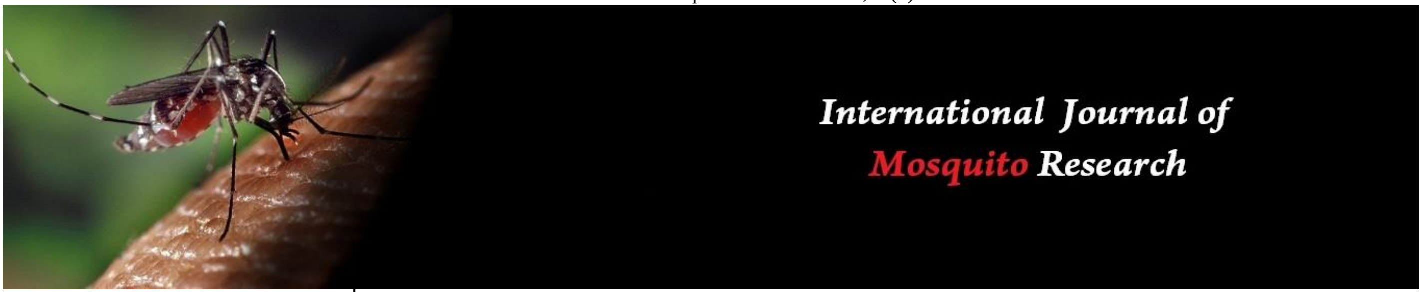

ISSN: **2348-5906**
CODEN: **IJMRK2**
Impact Factor (RJIF): 5.82
IJMR 2025;12(6):71-77

https://www.dipterajournal.com
Received: 10-09-2025
Accepted: 15-10-2025

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Influence of rising water table on mosquitoes' diversity and abundance in Niamey city, Niger

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DOI: https://www.doi.org/10.22271/23487941.2025.v12.i6a.873

Abstract
To determine the influence of water table rising on mosquitoes' ecology, we carried out an entomological monitoring, throughout 72 sampling locations in three different areas at Niamey city. Mosquitoes were collected using insecticides spray and light traps. Specimen were morphologically identified and, abundance and diversity parameters were estimated using PAST software. A total of 3,609 specimens were identified, belonging to four genera: *Culex* (69.74%), *Anopheles* (29.68%), *Aedes* and *Mansonia* (<1% each). Species richness varied from 3 to 5 and abundance was found high, around 45% in the flooded areas while it was four times lower in the non-flooded site (10.11%). β diversity indexes indicated that flooded sites are markedly similar and homogeneous (β=0.11) and strongly associated with *Anopheles* and *Culex* abundance during rainy and cold seasons, respectively. These results suggested that water table rising and resulting waterholes could play a key role in increasing vector-borne diseases transmission.

Keywords: Mosquitoes, diversity, abundance, flooding, Niger

1. Introduction

In addition to being highly exposed and vulnerable to climate change impacts [1, 2], Sub-Saharan African countries are dealing one of the highest population growth rate of 2.7% per year compared to other parts of the world where the rate varies from 0.3 to 1.8% [3, 4]. As a result, the urban process is intensifying [5-7], and this would impact the dynamics of water reservoirs, including groundwater aquifers, illustrated by rising water tables which caused flooding by resurgence phenomenon [8-11]. One assumes that high population growth coupled with rapid urbanization would increase flooding risks over time [12, 13]. Previous hydrogeological studies carried out in Niamey city, have highlighted the rising water table phenomenon due to favourable rainfall conditions as well as of urbanization impact on vegetation cover, thereby changing the rainwater redistribution and impacting groundwater recharge [10, 11;14-16]. In the city, upwelling-induced resurgence can be observed in many areas, especially in depressions and valleys where several living quarters and houses are now flooded all year round [8, 10, 14]. By the way, some of these have even been abandoned by their occupants [10, 17]. However, floods systematically result in the formation of whether permanent or temporary waterholes, which represent suitable microhabitats for the development of various and varied pests [18] including disease-carrying insects [19-23]. The well-known and documented genera insect vectors in Niamey are Culicidae including *Anopheles* genus grouping human malaria vector species [24-28] also involved in filariasis and arboviruses' transmission [29]. Previous studies have shown that, the high abundance and diversity of Culicidaen species are mainly observed along the Niger River, in some areas where sewage drainage channels still remain open and/or in the districts located in the lowlands of Niger River valleys watersheds [27, 30]. But the rising water table and floods phenomena it causes, as observed in some of living quarters and houses, would affect mosquitoes' proliferation in terms of both diversity and abundance. This is not without negative impact on population health. So, the aim of the present study is to determine how rising water table and its corollaries increase the risk of diseases transmission in areas affected by the phenomenon.

