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First Comprehensive Assessment of *Aedes aegypti*, Bio-Ecology, Spatial Distribution and Arbovirus Transmission in Niger

Maiga Seydou Oumarou Ramatoulaye[1,2], Iro Souleymane[1], Mamane Salé Noura[1,3*], Ibrahim Issa Arzika[1], Olivier Manigart[4,5], Lagaré Adamou[1], Diallo Mawlouth[6], Ibrahim Maman Laminou[1,3], Athanase Badolo[2]

[1]Unité de Paludologie et d'Entomologie Médicale, Centre de Recherche Médicale et Sanitaire de Niamey (CERMES), Niamey, Niger
[2]Department of Biology and Animals Physiology, University of Joseph Ki Zerbo (UJKZ), Ouagadougou, Burkina Faso
[3]Département de Biologie, Faculté des Sciences et des Technologies, Université Abdou Moumouni de Niamey (UAM), Niamey, Niger
[4]West African Health Organization (WAHO), Abidjan, Cote d'Ivoire
[5]Gembloux Agro Bio-Tech, ULiège, Liège, Belgium
[6]Pole Zoologie et Entomologie Médicale de l'Institut Pasteur de Dakar (IPD), Dakar, Sénégal
Email: *sale.noura@cermes.org

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Abstract

Introduction: Arboviruses, transmitted mainly by the *Aedes aegypti* (*Ae. aegypti*) mosquitoes, represent a major global public health issue. The scale of the problem has been amplified by climate change, urbanization and human mobility. In Niger, 308 cases of Yellow Fever, Zika and Chikungunya have been reported since 1960, and the recent detection of Dengue virus in Niamey highlights the need for rigorous surveillance. **Objectives:** The objectives of this study were to describe the bio-ecology of *Ae. aegypti*, assess stegomyian indices and to monitor the potential circulation of dengue virus (DENV), Zika virus (ZIKV), yellow fever virus (YFV) and chikungunya virus (CHIKV) in Niger. **Methodology:** A descriptive and analytical longitudinal study was conducted in ten localities of Niger between January and December 2023 to investigate the spatial and temporal dynamics of *Aedes* mosquitoes and arbovirus circulation. Various devices (Ovitraps, BG Sentinel, prokopack, domestic larval surveys) were used to capture mosquitoes. Larvae were collected for estimation of stegomyian Indices (Container, Habitats and Breteau Indices) through WHO guideline. After morphological identification, some adults were randomly selected and tested by RT-PCR for DENV, ZIKV, YFV and CHIKV viruses. **Results:** *Aedes* spp eggs were detected in all 7/10 sites. The Stegomyian indices were above the WHO thresholds in Niamey and Gaya. A total of 7308 mosquitoes were collected dominated by Culex 73.1% (5344/7308), followed by *Aedes* 12.35% (903/7308), using BG traps and prokopack. Of these,

only *Ae. aegypti* were recorded, and no *Aedes albopictus* were observed. Specifically, regarding the *Aedes* species, Niamey recorded the highest abundance 46.2% (417/903), followed by Tessaoua 19.3% (174/903). Host-seeking activity assessed using BG traps showed higher outdoor activity in Niamey and Gaya. However, no arboviral infection was detected in any of the mosquitoes tested. **Conclusion:** *Aedes aegypti* is widely established in Niger, with Niamey and Gaya representing priority areas for surveillance and vector control. The findings from Tessaoua suggest that reliance on domestic larval surveys alone may underestimate arbovirus transmission risk emphasizing the importance of incorporating public and peri-domestic habitats into surveillance programs.

Keywords

Assessment, Bioecology, Spatial, Distribution, *Aedes aegypti,* Arbovirus, Niger

1. Introduction

Aedes aegypti (*Ae. aegypti*) is the vector of several arboviruses, including yellow fever, chikungunya, Dengue and Zika [1]-[9].

Aedes aegypti is also widespread throughout the world and has developed a strong capacity to adapt to urban areas [10]. Its expansion is also facilitated by international movements through trade, human mobility, and unstructured galloping urbanisation leading to the creation of breeding sites favourable to the development of the mosquito [11].

In sub-Saharan Africa, epidemics caused by emerging and re-emerging arboviruses such as yellow fever, Rift Valley fever (RVF), dengue and Zika virus disease have been reported in recent years [12]. The most recent arboviruses outbreaks include RVF in Niger [13], dengue fever in Burkina Faso in 2016 and 2022 [14] and in the regions of West Africa where it is the most common arboviruses [15], Zika in Cape Verde [16] and yellow fever in Ghana and Nigeria [17] [18].

In the absence of a specific treatment and an effective vaccine [19], control of these diseases is based essentially on vector control. However, vector control faces enormous problems, such as the lack of consistent data on the behaviour and bioecology of vectors and the arboviruses they transmit in Africa, which seriously weakens the effectiveness of control interventions. Appropriate control strategies still need to be implemented [8] [14].

Because of its geographical position, Niger is one of the countries at risk from these arboviruses according to the WHO. This was confirmed by the detection of the KOUTANGO arbovirus (WN-KOUTV) in sandflies, a highly virulent lineage of West Nile virus, collected during the recent RVF epizootic in 2016 by Gamou & *al. Aedes aegypti* proved to be a competent vector for transmission after a blood meal with a high viral dose, suggesting that this species of mosquito could probably transmit the WN-KOUTV lineage to humans [20]. It has also been shown that

Aedes aegypti could transmit this virus vertically [21].

Niger had its first autochthonous cases of detected arboviruses in 1963 then 2024, antibodies IGG to Yellow Fever, Zika, and Chikungunya viruses were detected in Tera, as well as viral RNA for the Dengue virus in native subjects Niamey areas [22] [23].

Although the presence of *Aedes aegypti* has been demonstrated in Niger, data on the bioecology, ethology and circulation of arboviruses remain limited. These gaps can be explained by several factors: (1) A lack of knowledge about the syndromic diagnosis of these arboviruses among health personnel; (2) The unavailability of appropriate techniques for detecting these arboviruses; (3) The lack of reporting of symptomatic cases, particularly in remote areas, due to the similarity of symptoms to yellow fever, hepatitis and other febrile illnesses; (4) The almost total absence of longitudinal entomological data [1]. This study aims to fill some of these gaps by characterizing the bio-ecology of *Aedes aegypti* in Niger and assessing the potential circulation of Dengue (DENV), Zika (ZIKV), Yellow Fever (YFV) and Chikungunya (CHIKV) viruses.

Unfortunately, however, this situation affects the whole of West Africa, where there is currently no longitudinal data on the bio-ecology of this vector. The rare data available on this species come from specific, one-off surveys of yellow fever outbreaks.

Vector control being the only alternative for controlling these vectors, this study aims to provide a comprehensive assessment of bio-ecology, stegomyian indices (Breteau Indices BI; Habitat Indices HI and Container Indices CI), spatio-temporal distribution and arbovirus such as DENV, ZIKV, YFV and CHIKV of *Aedes aegypti* across multiple ecological settings in Niger.

