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Breeding ecology and distribution of culex mosquitoes in Minna, Nigeria: Implications for vector control

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Abstract

The ecological characteristics of mosquito breeding sites are a fundamental determinant of population dynamics and, consequently, the transmission potential of mosquito-borne diseases. To elucidate the local factors driving vector proliferation, this study investigated the occurrence and spatial distribution of *Culex* mosquito larvae across six distinct and representative breeding habitats within Minna, Niger State, Nigeria. Over the course of the survey, larval sampling was conducted in rice fields, open drainage gutters, dams, slow-moving streams, temporary rain pools, and water-collecting discarded tyres. Collected larvae were transported to an insectary and reared under standardized conditions to adulthood to facilitate accurate species identification. The relative abundance of *Culex* mosquitoes was then calculated for each habitat type to determine their comparative contribution to the local vector population. The results revealed a clear and striking hierarchy in larval density. Rice fields were the most productive habitat, accounting for a substantial 36.0% of all larvae collected. This was followed by gutters (21.6%), which served as significant urban breeding grounds. Dams (12.6%), streams (11.6%), and rain pools (10.7%) supported moderate densities, while discarded tyres (7.5%) represented the least common habitat. The marked predominance of rice fields and gutters underscores their exceptional ecological suitability for *Culex* proliferation, a phenomenon likely driven by persistent stagnant water, high organic nutrient loads from decomposition and waste, and minimal environmental disturbance. These findings strongly indicate that human activities and specific habitat types are primary drivers shaping the distribution and abundance of mosquito populations in the region. A deep understanding of this localized breeding ecology is therefore critical for designing and deploying effective, targeted vector control strategies. Interventions focusing on environmental management and larval source reduction in the identified priority habitats specifically rice fields and drainage systems could substantially suppress *Culex* mosquito populations and thereby reduce the associated risks of arboviral and filarial disease transmission in Minna and similar endemic settings.

Keywords: *Culex* Mosquitoes; Breeding Ecology; Larval Habitats; Minna; Nigeria; Vector Control; Larval Source Management

1. Introduction

Mosquito-borne diseases persist as one of the most formidable challenges to global public health, responsible for millions of deaths and a significant burden of morbidity each year [1]. While the role of *Anopheles* mosquitoes in malaria

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transmission is widely recognized, species within the genus *Culex* are also of critical epidemiological importance. They function as primary vectors for a range of debilitating arboviral and filarial infections, including West Nile virus, Japanese encephalitis, St. Louis encephalitis, and lymphatic filariasis [2, 3]. The impact of these diseases extends beyond immediate health consequences, imposing profound social and economic strains on affected communities, particularly in low- and middle-income nations [4].

Culex mosquitoes are notably adaptable and ubiquitous, capable of thriving in a wide spectrum of environments, from rural agricultural landscapes to densely populated urban centers [5]. Their larval habitats are equally diverse, encompassing natural water collections like streams and seasonal rain pools, as well as human-made sites such as rice paddies, clogged drainage gutters, and various artificial containers [6]. The specific characteristics of these larval habitats directly influence key population parameters, including density, survival rates, and the overall vectorial capacity of *Culex* species [7]. Therefore, a detailed understanding of breeding site ecology is not merely an academic exercise but a crucial prerequisite for effective vector control, given that larval source management remains one of the most potent and sustainable preventive measures available [8].

Within Nigeria, mosquito-borne diseases constitute a major public health priority. However, research efforts have historically been disproportionately focused on *Anopheles* mosquitoes due to the overwhelming burden of malaria [9]. Consequently, studies dedicated to the breeding ecology of *Culex* species, especially in the North-central region of the country, remain relatively scarce and fragmented [10]. This significant knowledge gap directly hinders the development of targeted, evidence-based interventions. This is particularly problematic in rapidly urbanizing settings like Minna, where factors such as inadequate waste management, expansive irrigation for agriculture, and the proliferation of stagnant water bodies create abundant opportunities for mosquito breeding. This study was therefore designed to investigate the breeding ecology and distribution patterns of *Culex* mosquitoes across representative larval habitats in Minna, Niger State, Nigeria. By identifying the most productive breeding sites and quantifying their relative contribution to the mosquito population, the findings provide essential ecological insights that can directly inform the planning and implementation of integrated vector management strategies and guide public health interventions for disease reduction.

2. Materials and Methods

2.1. Description of the Study Area

This research was conducted in Minna, the capital city of Niger State, located in North-central Nigeria. Geographically, Minna lies between latitude 9°36'N and longitude 6°33'E and is home to an estimated population exceeding 500,000 people [11]. The city experiences a tropical climate characterized by two distinct seasons: a prolonged wet season from May to October and a pronounced dry season from November to April. The area receives an annual rainfall ranging between 1,200 and 1,300 millimeters, while mean monthly temperatures fluctuate from 22 °C to 34 °C. Common anthropogenic activities that influence mosquito ecology include extensive rice farming, smaller-scale irrigation projects, and urban agriculture. These practices create a mosaic of diverse aquatic habitats that are highly suitable for the breeding and development of various mosquito species, including *Culex*.

2.2. Selection and Characterization of Breeding Sites

Based on preliminary reconnaissance surveys and existing knowledge of local mosquito breeding activity, six representative habitat types were selected for sampling within the Minna metropolis. These sites were chosen to reflect a spectrum of both natural and artificial water bodies:

- Rice fields: Irrigated agricultural plots used for rice cultivation.
- Gutters: Open drainage channels common in residential and commercial areas.
- Dams: Man-made water retention structures.
- Streams: Natural, slow-flowing water bodies.
- Rain pools: Temporary collections of water formed after rainfall events.
- Discarded tyres: Artificial containers that collect and hold rainwater.