2. Materials and Methods

2.1. Study Sites: Entomological monitoring was carried out through three different sites all located in Niamey city (Figure 1). Two of them, Sonuci and Daressalam are along a Valley watershed named Gunti Yena, from upstream to downstream. They were also permanently flooded due to the water table rising and rainwater falls. As for the third one (Karsamba), it is also located on the same valley watershed but has different hydroclimatic conditions from those observed at the two other sites. Indeed, the site is never flooded so, we considered it as a control site.

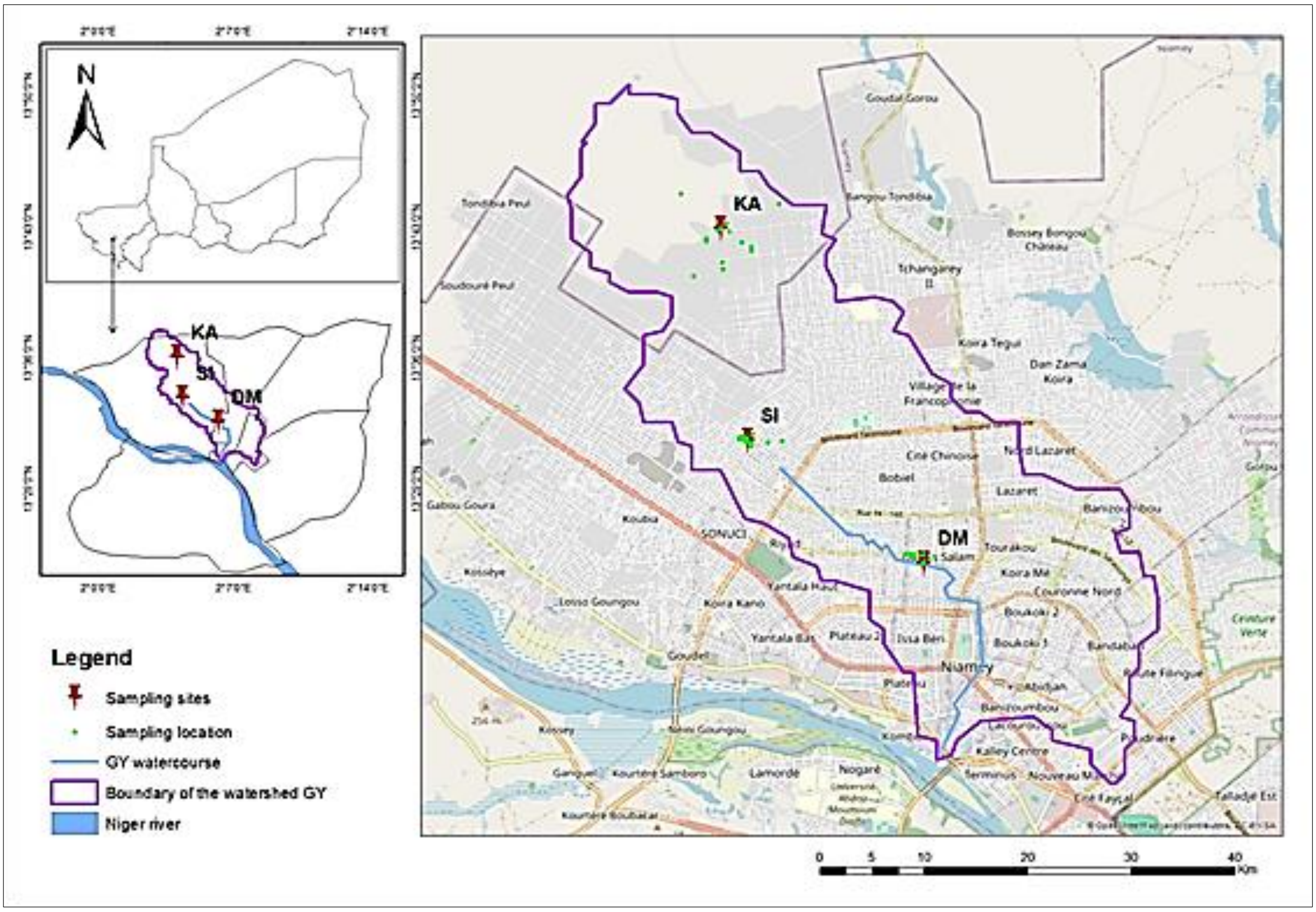

Fig 1: Location of the study sites (SI =SONUCI;DM = Daressalam;KA = Karsamba) and sampling locations.

2.2. Mosquitoes sampling and morphological identification

Data collecting campaigns were conducted over a 9-month period, from October 2020 to June 2021, including the three seasons of the year: the dry season, divided in cold and hot and the rainy season. Mosquitoes were collected using two distinct methods according to previously described methods: Pyrethrum Spray and Light traps [31]. For sampling, 24 compounds were randomly selected for each site. These include 20 for Pyrethrum Spray and 4 for Light traps. Each compound was prospected three times due to one collect per season and each collect include 3 trap-nights.

To collect endophilic mosquitoes, we used Pyrethrum Spray method which consists of indoors spraying insecticide, typically pyrethroids, early in the morning. Prior to spraying, all flat surfaces were covered with white sheets making it easier to collect all residual mosquitoes that would fall under the insecticide effect, 15 minutes after spraying.

Light traps were used mainly to detect species composition and abundance as well as endophilic/exophilic rates. So, 2 light traps (one indoor and the other one, outdoor) were systematically set in each compound. traps were set in the evening but activated at nightfall and checked the following morning.

All captured mosquitoes were collected and preserved in Petri dishes for subsequent identification and other analysis.

Collected specimens were identified morphologically using required identification keys [32, 33]. They were observed through a binocular microscope and grouped by genus, species and sex according to their own morphological traits. We used also Xper2 software, which is a plate-form dedicated to taxonomic descriptions and computer-aided-identification.