2. Methodology

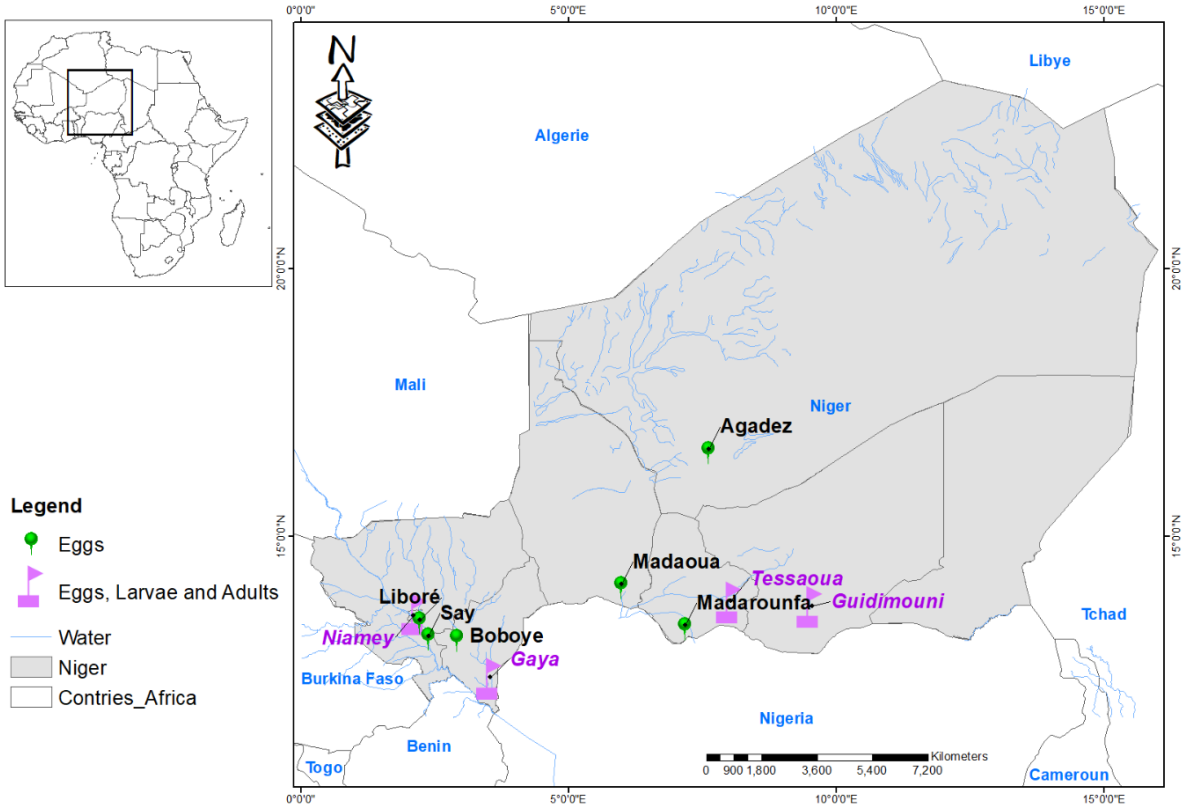
2.1. Study Site

Niger is a landlocked country in West Africa, covering an area of 1,267,000 km^2. The territory extends between 11˚37' and 23˚33' north latitude and between 0˚06' and 16˚ east longitude from the Greenwich meridian. Geographically, approximately 80% of the territory consists of the Sahara and Sahel, while a southern strip characterised by more abundant vegetation constitutes the Sudanese zone [1]. The latter receives more than 600 mm of annual rainfall, while Niamey, the capital, receives between 300 and 600 mm per year, with highly developed trade. Water is mainly available from the banks of the Niger River, which crosses the country for a distance of 550 km.

2.2. Choice of Sites

A descriptive and analytical longitudinal study was conducted in ten localities of Niger between January and December 2023 to investigate the spatial and temporal dynamics of *Aedes* mosquitoes and arbovirus circulation: Guidimouni, Tessaoua, Niamey, Liboré, Say, Agadez, Boboye, Madarounfa, Madaoua and Gaya (**Figure**

1). On the basis of criteria such as the ecology of the area, the density of human populations, the level of urbanisation, the density of vectors and seroprevalence data from previously detected cases of arboviruses, four sites (Niamey, Gaya, Tessaoua and Guidimouni) were selected for entomological monitoring of vectors (eggs, larvae and adults) on a fortnightly basis for one (1) year with a bi-month collection. Each locality is stratified into three (3) zones: an urban zone, a peri-urban zone and a rural zone. For adult mosquito surveillance, the same households were monitored throughout the study period for BG-Sentinel trapping and Prokopack collections. In contrast, larval surveys were conducted in 15 randomly selected households at each bimonthly sampling round.



Source: This map is based on our GPS coordinates recorded during the study's data collection sessions.

Figure 1. Study sites.

2.3. Mosquito's Collection

Collection of larvae: this was carried out to determine the epidemiological risks of transmission of arboviruses and the typology of *Aedes aegypti* breeding sites. In each of the 4 sites: Niamey, Gaya, Tessaoua and Guidimouni, larvae surveys were conducted in 15 randomly selected households at each bimonthly sampling round among urban, peri-urban and rural areas. In each house, all water storage containers (**Figure 2**, **Figure 3**) and abandoned containers (**Figure 4**) were inspected, and the geo-referenced coordinates (GPS) were recorded. After collection, larvae were transported to the insectary of Entomology Laboratory of Health

and Sanitary Research Center of Niamey and maintained under controlled environmental conditions at a temperature of 27˚C ± 1 and relative humidity of 78% ± 1. *Aedes* emerged were pooled of 10 or few mosquitoes were formed according to the type of capture and stored in RNALater (SIGMA®) at −80˚C [24].

Risk indices (Breteau Index BI, Habitat Index HI, Container Index CI) were estimated according to the WHO protocol, 2014 (CI > 3%, HI > 4% and BI > 5%) [25]. The number of inspected houses per locality did not reach the WHO recommended threshold of 100 houses, the estimation of the BI may be affected by sampling variability and potential over or ender estimation. Therefore, a Generalized Linear Mixed Model (GLMM) approach was additionally applied to strengthen the robustness of comparisons between localities.



Figure 2. Prospection of peri-domestic containers (water storage).



Figure 3. Container of *Aedes* breeding site (abandoned containers).



Figure 4. Container of *Aedes* breeding site (watering through).

Egg collection: Thirty (30) nesting boxes (Figure 5) per locality were laid for one (1) year, with weekly collections of nesting papers for all 10 sites. The egg-laying papers were collected every 7 days and dried for a maximum of 24 hours in the shade. They were then packed in airtight bags to prevent the eggs from drying out and conserved in 27˚C ± 1 of temperature and 78% ± 1 humidity conditions at insectary. Every month, all the egg-laying boxes were observed with a magnifying glass, the eggs counted were placed in water (Figure 6) at the insectary and the density of emerging species was estimated. These eggs will be used to identify the *Aedes* species present in the locality and to detect arboviruses, insecticide resistance determination. After identification, mosquitoes were pooled according to sex, locality, capture method and collection period to preserve epidemiological stratification and stored in RNALater (SIGMA®) at −80˚C before analysis.



