sites were predominantly occupied by *Aedes* mosquitoes, which accounted for 66.4% of all identified sites, followed by *Culex* species (23.5%). Mixed breeding sites, containing multiple genera, represented 8.9%, while sites exclusively positive for *Anopheles* were scarce (1.2%). Although different mosquito species were identified, data analysis did not reveal a significant association with the distribution of positive breeding site types (Fisher's Exact Test; *p-value* = 0.864), indicating that the use of larval habitats is generally comparable across the observed species.

Abandoned household containers were the most common breeding sites, accounting for 53.0% of positive habitats, highlighting their major role in supporting mosquito proliferation, particularly for *Aedes*. In contrast, construction equipment and vegetation contributed minimally to larval site formation. This pattern underscores the significant influence of human activity and inadequate waste management on mosquito reproductive dynamics and the maintenance of urban vector populations.

Entomological indices

Entomological indices were calculated following WHO guidelines. The House Index (HI), representing the percentage of houses with at least one *Ae. aegypti* positive container, was 93.2% (1,283/1,376). The Container Index (CI), reflecting the proportion of positive breeding sites among all water-holding containers, was 19.9% (558/2,802). The Breteau Index (BI), defined as the number of positive breeding sites per 100 houses, was 5.58, which falls within the WHO density scale of 1–9.

Additional indices indicated high mosquito productivity. The larval density index averaged 37.52 larvae per house, and the nymphal index averaged 15 pupae per house. While most indices were within the WHO recommended range (1–9), the larval and nymphal indices were notably higher, highlighting intense breeding activity across the study areas.

DISCUSSION

This study surveyed 1,376 households (93 negative and 1,283 positive), encompassing 3,675 sleeping spaces and an estimated population of 377,146 inhabitants across five localities in Bobo-Dioulasso. Six bimonthly entomological missions were conducted over a one-year period, integrating community awareness activities on personal protection and environmental management with systematic larval surveys. The study primarily aimed to identify and characterize mosquito breeding sites, assess larval productivity, and evaluate the susceptibility of emerging adult mosquitoes to chemical insecticides. Entomological parameters were analyzed in relation to seasonality (rainy versus dry seasons), environmental setting (urban versus rural), and breeding site typology (Montgomery *et al.*, 2025).

Marked differences in population density, household size, and sleeping arrangements were observed among study sites, reflecting variations in housing structures, lifestyles, and sociocultural practices. In peripheral sector 33, which retains a semi-rural, village-like structure, indigenous populations typically live in large extended family units, resulting in multiple households per compound and high occupancy rates (Rossier *et al.*, 2012).

Conversely, urban sectors were predominantly inhabited by migrants seeking employment, who generally lived in smaller households or alone. These demographic patterns influence the number of sleeping spaces and the use of mosquito nets, both of which are key determinants of vector–human contact and disease transmission risk.

Larval productivity and breeding sites

The findings underscore the central role of larval habitat availability in arbovirus transmission dynamics. Mixed breeding sites were frequently observed, reflecting the coexistence of multiple mosquito genera within the same aquatic habitats. The high larval-to-pupal ratio observed across sites indicates active larval development and substantial productivity. *Aedes aegypti* exhibited a marked preference for slightly alkaline breeding sites (pH 7.2–8.3) with elevated temperatures, corroborating its established role as the primary vector of dengue and chikungunya viruses in Burkina Faso (Ouédraogo *et al.*, 2022).

Mosquito abundance and spatial distribution were closely associated with the availability of suitable larval habitats, particularly in urban environments. Anthropogenic containers—including domestic water storage vessels, discarded household items, and unmanaged waste—provided optimal conditions for mosquito development. These results highlight the dominant influence of human activities on vector ecology, especially in densely populated and highly anthropized settings (Damuna *et al.*, 2025; Ouédraogo *et al.*, 2024). The close proximity of breeding sites to human dwellings substantially increases vector–human contact, thereby elevating the risk of arbovirus transmission.

A wide diversity of breeding sites was documented, including gutters, household utensils, livestock containers, vehicle wrecks, construction equipment, and vegetation-related habitats.

Gutters were frequently recorded as negative sites, possibly due to water flow dynamics or lower suitability for *Aedes* oviposition. Vegetation-associated habitats, such as watering cans and tree holes, reflected urban agricultural practices, particularly in central districts (Atangana *et al.*, 2012). Abandoned tyres and small neglected containers were among the most productive *Ae. aegypti* breeding sites, as they readily collect and retain rainwater. Household utensils—such as handwashing containers introduced during COVID-19 prevention campaigns and vessels used for local beverage production (e.g., dolo)- also contributed substantially to larval proliferation (Olive *et al.*, 2020).