2.3. Data analysis

Specimens were enumerated using total counts, to determine species richness and abundance, α and β diversity index, this for overall sample, by species and site subsampling. We used PAST software, version 4.03 [34] to calculate, α [35] and β [36] index, respectively referred to describe species diversity within community (richness) and between species communities (similarity) as the amount of differentiation for the latter, the assumption is that more β value increases, more species similarity between 2 communities, is low.

3. Results

3.1. Species composition and their relative abundance

A total of 3,609 mosquitoes were collected and examined during the study period. Five species of mosquitoes were identified belonging to four genera: Anopheles, Aedes, Culex and Mansonia (Table 1). Anopheles (An. gambiae s.l., An. rufipes) and Aedes species (Ae. Aegypti), were unambiguously identified while Culex and Mansonia species were not so, they were combined into a single group. Our results show that relative abundance varied significantly (Chi2 = 6757, df = 4, p-value < 0.001) by species. Thus, the most abundant were Culex sp. (69.7%) and Anopheles gambiae s.l. (29.7%), almost representing 99% of total abundance. Consequently, other species (Mansonia sp., Ae. aegypti and An. rifupes) all put together represent less than 1% (Table 1).

Table 1: species composition and their relative abundance observed overall the sample. N = Number of individuals

Genus	Species	N	Abundance (%)	Chi2	ddl	p-value
Aedes	*Aedes. aegypti*	6	0.17	6757	4	< 0.001
Anopheles	*Anopheles. gambiae*	1071	29.68			
	Anopheles. rufipes	5	0.14			
Culex	*Culex.sp*	2517	69.74			
Mansonia	*Mansonia.sp*	10	0.28			

In terms of species composition, we found a significative difference (Chi2 = 403, df = 8, p-value < 0.001) between sites. In addition to being the most abundant, Culex sp. and An. gambiae s.l., were found common for all sampled sites (Table 2). However, Anopheles rifupes and Mansonia sp. were found only at flooded sites: Sonuci and Daressalam. As for Aedes aegypti, it has been absent from one flooded site (Daressalam) but observed at the other one (Sonuci) and the control site (Karsamba). Overall abundance was significantly difference (p < 0.001) between sites. It was particularly high for flooded sites respectively Dar Salam (47.63%) and Sonuci (42.26%) while it was four times lower in the control, Karsamba (10.11%).