Figure 5. Ovitraps used for this study.



Figure 6. Hatching of *Aedes* eggs in the insectary.

Collection of adult mosquitoes: This study took place at 4 sites: Niamey, Gaya, Tessaoua and Guidimouni. At each site, 6 human skin lure BG Sentinel traps were placed every 2 months inside and outside of 3 houses randomly selected for all the study period. Mosquitoes were collected every 12 hours for 2

successive days (Figure 7).

In the same localities, series of aspirations using the prokopack (Figure 8). were carried out over 2 successive days inside and outside of 3 other houses in order to determine the spatio-temporal dynamics of the species and their host-seeking activity and resting behaviour. mosquitoes were pooled according to sex, locality, capture method and collection period to preserve epidemiological stratification and stored in RNALater (SIGMA®) at −80˚C before analysis.



Figure 7. Mosquitoes collection by BG sentinel traps.



Figure 8. Mosquitoes collection by prokopack.

2.4. Morphological Identification of *Aedes*

All mosquitoes collected or having emerged were morphologically identified by binocular glass using a dichotomous identification key [24]. After identification, mosquitoes were pooled according to sex, locality, capture method and collection period to preserve epidemiological stratification and stored in RNALater (SIGMA®) at −80˚C before analysis. Therefore, some pools contained fewer than 10 mosquitoes leading in a higher number of pools than expected. For RT-PCR analyses, 500 mosquitoes were collected by BG Sentinel Traps, 200 for prokopack collection, 112 mosquitoes for respectively each egg and larvae emergence were randomly selected. Hence 924 mosquitoes were analyzed by RT-PCR for circulation of DENV, YFV, CHIKV, ZIKV.

2.5. Molecular Screening of Arboviruses Detection

2.5.1. Viral RNA Extraction from Mosquitoes

The mosquito pools were removed from the RNALater, transferred to 2 mL Eppendorf tubes containing Leibovitz L15 medium, ground and automatically homogenized using the Tissue-Lyser II (Qiagen, Hilden, Germany 2013-25, LT). The homogenate was then centrifuged at 10,000 rpm at 4˚C for 20 min. Viral RNA was extracted from the supernatant using the QIA amp Viral RNA Mini Kit (Qiagen, Hilden, Germany). Then, RNA was stored at −80˚C until molecular screening.

2.5.2. Viral Detection by Real-Time RT-PCR

The detection of Dengue [26], Yellow Fever [27], Zika [28] and Chikungunya [29] viruses, was screened by real-time RT-PCR on all mosquito shreds using Lyophilized one-step RT-PCR Polymerase Mix (TIB MOLBIOL, Berlin, Germany). The reaction mixture consists of 5 µL of extracted RNA, 10 µL of enzyme, 1 µL (10 µM) of each virus forward primer, 1 µL (10 µM) of each virus reverse primer, 0.5 µL (10 µM) of each virus probe, and 2.5 µL of water, PCR grade. Real-time RT-PCR was performed using Applied Biosystem 2500. The thermal cycling profile of this assay consists of a 10-min reverse transcriptase (RT) step at 55˚C 95˚C for 1 min, and then 40 cycles of 95˚C for 15 s and 60˚C for 30 s. Human positive controls for DENV, ZIKV, YFV and CHIK were used as positive controls to validate the results. Any sample with a Cycle threshold (Ct) ≤ 38 [30] was considered positive due to the low viral load in mosquitoes. The primers and probe used in this study are shown in **Table 1**.

Table 1. Quantitative RT-PCR primers used for viruses detection.

Virus	Primer/Probe	Sequence (5′-3′)	References
DENV	Forward	AAGGACTAGAGGTTAKAGGAGACCC	[26]
	Reverse	GGCCYTCTGTGCCTGGAWTGATG	
	Probe	5′-6FAM-AACAGCATATTGACGCTGGGARAGACC-BBQ	
YFV	Forward	ATTGAGGTGYATTGGTCTGC	[27]
	Reverse	GTCRRTTCTCTGCTAATCGCTCA	
	Probe	5′-6FAM-AGTTGCTAGGC+A+AT+A+A+A--BBQ	
ZIKV	Forward	AARTACACATACCARAACAAAGTGGT	[28]
	Reverse	TCCRCTCCCYCTYTGGTCTTG	
	Probe	5′-FAM-CTYAGACCA+G+C+T+GAAR--BBQ	
CHIK	Forward	AAG CTY CGC GTC CTT TAC CAA G	[29]
	Reverse	CCA AAT TGT CCY GGT CTT CCT	
	Probe	6′-FAM-CCA ATG TCY TCM GCC TGG ACA CCT TT-TMR	

2.6. Data Analysis

Larval densities, which were used to determine risk factors, were determined as a function of the total number of larvae collected per type of site.

For the entomological risk indicators that were evaluated, the World Health Organization (WHO, 2014) protocol (CI > 3%, HI > 4% and BI > 5%) [25] was used according to the following formulas:

Breteau index (BI): corresponds to the number of positive gites per 100 houses visited BI: (Number of positive gites/Number of houses inspected)*100 House index: percentage of houses with at least one positive gite **HI**: (Number of positive houses/Number of houses inspected) × 100 Container index: Percentage of positive containers (larval gites) among all the containers in water (potential gites) **CI**: (Number of positive containers/Number of containers in water) × 100 For the determination of the stegomyian indices. The number of positive containers was modelled using a poisson regression farmework with the logarithm of inspected houses. Model fit and overdispersion were evaluated and comparison between localites were performed at a 95% confidence interval with significance defined a $p < 0.05$. Statistical analysis were performed using Chi-square tests to compare mosquito proportions between localities, collection sites, and behavioural categories. Statistical significance was set at $p < 0.05$ with 95% confidence intervals. All the analyses. were carried out using Excel and R software.

2.7. Ethical Considerations

This study is part of the arboviruses surveillance activities carried out by the Medical and Health Research Centre (CERMES), the Reference National Laboratory of the Ministry of Public Health for 7 diseases including arboviruses in Niger. However, access to households was authorised by the consent of the heads of household before each survey.