The near absence of *Anopheles* larvae in domestic environments is consistent with their preference for different aquatic habitats. When present, *Anopheles* larvae were typically found in mixed breeding sites alongside *Aedes* and *Culex*, illustrating species-specific habitat selection and ecological adaptability (Lushasi *et al.*, 2024). Although *Culex* species are of lesser epidemiological relevance for dengue and chikungunya, their presence contributes to nuisance biting and serves as an indicator of environmental conditions favorable to mosquito proliferation.

Seasonal dynamics

Longitudinal surveillance revealed pronounced seasonal variations in mosquito abundance. Vector populations peaked during the rainy season, particularly between September and October, while a substantial decline in positive *Aedes* breeding sites was observed during the dry season. Nevertheless, urban areas continued to harbor breeding sites, mainly abandoned containers and livestock-related vessels, demonstrating the species' strong adaptation to anthropogenic environments. Rainfall generates numerous temporary breeding sites, whereas dry-season conditions compel mosquitoes to rely on permanent, human-made habitats, highlighting their ecological resilience and adaptive capacity (Noura *et al.*, 2024).

Urban sectors, notably sectors 9 and 22, exhibited the highest densities of larval habitats and adult mosquitoes. This pattern correlated with high population density, intensive human activity, and extensive environmental modification. Commercial and industrial zones containing water-retaining objects—such as tyre depots, container yards, and areas of industrial water discharge—further promoted *Aedes* proliferation. These findings reinforce the need for targeted environmental management and sustained community engagement as core components of vector control strategies (Deepa *et al.*, 2023).

Entomological indices and vector risk

High larval productivity during the rainy season was strongly associated with both the abundance and diversity of breeding sites. Seasonal rainfall enhances water retention in a wide range of containers and microhabitats, creating optimal conditions for mosquito development (Danks, 2006). During the dry season, the desiccation of temporary habitats concentrates mosquito populations in permanent or neglected containers. Physicochemical parameters, particularly water temperature and pH, were positively correlated with larval productivity, underscoring the importance of microenvironmental conditions in mosquito bioecology (Hessou-Djossou *et al.*, 2022).

Entomological indices—including the House Index (HI), Container Index (CI), Breteau Index (BI), and larval and pupal densities—varied significantly between urban and rural settings, reflecting the central role of domestic water storage, household utensils, and waste in sustaining larval populations. These indices are essential tools for dengue surveillance and for assessing the effectiveness of vector control interventions (Lecollinet *et al.*, 2022). Elevated larval and pupal indices likely served as early warning indicators of the dengue epidemic that emerged in 2023. Targeted control measures implemented during periods of high vector abundance can significantly reduce these indices, enabling health authorities to anticipate and mitigate outbreak risks.

Implications for vector control

The predominance of *Ae. aegypti* and *Culex* species underscores the urgent need to strengthen integrated vector management strategies in Bobo-Dioulasso. Effective control should prioritize environmental management, community participation, systematic elimination of artificial breeding sites, and judicious insecticide application guided by resistance surveillance. Addressing anthropogenic drivers—such as inadequate waste management, improper water storage, and unplanned urbanization—is critical to reducing vector densities and limiting arbovirus transmission in rapidly expanding urban settings (Inoussa *et al.*, 2025; Verma *et al.*, 2025).

CONCLUSION

This study provides a comprehensive characterization of *Aedes aegypti* larval habitats, their density, specificity, and spatiotemporal dynamics in Bobo-Dioulasso. *Aedes* mosquitoes were found to exploit a wide range of domestic and peri-domestic breeding sites, with a marked preference for artificial containers such as tyres, cans, handwashing basins, and flowerpots.

Larval productivity was strongly influenced by physicochemical factors, particularly slightly alkaline water (pH 7.2–8.3) and elevated temperatures. Clear seasonal patterns were observed, with peak larval abundance during the rainy season, while permanent breeding sites sustained mosquito populations throughout the dry season.

Overall, this entomological surveillance highlights the central role of anthropogenic habitats in *Aedes* proliferation and provides critical evidence to support targeted and context-specific vector control strategies. Strengthening environmental management practices, improving public awareness of mosquito biology, and promoting personal protective measures against mosquito bites are essential components of sustainable arbovirus prevention.

Future research should incorporate insecticide susceptibility testing to better characterize resistance profiles in *Aedes* populations and to inform the design and implementation of effective, evidence-based vector control interventions.

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