Table 2: Species distribution per sampled site

	Localities			Stats		
Species	**Daressalam**	**Karsamba**	**Sonuci**	**Chi2**	**ddl**	**p-value**
Aedes aegypti	0	2	4	403	8	< 0.001
Anopheles gambiae	275	77	719			
Anopheles rufipes	4	0	1			
Culex.sp	1432	286	799			
Mansonia.sp	8	0	2			
	1719	365	1525			

3.2. Seasonal dynamics of species abundance

Our results showed that species abundance dynamics was closely related to seasons with different specific-patterns. Thus, for Anopheles and Aedes species, high abundances seem to be associated with the rainy season for all sampled sites (p < 0.001). As for Mansonia and Culex, their abundances were observed mainly during the cold season, except for Sonuci site, where Culex was more abundant during the rainy season (p < 0.001). Finally, for all species and at all sites, low abundances were found associated to the hot season (Table 3).

Table 3: Seasonal variations of species distribution (presence/absence) and abundance (number of individuals) per site.

		Season			Stats		
Localities	**Species**	**Rainy**	**Cold**	**Hot**	**N**	**Test**	**p-value**
Daressalam	*Aedes aegypti*	0	0	0	1719	Fisher`s test	< .001
	Anopheles. gambiae	156	117	2			
	Anopheles.rufipes	4	0	0			
	Culex.sp	183	1239	10			
	Mansonia.sp	0	8	0			
Karsamba	*Aedes aegypti*	2	0	0	365	Fisher`s test	< .001
	Anopheles. gambiae	70	7	0			
	Anopheles.rufipes	0	0	0			
	Culex.sp	121	160	5			
	Mansonia.sp	0	0	0			
Sonuci	*Aedes aegypti*	4	0	0	1525	χ^2 test	< .001
	Anopheles. gambiae	693	25	1			
	Anopheles.rufipes	1	0	0			
	Culex.sp	498	297	4			
	Mansonia.sp	0	2	0			
Overall	*Aedes aegypti*	6	0	0	3609	Fisher`s test	< .001
	Anopheles. gambiae	919	149	3			
	Anopheles.rufipes	5	0	0			
	Culex.sp	802	1696	19			
	Mansonia.sp	0	10	0			

3.3. Mosquitoes communities' diversity: No significant difference found between sites in terms of species richness even though it varied from 3 to 5 species (Table 4) with an average of 4 species overall the sampled sites. Diversity was also weak within sites;α Mg ranged from 0.34 to 0.55. and no significant difference between sites (P = 0.23).

The average value of similarity index across all the sites (β = 0.25) reflected a high similarity between sites sharing 75% of species richness so, each species was observed in at least two different sites whatever the period considered.

Table 4: species richness, abundance and diversity indexes

	Localities			Stats	
Index	**Daressalam**	**Karsamba**	**Sonuci**	**Test**	**p-value**
Richness_[S]	4	3	5	Fisher`s test	0.23
α [Margalef]	0,40	0,34	0,55		
β [Whittaker]	0,25				

Similarity index values obtained per pairs of sites, suggested that the flooded sites (Sonuci & Dar Es Salaam) were obviously the most similar (β = 0.11). Compared to the flooded sites, the control (Karsamba) was less similar with Dar Es Salaam (β = 0.42) than Sonuci (β = 0.25) (Figure 2).