3. Results

3.1. Determination of the Presence of *Aedes* spp. in Niger Using Ovitraps

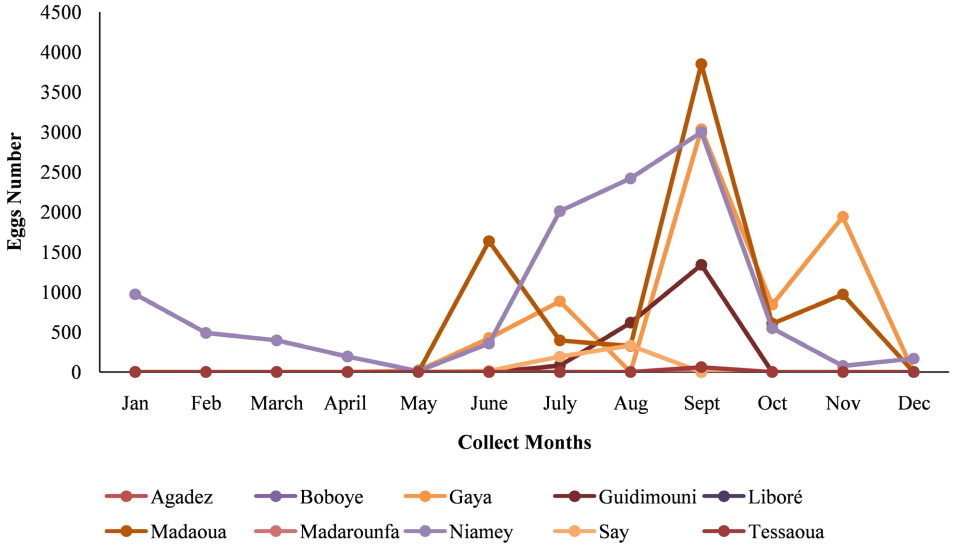


Figure 9. Spatio-temporal variation of *Aedes* presence by ovitraps in Niger.

Aedes spp eggs were detected in seven study sites indicating widespread distribution across Niger. Ovitraps positivity varied by locality and ecological setting, with higher egg densities observed in urban and peri-urban area (Niamey, Gaya, Madaoua and Guidimouni) compared to rural settings (Say, Tessaoua, Boboye). Temporal variation showed increased eggs abundance during the rainy season (June-October-December) with a peak in September. suggesting favourable breeding conditions linked to rainfall patterns. Adult emergence identified *Aedes aegypti* in 7 sites (Niamey, Gaya, Guidimouni, Tessaoua, Madaoua, Say and Liboré) and *Aedes luteocephalus* only in Madaoua (Figure 9).

3.2. Estimation of Entomological Risk Indices for Arboviruses Epidemics

Overall, 360 houses either 90 houses by site were visited and 1620 containers inspected during the study. Of these houses, 23 (6.38%) were found to be infested with mosquito larvae in 40 (2.46%) containers. A total of 2597 larvae were collected and 2403 larvae emerged with 965 for Niamey, 748 for Gaya, 75 for Guidimouni and 615 for Tessaoua.

3.2.1. Typology of Larval Breeding Sites

The types of potential sites encountered at all 4 collection sites were tyres, cans, jars, barrels, water troughs and abandoned containers. In Niamey the sites most infested with *Aedes* larvae were barrels and cans, while in Gaya it was abandoned containers and barrels that were most positive for larvae. In Guidimouni and Tessaoua, the containers most infested with larvae were cans and jars (Figure 10).

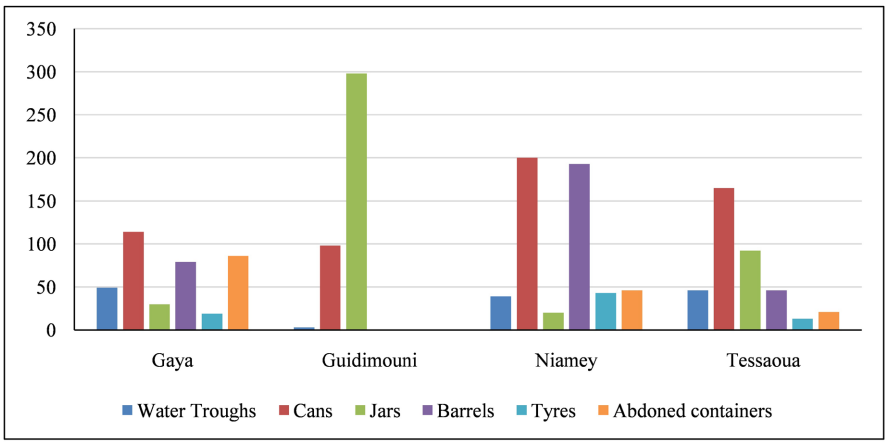


Figure 10. Typology of *Aedes spp* breeding sites in Niger.

3.2.2. Stegomyian Indices

The Breteau Indices (BI) (20% and 15.55%), the Container Indices (CI) (3.19% and 3.71%) and the Habitat Indices (HI) (20% and 8.89%) for Niamey and Gaya respectively exceed the WHO threshold (CI > 3%, HI > 4% and BI > 5%), while they are relatively low in Guidimouni and Tessaoua (Table 2).

Although the GLMM analysis, using a Poisson Regression model with the num-

ber of positive containers as the outcome variable and the number of inspected houses as an offset, demonstrated significant heterogeneity between localities (χ^2 = 16.6, df = 3, $p < 0.001$). Pairwise comparisons revealed significantly higher infestation risk in Niamey compared with Tessaoua and Guidimouni.

The GLMM approach confirmed that the elevated infestation observed in Niamey and Gaya was not solely due to sampling effort but reflected genuine spatial variation in *Aedes aegypti* breeding site abondance.

Table 2. Stegomyian Indices of *Aedes aegypti* breeding sites in Niger localities.

Sites	Visited houses (nh)	Positive houses (nph)	Prospected containers (nc)	Positive containers (npc)	Entomological indices (b)		
					HI (%)	CI (%)	BI
Niamey	90	18	460	18	20	3.19	20
Gaya	90	8	377	14	8.89	3.71	15.55
Tessaoua	90	4	383	4	4.44	1.06	4.44
Guidimouni	90	3	399	3	3.33	0.75	3.33

Note: Legend: House Index **(HI)**, Container Index **(CI)**, Breteau Index **(BI)**, Number of visited houses **(nh)**, Number of positive houses **(nph)**, Number of containers **(nc)**, Number of positive containers **(npc)**.

3.3. Distribution of *Culicidae* after Emergence of the Larvae Collected

On the graphic below (Figure 11), a predominance of mosquitoes of the genus *Culex sp* in all the locations monitored was determined. Among the *Aedes* mosquitoes species, larvae of *Aedes aegypti* and *Aedes vitattus* were collected in Gaya in September and *Aedes aegypti* in the 3 other localities, Niamey, and Guidimouni with a peak in September. In Niamey larvae were regularly found during all the months of collection except March and September with a peak in January. In Guidimouni, a low density of *Aedes* species was noted in September, while in Tessaoua, only Culex larvae were found during larval surveys. A few *Anopheles spp* were collected only in Gaya and Niamey.