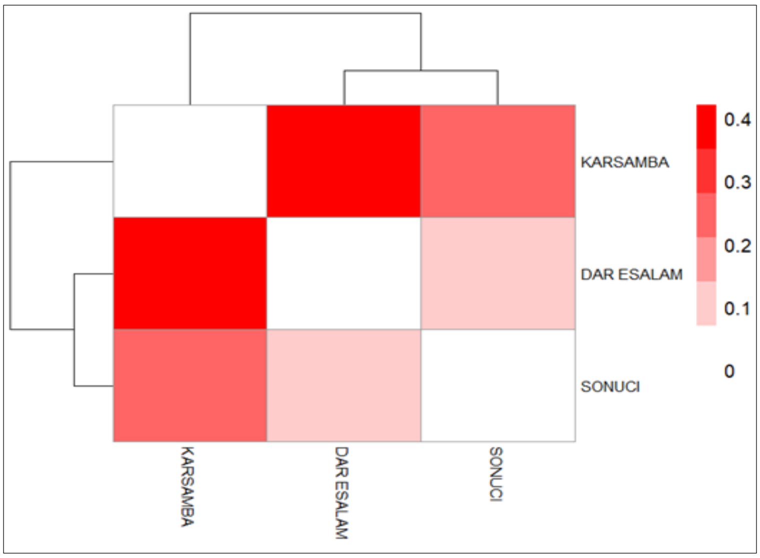

Fig 2: Heatmap of Whitaker beta diversity values, illustrating the similarity/dissimilarity per pairs of sites

4. Discussion

The present study aimed to determine the impact of rising water table phenomenon on mosquitoes' diversity and abundance in urban areas of Niamey city, Niger. Over the study period and across all sites, 3,609 mosquitoes were collected and identified, representing four genera and five species which are already known as common and typical Culicidean fauna of Niger [27]. Among these, Culex sp. was the most abundant representing 69.7% of total abundance, followed by Anopheles with 29.7%. The other species (Mansonia sp., Ae. aegypti and An. rifupes) all put together represent less than 1%.

It is well-known and fairly common that Culex and Anopheles would be the most abundant species in urban Culicidean fauna as documented by several studies but in most of cases, Culex are more abundant than Anopheles [27, 37, 38]. However, the opposite situation where Anopheles was more abundant than Culex, may also be observed. For instance, it was observed 73.9% and 83.61% for Anopheles vs 21.9% and only 10.50% for Culex respectively at Madagascar [39] and in Sudan's White Nile state [40]. Such higher abundances could be attributed to two main factors. First, as it known, waterholes serve as potential breeding sites of mosquitoes, thereby facilitating the completion of pre-imaginal stages [41, 42]. Second, considering the physico-chemical characteristics of waterholes resulting to the less developed sewerage system in Niamey city, which are typically stagnant and polluted in short, whatever preferred by Culex [41]. As for Anopheles gambiae, favorite gites are clear stagnant water and well oxygenated [42] and this, is very common especially in upwelling areas that are permanently flooded and continuously renewed as it is the case for Sonuci and Daressalam sites [10, 24]. As evidenced by species abundance patterns observed from one season to another, previous argument is reinforced by finding that high densities of Culex were recorded during cold season while for Anopheles, their high abundances were found associated with the rainy season. Indeed, in the rainy season, water inflows are more important and regular, contributing to make water less polluted and therefore, more favourable for Anopheles development.

In contrast, the very low abundance observed for Aedes appears unusual as it has been shown that Aedes species abundances tend to increase of 9.5% globally [43] although, there is evidence that abundance of Aedes mosquitoes is closely linked to precipitation in addition to vary by region, season, and species to their abundance [44]. The low abundance recorded for Aedes could be related to the trapping method we used, CDC Light traps while recent studies have reported that Aedes seem to be better captured with BG Sentinel traps than CDC Light traps [45-47].

Our results showed that species abundances varied significantly (p<0,001) between flooded and non-flooded sites respectively characterized by high (about 90%) and low (10%) abundances. It was not found significant variations between sites, with regard to species richness and α diversity index but, the similarity index revealed a greater similarity between flooded sites than with the non-flooded one. These results indicated that flooding led to increased mosquitoes' abundance do to their specific environmental conditions, particularly the availability of stagnant water which consist of breeding sites as discussed above. The diversity parameters, although not significant, provide interesting information in terms of species richness and diversity considering the site status flooded vs non-flooded. The latter, when compared with cited literature results, both similarities and discrepancies emerge. Our results are thus consistent those were found at Algerian wetlands characterized by very high mosquitoes abundance [48]. But, diverge from those of Gabonese wetlands where it was recorded lower diversity indexes [49].

We found that, the most abundant species in flooded areas of Niamey city, are Culex sp. (69.97%) and An. gambiae (29.31%) which are well known for their epidemiological roles, in particular An. gambiae, the main vector of malaria in Niger [24, 27, 28, 50]. These findings suggest that populations living in these areas, are potentially most exposed to vector-borne diseases such malaria, filariasis as well as arboviruses. These results highlight the importance of considering the diversity of wetlands in mosquito vectors control which, must necessarily integrate environmental as determining factors to enhance our understanding on underlying mechanisms of these observations.

5. Conclusion

Our results showed that species richness and abundance as well as diversity were higher in flooded than non-flooded areas. Another significant achievement of the study was that Anopheles gambiae s.l. and Culex sp. were found strongly associated with flooded sites mainly during rainy and cold seasons, respectively. These results highlighted the crucial role of waterholes resulting of groundwater rising, as major has risk factors for vector-borne disease transmission in the affected areas. Understanding these dynamics is essential to effectively guide prevention and control strategies against vector-borne diseases such as Malaria.

Acknowledgement

We would like to thank both CERMES and SFR-RACINES for funding and all the logistical support and facilities they provided. Thanks to Halido Hassane and Mahamadou Izamane for their assistance during samples collection. We are particularly grateful to all householders for permitting us to mosquitoes' traps in their homes and workplaces.

References

1. Ayodotun B, Bamba S, Adio A. Vulnerability Assessment of West African Countries to Climate Change and Variability. Journal of Geoscience and Environment Protection. 2019;07:13-15.
2. Diba I, Camara M, Diedhiou A. Impacts of the Sahel-Sahara Interface Reforestation on West African Climate: Intra-Annual Variability and Extreme Temperature Events. Atmospheric and Climate Sciences. 2019;09:35-61.
3. Donnelly MJ, McCall P, Lengeler C, Bates I, D'Alessandro U, Barnish G, *et al.* Malaria and urbanization in sub-Saharan Africa. Malaria Journal. 2005;4:12.
4. Tabutin D, Schoumaker B. La démographie de l'Afrique au sud du Sahara des années 1950 aux années 2000. Population. 2004;59:521-622.
5. Bickler SW, Wang A, Amin S, Halbach J, Lizardo R, Cauvi DM, *et al.* Urbanization in Sub-Saharan Africa: Declining Rates of Chronic and Recurrent Infection and Their Possible Role in the Origins of Non-communicable Diseases. World Journal of Surgery. 2018;42:1617-1628.
6. Obilor NM, Awogu CO. Urbanization and Food Production in Owerri North Local Government Area, Nigeria. THE PROGRESS: A Journal of Multidisciplinary Studies. 2023;4:14-20.
7. Parienté W. Urbanization in sub-Saharan Africa and the challenge of access to basic services. Journal of Demographic Economics. 2017;83:31-39.
8. Favreau G, Nanzoumou Y, Leblanc M, Guéro A, Baba G. Groundwater resources increase in the Iullemmeden Basin, West Africa. 2012. IAH Blue Book Series Publi 113-128.
9. Nanzoumou Y, Favreau G, Mahaman MA, Maïnassara I. La petite irrigation par les eaux souterraines, une solution durable contre la pauvreté et les crises alimentaires au Niger ? Cah Agric. 2016;25:15003.
10. Alassane HH, Adamou MM, Favreau G, Boucher M, Hima K, Dan Dano I. Rise of Urban Water Table as a Cause of Flooding: Improving Knowledge in the City of Niamey (Niger Republic). Journal of Water Resource and Protection. 2021;13:976-999.
11. Favreau G, Leduc C. Fluctuations à long terme de la nappe phréatique du Continental Terminal près de Niamey (Niger) entre 1956 et 1997. AISH. 1998;252
12. Keating A, Mechler R, Mochizuki J, Kunreuther H, Bayer J, Hanger S, *et al.* Operationalizing Resilience Against Natural Disaster Risk: Opportunities, Barriers, and a Way Forward. 2014;Zurich Flood Resilience Alliance.
13. Maillot M. Étude des remontées de nappe de Paris et de la Petite Couronne lors des épisodes de crue de la Seine et de la Marne. Paris Sciences et Lettres ComUE). 2019.
14. Boubakar HA. Aquifères superficiels et profonds et pollution urbaine en Afrique : Cas de la communauté urbaine de Niamey (NIGER). Thèse de Doctorat. 2010;Université Abdou Moumouni.
15. Leduc C, Favreau G, Schroeter P. Long-term rise in a Sahelian water-table: the Continental Terminal in South-West Niger. Journal of Hydrology. 2001;243:43-54.
16. Leduc C, Taupin J-D. Hydrochimie et recharge de la nappe phréatique du Continental Terminal (Niamey, Niger). IAHS Publications-Series of Proceedings and Reports-Intern Assoc Hydrological Sciences. 1997;244:235-244.
17. Mamadou I, Alassane OS, Malam AM, Garba Z. Risques D'inondation Et Proposition D'un Plan D'évacuation Des Eaux De Pluie Dans La Ville De Kantché, Région De Zinder Au Niger. European Scientific Journal. 2019;15:88-104.
18. Namegabe M, Matabaro B, Mwangamwanga I, Kaningu