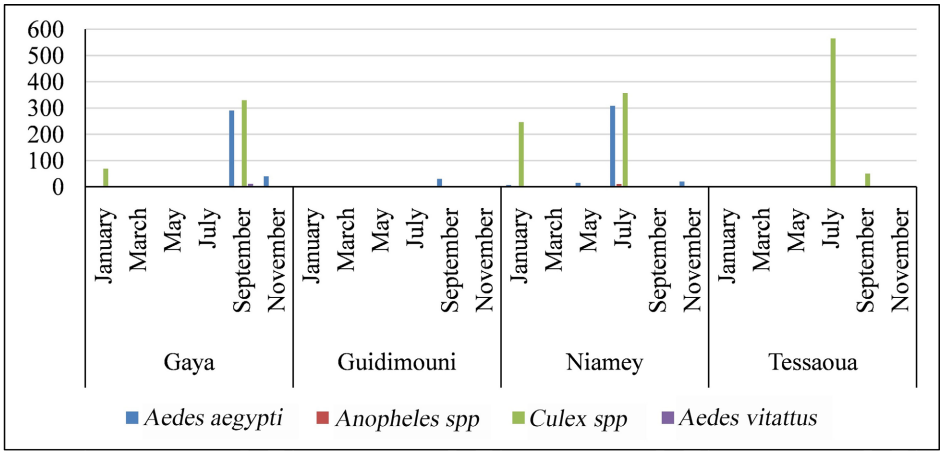


Figure 11. Distribution of *Culicidae* after larval emergence.

4. Vector Biology Studies

During this study, 7363 specimens were captured by BG-Sentinel and Aspiration (prokopack), of which 7308 were mosquitoes. Globally, Niamey recorded the higher number of *Culicidae* with 2598. These mosquitoes were distribuated among 6 species in the following proportions *Culex sp*, *Aedes aegypti sp*, *Anopheles gambiae sl*, *Anopheles funestus*, *Anopheles rufipes* and *Mansonia sp*. These results did not show the presence of any *Aedes albopictus*. These results are set out in (Table 3) and divided into the following strata: City centre or urban, peri-urban and city periphery.

4.1. Spatial Dynamics of *Culicidae* Species in Niger

The spatial variation in culicine species collected during this study was determined in Table 3. The number of mosquitoes of the genus *Culex sp* was 81.06%, 29.68%, 79.52% and 77.54% respectively in Gaya, Guidimouni, Niamey and Tessaoua. As for *Anopheles* species, the density of *Anopheles gambiae* was 9.24% in Gaya, 36.6% in Guidimouni, 4.42% in Niamey and 10.01% in Tessaoua.

Table 3. Spatial dynamics of *Culicidae* species in Niger.

Localities	Species							
	Sites	*Aedes aegypti*	*Anopheles funestus*	*Anopheles gambiae*	*Anopheles rufipes*	*Culex sp*	*Mansonia sp*	Total
Gaya	Urban	47 (5.10)	0 (0)	100 (10.86)	0 (0)	773 (84.02)	0 (0)	920 (59.46)
	Peri-urban	51 (17.28)	0 (0)	23 (7.79)	0 (0)	221 (74.91)	0 (0)	295 (19.06)
	Rural	52 (15.66)	0 (0)	20 (6.02)	0 (0)	260 (78.31)	0 (0)	332 (21.46)
Total Gaya		150 (9.69)	0 (0)	143 (9.24)	0 (0)	1254 (81.06)	0 (0)	1547 (21.16)
Guidimouni	Urban	56 (19.11)	23 (7.84)	113 (38.56)	2 (0.68)	74 (25.25)	25 (8.53)	293 (32.7)
	Rural	48 (16.78)	21 (7.34)	107 (37.41)	0 (0)	94 (32.86)	16 (5.59)	286 (31.91)
	Peri-urban	58 (18.29)	21 (6.62)	108 (34.06)	1 (0.31)	98 (30.91)	31 (9.77)	317 (35.37)
Total Guidimouni		162 (18.08)	65 (7.25)	328 (36.6)	3 (0.33)	266 (29.68)	72 (8.03)	896 (12.22)
Niamey	Urban	208 (25.42)	0 (0)	25 (3.06)	0 (0)	585 (71.51)	0 (0)	818 (31.48)
	Peri-urban	152 (15.63)	0 (0)	21 (2.16)	0 (0)	799 (82.20)	0 (0)	972 (37.41)
	Rural	57 (7.05)	0 (0)	69 (8.53)	0 (0)	682 (84.40)	(0)	808 (31.1)
Total Niamey		417 (16.05)	0 (0)	115 (4.42)	0 (0)	2066 (79.52)	0 (0)	2598 (35.55)
Tessaoua	Urban	55 (9)	14 (2.29)	56 (9.16)	0 (0)	472 (77.25)	14 (2.29)	611 (26.95)
	Peri-urban	58 (8.32)	16 (2.29)	81 (11.62)	0 (0)	520 (74.6)	22 (3.15)	697 (30.74)
	Rural	61 (6.36)	18 (1.87)	90 (9.38)	0 (0)	766 (79.87)	24 (2.5)	959 (42.3)
Total Tessaoua		174 (7.67)	48 (2.11)	227 (10.01)	0 (0)	1758 (77.54)	60 (2.64)	2267 (31.02)
Global Total		903 (12.35)	113 (1.54)	813 (11.12)	3 (0)	5344 (73.12)	132 (1.80)	7308 (100)

According to the Table 3, for all the *Culicidae* collected in each of the four local-

ities, *Aedes aegypti* was collected in Gaya, Guidimouni, Niamey and Tessaoua respectively in proportions of (150/1547) 9.69% and (162/896) 18.08%, (417/2598) 16.05% and (174/2267) 7.67%.

Specifically, regarding to the *Aedes* species, Niamey recorded the highest abundance 46.2% (417/903), followed by Tessaoua 19.3% (174/903).

According to the collection areas, *Aedes aegypti* was collected most in the urban area of Niamey (25.42%), followed by the peri-urban area of the city (7.05%).

Mosquito species distribution differed significantly across study localities (Chi-square test, $\chi^2 = 1557.23$, df = 15, $p < 0.001$; 95% CI), indicating marked spatial heterogeneity in *Culicidae* composition.

4.2. Spatio-Temporal Dynamics of *Aedes aegypti* in Niger

A similarity in the temporal dynamics of *Aedes aegypti* for Gaya, Guidimouni and Tessaoua where in January there is the end of a peak while in March there is a considerable decrease in the population of these species. Between March and May, the population increases and then stabilises from May for Guidimouni and Tessaoua and in September for Gaya. In the city of Niamey, a permanent distribution was observed throughout the collection periods, with an increase from January to March and then a decrease between March and September. After September, the population increased (Figure 12).

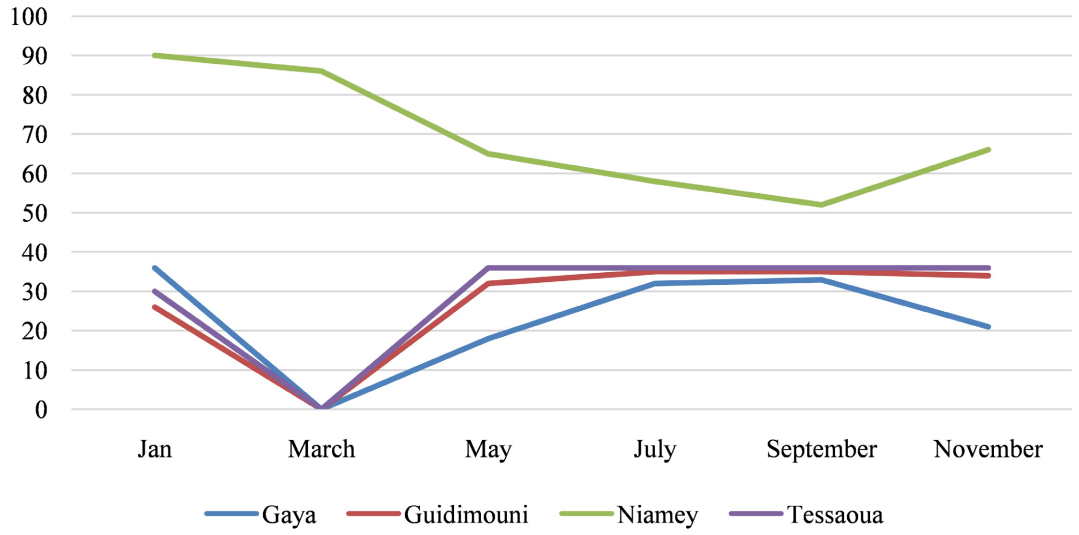


Figure 12. Spati-temporal dynamic of *Aedes aegypti* in Niger.

4.3. Determination of the Host-Seeking Activity of *Aedes aegypti* by BG Sentinel Traps

Aedes aegypti in Niamey and Gaya are much more active between 6 p.m. and 6 a.m. than between 6 a.m. and 6 p.m. whereas in Guidimouni and Tessaoua the trends are indistinguishable. We can therefore deduce that *Aedes aegypti* in Niamey and Gaya have a higher host-seeking activity at twilight, whereas in Guidimouni and Tessaoua they were both during the day and at night (Figure 13).

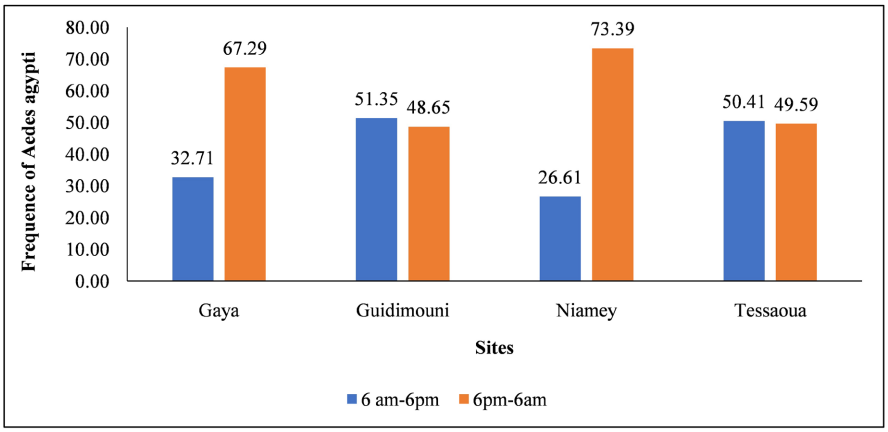


Figure 13. Host-seeking activity moment of *Aedes aegypti* by BG Sentinel Traps in Niger.

4.4. Host-Seeking Activities Place of *Aedes aegypti* by BG Sentinel Traps in Niger

In Gaya *Aedes aegypti* have a host-seeking activities outside than inside the houses respectively (66% vs 34%) and Niamey (77.46% vs 22.54%), whereas in Guidimouni (49.38% vs 50.62%) and Tessaoua (50% vs 50%) it is both outside and inside the house (**Figure 14**). Thus, we can suggest that *Aedes aegypti* have a higher outdoor host-seeking activity in Gaya and Niamey while in Guidimouni and Tessaoua they have both outdoor and indoor activity. The spatial distribution of *Aedes aegypti* host-seeking activity differed significantly between indoor and outdoor environments across localities (Chi-square test, $\chi^2 = 63.26$, df = 3, $p < 0.001$; 95% CI). Outdoor host-seeking activity was higher in Gaya and Niamey.

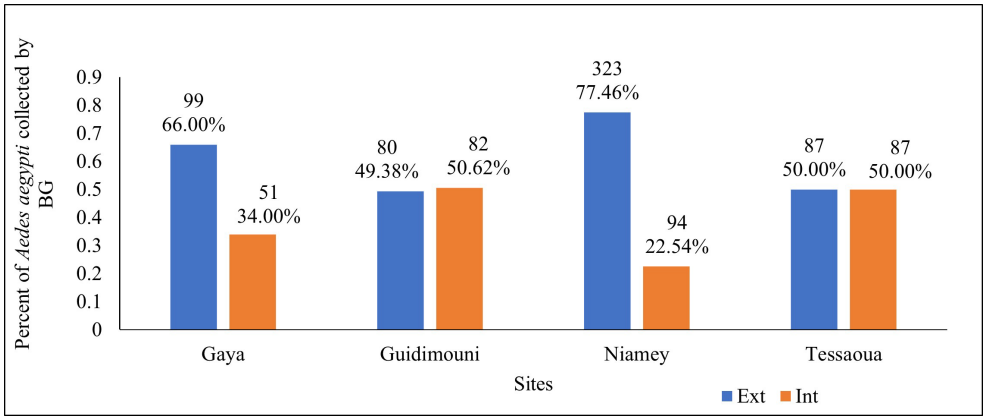


Figure 14. Spatial variation of the host-seeking activity of *Aedes aegypti* in Niger.

4.5. Resting Behaviour of *Aedes* by Prokopack Collection

Prokopack collections indicated a higher proportion of *Aedes aegypti* resting outside habitats regardless of Niamey (68.89%) and Gaya (62.79%) while in Guidimouni and Tessaoua they rest outside and inside habitats. However, this pattern may be influenced by environmental conditions (**Figure 15**).

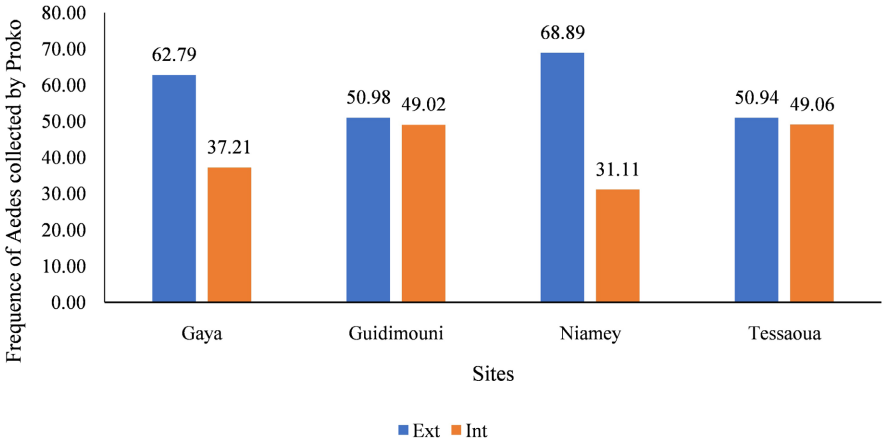


Figure 15. Variation of *Aedes aegypti* resting behaviour.