B, Mana N, Ciregereza B, *et al.* Enquête sur les conséquences de l'action anthropogénique sur l'environnement en milieu rural: cas d'Irhambi/Katana, Territoire de Kabare, Sud-Kivu. International Journal of Innovation and Applied Studies. 2014;7:1625

19. Badiane D, Gueye MT, Coly EV, Faye O. Gestion intégrée des principaux ravageurs du cotonnier au Sénégal et en Afrique occidentale. International Journal of Biological and Chemical Sciences. 2015;9:2654-2667.
20. Huignard J, Glitho IA, Monge J-P, Regnault-Roger C. Insectes ravageurs des graines de légumineuses: Biologie des Bruchinae et lutte raisonnée en Afrique. 2011;Éditions Quae.
21. Marc I, Chibani A, Alemad A, Alkhali A, Belala A, Hadji M, Belghyti D. Étude écologique et entomologique des culicides larvaires des gîtes de la province de Kenitra (Maroc). European Scientific Journal. 2016;vol.12, No.32: 398-409.
22. Polack B, Boulouis H-J, Guillot J, Chermette R. Les zoonoses (tableaux synthétiques: animaux réservoirs de pathogènes et modes de transmission). Revue Francophone des Laboratoires 2015;67-79.
23. Renaudin J-M. Allergie aux insectes piqueurs et maladie professionnelle. Revue Française d'Allergologie. 2010;50:137-140.
24. 24. Iro SM, Doumma A, Seydou YA. Mesures des indicateurs de prolifération des larves de moustiques au niveau des mares permanentes et semi permanentes de Saga, Niger. International Journal of Biological and Chemical Sciences. 2020;14:1188-1202.
25. Julvez J, Develoux M, Mounkaila A, Mouchet J. Diversité du paludisme en zone sahélo-saharienne. Ann Soc Belge Med Trop. 1992;72:163-177
26. Julvez J, Chippaux J-P, Garba A, Lamotte M, Labbo R. Les maladies transmissibles en milieu urbain sahélien: Niamey, Niger. Maladies à transmission vectorielle. Colloque International "Eau/Santé-Ouaga. 2000.
27. Labbo R, Fandeur T, Jeanne I, Czeher C, Williams E, Arzika I, *et al.* Ecology of urban malaria vectors in Niamey, Republic of Niger. Malaria journal. 2016;15:1-17.
28. Toudou BIM, Doumma ALI, HIMA MK. Pratiques et risques sanitaires associés aux produits anti-moustiques utilisés dans la lutte anti-vectorielle dans la ville de Niamey au Niger. Afrique SCIENCE. 2021;19:136-148.
29. Carnevale P, Robert V. Les anophèles: biologie, transmission du Plasmodium et lutte antivectorielle. 2017;IRD éditions
30. Julvez J, Mouchet J, Michault A, Fouta A, Hamidine M. Eco-épidémiologie du paludisme à Niamey et dans la vallée du fleuve, République du Niger, 1992-1995. Bull Soc Path Exot. 1997;90:94-100
31. Le Goff G, Carnevale P, Robert V. Comparaison des captures sur homme et au piège lumineux CDC pour l'échantillonnage des moustiques et l'évaluation de la transmission du paludisme au Sud-Cameroun, Annales de la Société Belge de Médecine Tropicale. 1993;55-60.
32. Gillies MT, Coetzee M. A supplement to the Anophelinae of Africa South of the Sahara. Publ S Afr Inst Med Res. 1987;55:1-143
33. WHO, Coetzee M. Clé d'identification des moustiques anophèles femelles de la région afrotropicale (Diptera: Culicidae). 2021;Organisation mondiale de la Santé.
34. Hammer Ø, Harper DA. Past: Paleontological Statistics software package for education and data analysis. Palaeontologia electronica. 2001;4:1.
35. Margalef R. Temporal succession and spatial heterogeneity in natural phytoplankton In Buzzati-Traverso, A. A. (ed.), Perspectives in Marine Biology. 1958;University of California Press, Berkeley, pp. 323-349.