5. Circulation of Arboviruses in *Aedes aegypti* in Niger

In the course of this study, 924 *Aedes aegypti* mosquitoes (500 mosquitoes collected by BG Sentinel Traps, 200 for prokopack collection, 112 mosquitoes for respectively each eggs and larvae emergence) including 754 females and 170 males from eggs, larvae and adults were randomly selected and divided into 113 pools for arboviruses screening. All batches were subjected to Real-time RT-PCR for the presence of Dengue, Yellow Fever, Chikungunya and Zika viruses. All the 113 pools were negative for the detection of the 4 arboviruses DENV, YFV, ZIKV and CHIKV (Figure 16).

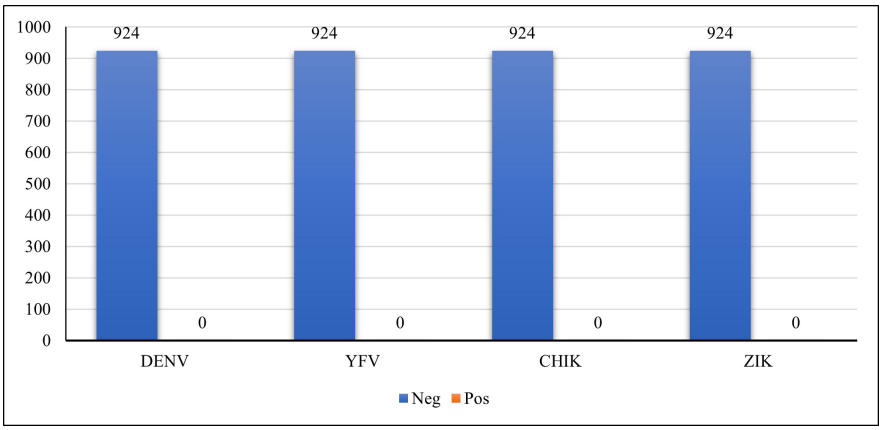


Figure 16. Results of DENV, YFV, CHIKV, ZIKV viruses by RT-PCR.

6. Discussion

This comprehensive study, provides the first structured entomological assessment of *Aedes aegypti* across an urbanization gradient in Niger filling critical knowledge gaps in West Africa arbovirus surveillance. These findings demonstrate that urbanization intensity significantly shapes vector ecology with urban centers exhibiting elevated transmission risk trough altered mosquito density, behaviour and spatial distribution patterns.

6.1. Species Diversity and Regional Context

The distribution of *Aedes aegypti* was almost uniform between the 4 collection sites except in Niamey where the abundance was very high in the urban and peri-urban area but also permanent throughout the study. This exclusive detection of *Aedes aegypti* in urban and peri-urban localities, alongside rare detection of *Aedes vittatus* (Gaya) after larval emergence and *Aedes luteocephalus* in Madaoua from respectively after eggs emergence underscores the dominance of anthropophilic subspecies *Aedes aegypti* in transformed environments through the creation of artificial breeding sites [14] [31]. The presence of *Aedes aegypti*, *Aedes vittatus* and *Aedes luteocephalus* has been demonstrated in Niger [32] [33]. The absence of *Aedes albopictus*, the invasive Asian tiger mosquito, is noteworthy and consistent with its limited distribution across West Africa where have been incriminated in the vertical transmission of Zika and the maintenance of the Zika virus has been demonstrated in these sylvatic species in Senegal [34]. In fact, the *Aedes aegypti* vector is confined to urban and peri-urban environments where its survival is maintained by human populations.

6.2. Breeding Site Ecology and Urbanization Gradients

The differential distribution of larval breeding habitats across Niger sites reflects established patterns of urbanization-driven vector ecology in West Africa. Container types such as barrels, cans and abandoned containers were the most productive larval sites, consistent with observations from neighboring Burkina Faso, where similar domestic and peri-domestic containers dominated *Aedes* breeding ecology during the 2016-2017 dengue outbreaks [14]. These results could be explained by the fact that the type of container influences the density of nymphs [8] also the difference in the level of urbanisation and sanitation in these 2 localities. Niamey is the Niger's capital and the population enjoys a higher level of sanitation than Gaya. From a climatic point of view, Gaya is located in the Sudanian zone, where rainfall exceeds 600 mm, whereas Niamey receives between 300 and 600 mm/year [35] and trade is highly developed. It therefore goes without saying that the traditional risk indices described by the WHO are higher in these 2 localities, as urbanization, rainfall, sanitation levels and trade are all favourable conditions for the proliferation of *Aedes* mosquitoes [10] [11] [14] [36] [37].

The Stegomyian indices (Breteau Index, Container Index, and Habitat Index) exceeded WHO epidemic thresholds in Niamey (BI = 20%, CI = 3.19%, HI = 20%) and Gaya (BI = 15.55%, CI = 3.71%, HI = 8.89%), confirming substantial entomological risk in these urban and peri-urban zones. To confirm this observation, the consistency between the GLMM results and classical stegomyian indices strongly suggests that the elevated infestation observed in Niamey and Gaya reflects true ecological differences rather than sampling artefacts. Indeed, despite equivalent sampling intensity (90 inspected houses per locality) Niamey and Gaya recorded substancially higher numbers of positive containers compared with Guidimouni and Tessaoua. Similar elevated indices have been reported in other West African

cities experiencing arboviral outbreaks [14]. The heterogeneity in breeding site typology across sites reflects localized adaptive responses of *Ae. aegypti* populations to microhabitat heterogeneity and urban infrastructure variations, a phenomenon documented across Ouagadougou, Ghana, and Senegal [38].

6.3. Spatio-Temporal Dynamics and Vector Behaviour

The permanent distribution of *Ae. aegypti* throughout the year in Niamey contrasts markedly with the seasonal patterns observed in Gaya, Guidimouni, and Tessaoua, where populations exhibited marked declines during dry months (March-May). This phenological divergence reflects both climatic variation and the urban heat island effect that characterizes capital cities in West Africa. Urban areas, with their modified microclimates, reduced water infiltration, and persistent anthropogenic water storage, provide stable breeding conditions regardless of seasonality, whereas peri-urban and rural zones depend on rainfall-fed containers and natural habitats.

Host-seeking activity patterns revealed striking behavioural variation across sites. Niamey and Gaya populations demonstrated marked nocturnal outside activities (77.46% and 66% outdoor host-seeking, respectively), with peak activity between 6 p.m. and 6 a.m., particularly at Conversely, Guidimouni and Tessaoua populations exhibited more mixed inside and outside behaviour, hours. with approximately equal proportions of host-seeking activity indoors and outdoors. This behavioural plasticity has been attributed to rapid urbanization and the evolution of human specialist populations in West African cities over the past 20 - 40 years, driven by increased availability of human hosts and artificial breeding sites twilight [39]. Such behavioral shifts have profound implications for vector control strategy design, as traditional indoor residual spraying programs may be less effective against predominantly outdoor-biting populations [40].

Resting behaviour patterns corroborated host-seeking data, with predominantly exophilic resting in Niamey and Gaya (68.89% and 62.79% outdoor resting, respectively) and mixed endophilic-exophilic patterns in Guidimouni and Tessaoua. These findings are consistent with a broader regional pattern across West Africa, where urban *Ae. aegypti* populations exhibit pronounced exophily while maintaining residual endophily, necessitating integrated vector control approaches [14]. Environmental conditions, including ambient temperature, humidity, and shelter availability, likely modulate these behavioral patterns, underscoring the need for context-specific surveillance and control strategies [41].

The discrepancy observed in Tessaoua between low domestic stegomyia indices and relatively high abundance of adult *Aedes aegypti* suggests the household larval surveys may not have capture the most productive breeding habitats. Similar observations have been reported elsewhere, traditional stegomyia indices showed limited correlation with adult mosquuito abundancd and transmission risk [14].

6.4. Arbovirus Circulation and Vector Competence

Despite serological in human sera (IgM/IgG) and molecular evidence (by RT-PCR) of DENV, YFV, ZIKV, and CHIKV circulation in Niger's human popula-

tion from 1963 to 2024 [22] [36] [42] [43], RT-PCR screening of 924 *Ae. aegypti* individuals across all life stages yielded no detectable arboviruses. This apparent discrepancy between human seroprevalence and vector infection rates may reflect several mechanisms: (1) temporal asynchrony between mosquito surveillance and human infection peaks; (2) low infection prevalence in mosquito populations due to recent transmission decline; or (3) limited vector competence of Niger's *Ae. aegypti* populations for certain virus strains. Similar negative RT-PCR results have been reported in Ghana despite confirmed DENV-2 circulation in human populations [8], suggesting that West African *Ae. aegypti* populations may exhibit variable or reduced competence for some arbovirus strains compared to populations from endemic regions.

Vector competence studies from the region are crucial for risk assessment. Recent investigations have documented that West African *Ae. aegypti* exhibit heterogeneous competence depending on virus strain, viral genotype, and population origin [44]. Senegal's *Ae. aegypti* populations have demonstrated high disseminated infection rates for local DENV-2 and YFV isolates [44] while populations from Burkina Faso show variable competence contingent on both virus isolate and mosquito strain [45]. The refractory nature historically attributed to West African *Ae. aegypti formosus* subspecies (forest-dwelling, zoophilic) has been challenged by recent evidence showing that some West African populations, particularly the anthropophilic *Ae. aegypti aegypti* subspecies dominant in urban areas, can efficiently transmit multiple arboviruses [46]. Senegal hosts a population that is highly anthropophilic (78.6% human blood meals) and has demonstrated active dengue circulation [46]. highlighting the regional epidemiological variability.

Niger's vector surveillance data should be integrated with serological monitoring of human populations and retrospective epidemiological investigations of reported arboviral cases to better assess the public health significance of local *Aedes aegypti* populations. The absence of arboviral RNA detection in mosquitoes collected during this study may reflect low virus circulation during the survey period, although low infection prevalence and sampling limitations cannot be excluded. Nevertheless, the widespread presence of *Ae. aegypti* across Niger, particularly in Niamey and Gaya where high vector densities, elevated Stegomyia indices, and year-round occurrence were observed, highlights the potential for arbovirus transmission should viruses be introduced through human movement or cross-border circulation. In addition, the relatively high abundance of adult *Ae. aegypti* and repeated ovitrap positivity recorded in Tessaoua, despite low domestic larval indices, suggest that important breeding habitats may occur outside surveyed households, indicating that local transmission risk could be underestimated when assessments rely solely on household-based larval surveys.

6.5. Implications for Vector Control and Surveillance

The heterogeneous distribution of *Ae. aegypti* across the study sites indicates that vector surveillance and control strategies in Niger should be adapted to local eco-

logical conditions. In Niamey and Gaya, where vector abundance and entomological risk indicators were highest, integrated vector management approaches combining community-based source reduction, improved management of water-storage containers, waste tire disposal, and targeted vector control interventions may be particularly beneficial [40]. These measures are especially important given the predominance of domestic containers and discarded tires among the breeding habitats identified during the study.

Differences in the indoor and outdoor distribution of collected mosquitoes among study sites suggest spatial variability in vector activity and habitat use. Such variations may influence the effectiveness of vector control interventions and highlight the need for locally adapted surveillance strategies [14]. Because adult collections were based on BG-Sentinel traps and Prokopack aspirations, these findings should be interpreted as patterns of mosquito occurrence and capture location rather than direct evidence of biting preference or feeding behavior. Consequently, control strategies should consider both domestic and peri-domestic environments when targeting *Ae. aegypti* populations in Niger.

Insecticide resistance surveillance is critical. A recent survey in Niamey documented the presence of pyrethroid resistance-associated kdr mutations (F1534C, V1016I, V410L), population, [47] indicating that resistance management strategies should be integrated with vector control programs. Metabolic resistance mechanisms have been documented in Burkina Faso populations [48] and similar investigations in Niger will be essential to guide rational insecticide selection.

6.6. Limitations and Future Research Priorities

This study's primary limitation was the circumscribed temporal window (2023) and sampling intensity at four intensive surveillance sites, which limits inference to broader seasonal and spatial patterns. Additionally, the study had limited statistical power to detect very low infection rates that are commonly observed in natural *Aedes* population. The sample size for RT-PCR analysis, while substantial (924 individual *Ae. aegypti*), may have been insufficient to detect low-prevalence virus circulation, particularly if infection rates in vectors are <1% - 2%. Longitudinal surveillance over multiple years, coupled with human serological and clinical surveillance, is essential to characterize arbovirus transmission dynamics.

7. Conclusion

This study provides the comprehensive assessment that establishes *Aedes aegypti* as a widespread, locally abundant arbovirus vector across Niger, with evidence of geographic variation in ecology, behavior, and epidemiological risk. Niamey and Gaya exhibited the highest entomological risk based on stegomyia indices and vector abundance supporting their prioritization for surveillance and vector control interventions. The absence of viral detection does not exclude low-level arbovirus circulation because infection prevalence in mosquito populations is generally very low and may fall below the detection threshold of the sampling effort.

However, the relatively high abundance of adult *Aedes aegypti* and the detection of eggs in Tessaoua, despite low domestic larval indices, suggest that important breeding habitats may occur outside surveyed households. This study indicates that epidemiological risk in some localities may be underestimated when assessments rely exclusively on domestic larval surveys. Expanded surveillance targeting public and peri-domestic environments is therefore essential for a more accurate evaluation of arbovirus transmission risk in Niger.

Consent to Publish Declaration

All authors read and approved the final manuscript.

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Authors Contribution

Conceptualization: MD, MSOR, AB, IML. **Data curation**: MSOR, AB, IML. **Formal analysis**: MSOR, AB, IML. **Funding acquisition:** MD, OM. **Investigation:** MSOR, AB, IML. **Methodology:** MD, MSOR, AB, IML, OM, IS, MSN, IIA. **Writing original draft**: MSOR. **Writing-review and editing**: MSOR, AB, MD, IML, IS, IIA, OM, LA, MSN.

Conflicts of Interest

The authors declare no competing interests.

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