36. Whittaker R. Evolution of species diversity in land communities. Evolutionary biology. 1977;10:1-67
37. Kaboré DPA, Soma DD, Gil P, Kientega M, Sawadogo SP, Ouédraogo GA, *et al.* Mosquito (Diptera: Culicidae) populations in contrasting areas of the western regions of Burkina Faso: species diversity, abundance and their implications for pathogen transmission. Parasites Vectors. 2023;16:438.
38. Matubi EM, Bukaka E, Luemba TB, Situakibanza H, Sangaré I, Mesia G, *et al.* Détermination des paramètres bioécologiques et entomologiques d'Anopheles gambiae sl dans la transmission du paludisme à Bandundu-ville, République Démocratique de Congo. Pan Afr Med J. 2015;22:108.
39. Ratovonjato J, Randrianarivelojosia M, Rakotondrainibe ME, Raharimanga V, Andrianaivolambo L, Le Goff G, *et al.* Entomological and parasitological impacts of indoor residual spraying with DDT, alphacypermethrin and deltamethrin in the western foothill area of Madagascar. Malar J. 2014;13:21.
40. Seufi AM, Galal FH. Role of Culex and Anopheles mosquito species as potential vectors of rift valley fever virus in Sudan outbreak, 2007. BMC Infectious Diseases. 2010;10:65.
41. Kinga H, Kengne-Ouafo JA, King SA, Egyirifa RK, Aboagye-Antwi F, Akorli J. Water Physicochemical Parameters and Microbial Composition Distinguish Anopheles and Culex Mosquito Breeding Sites: Potential as Ecological Markers for Larval Source Surveillance. J Med Entomol. 2022;59:1817-1826.
42. Smith MW, Macklin MG, Thomas CJ. Hydrological and geomorphological controls of malaria transmission. Earth-Science Reviews. 2013;116:109-127.
43. Liu-Helmersson J, Rocklöv J, Sewe M, Brännström Å. Climate change may enable Aedes aegypti infestation in major European cities by 2100. Environmental research. 2019;172:693-699.
44. Lamy K, Tran A, Portafaix T, Leroux MD, Baldet T. Impact of regional climate change on the mosquito vector Aedes albopictus in a tropical island environment: La Réunion. Science of the Total Environment. 2023;875:162484.
45. Li Y, Su X, Zhou G, Zhang H, Puthiyakunnon S, Shuai S, *et al.* Comparative evaluation of the efficiency of the BG-Sentinel trap, CDC light trap and Mosquito-oviposition trap for the surveillance of vector mosquitoes. Parasites Vectors. 2016;9:446.
46. Meeraus WH, Armistead JS, Arias JR. Field comparison of novel and gold standard traps for collecting Aedes albopictus in northern Virginia. Journal of the American Mosquito Control Association. 2008;24:244-248.
47. Reegan AD, Gandhi MR, Balachandar M, Farajollahi A, Kesavaraju B, Ignacimuthu S. Comparative efficacy of Biogents Sentinel and CDC traps for Aedes and Culex mosquito surveillance in India. JoBAZ. 2024;85:46.

48. Hamidi D. Biodiversité des Diptères-Nématocères dans quelques milieux à Djelfa [thesis]. Djelfa: Université Ziane Achour-Djelfa, Faculté des Sciences de la Nature et de la Vie;2019.
49. Mavoungou JF, Acapovi-Yao GL, Koumba Zinga CR, Mbang Nguema OA, M'batchi B. Diversité de l'entomofaune de la zone pétrolifère de Ntchengué à Port-Gentil au Gabon. Afrique Science. 2016;12:151-163.
50. Noura MS, Ibrahima I, Medard D, Yokoly FN, Maiga RSO, Wilfried ZH, *et al.* Identification et caractérisation des potentiels habitats larvaires de moustiques Anopheles spp. dans la ville de Niamey. International Journal of Biological and Chemical Sciences. 2024;18: 2221-2237.