This selection ensured a comprehensive assessment of the primary aquatic environments available for mosquito oviposition and larval development in the region.

2.3. Mosquito Collection, Transportation, and Rearing

Larval sampling was carried out using standard 350 ml WHO dippers [12]. At each designated breeding site, between 10 to 15 dips were taken, with the exact number adjusted based on the total surface area of the water body. The larvae collected from each dip were carefully transferred into pre-labeled, wide-mouthed plastic containers, which were partially filled with water from the respective collection site to maintain ambient conditions and minimize larval stress. The samples were then promptly transported to the insectary facility at the Department of Biochemistry, Federal University of Technology, Minna. In the insectary, the larvae were maintained under controlled environmental conditions (27 ± 2 °C temperature; $70 \pm 5\%$ relative humidity; a 12-hour light/12-hour dark cycle) and provided a diet of finely ground fish food or yeast. They were reared through their developmental stages until adult emergence. The resulting adult mosquitoes were then euthanized and identified morphologically to genus and species level using established, illustrated taxonomic keys [13].

2.4. Data Analysis

The abundance of *Culex* mosquitoes originating from each breeding site was calculated and expressed as a percentage of the total number of larvae collected across all six habitats. The comparative distribution of larvae was summarized using descriptive statistics. The results are presented in a summary table and can be supported by graphical figures to illustrate the relative productivity of the different habitat types.

3. Results

3.1. Distribution and Relative Abundance Across Habitats

All six surveyed larval habitats were found to support breeding populations of *Culex* mosquitoes, which were successfully reared to adulthood for species confirmation. The relative abundance and distribution of these mosquitoes across the different habitats are detailed in Table 1.

The results revealed marked and significant variability in larval abundance. Rice fields were, by a considerable margin, the most productive habitat, supporting 36.0% of the total collected larvae. This predominance is likely linked to the semi-permanent, stagnant nature of irrigated fields, the accumulation of organic matter from decomposing plant material, and prolonged water retention, all of which combine to create optimal conditions for mosquito larval development.

Table 1 Distribution and Relative Abundance of *Culex* Mosquito Larvae in Selected Breeding Habitats of Minna, Nigeria

Breeding Habitat	Number of Larvae (%)	Relative Contribution (%)	Rank Order of Abundance
Rice fields	360	(36.0)	Highest 1 st
Gutters	216	(21.6)	High 2 nd
Dams	126	(12.6)	Moderate 3 rd
Streams	116	(11.6)	Moderate 4 th
Rain pools	107	(10.7)	Moderate 5 th
Tyres	75	(7.5)	Lowest 6 th
Total	1000	(100.0)	

Values represent the percentage proportion of larvae collected across the six sites (Total N = 1000 larvae).

Drainage gutters constituted the second most significant habitat, accounting for 21.6% of the total collections. This highlights the critical role of poorly maintained urban drainage infrastructure in sustaining substantial *Culex* populations within both urban and peri-urban settings. The remaining habitats dams (12.6%), streams (11.6%), and rain pools (10.7%) exhibited moderate larval densities. Their productivity is likely influenced by factors such as seasonal rainfall patterns, water flow dynamics, and the overall stability and permanence of the habitat. Discarded tyres contributed the least (7.5%), a finding consistent with their typically small water-holding surface area and a greater tendency to dry out relatively quickly compared to larger water bodies.

In summary, the data clearly indicate that rice fields and gutters are the most productive breeding sites for *Culex* mosquitoes in Minna, providing exceptionally favorable ecological conditions for their proliferation. This finding

emphasizes the practical importance of prioritizing larval source management activities in these specific habitat types as a core component of any integrated vector control program in the region.

4. Discussion

This ecological study assessed the breeding patterns of *Culex* mosquitoes across six representative habitats in Minna, Nigeria, and conclusively identified rice fields and drainage gutters as the most productive larval sites. These findings offer critical, location-specific insights into the ecology of this important vector genus and carry direct implications for refining vector control strategies in North-central Nigeria.

The dominance of rice fields, which accounted for over a third of all larvae collected, aligns consistently with previous entomological reports from other parts of Nigeria and West Africa [14, 15]. Irrigated rice fields essentially function as expansive, semi-permanent water bodies that are often enriched with organic matter from fertilizers and decomposing plant residue. This combination creates an environment that is highly conducive to the proliferation of *Culex* larvae [16]. A parallel study conducted in Northern Ghana similarly identified rice paddies as the dominant habitat for *Culex quinquefasciatus*, responsible for over 40% of larval collections [17]. The stagnant nature of these agricultural waters allows for an extended larval development period and may facilitate year-round vector propagation in communities dependent on rice farming.

The significant contribution of gutters (21.6%) to the larval population underscores the profound impact of inadequate urban sanitation and poorly maintained drainage systems on mosquito ecology. Previous surveys in major Nigerian cities like Ibadan and Lagos have also consistently identified clogged gutters and open drains as major breeding grounds for *Culex* species, primarily due to the constant presence of stagnant wastewater and accumulations of organic debris [18, 19]. This recurring pattern suggests that the state of urban infrastructure is a key determinant in sustaining mosquito populations across Nigerian cities.

The moderate larval densities observed in dams, streams, and rain pools are consistent with findings from other Nigerian cities such as Zaria and Maiduguri, where semi-natural habitats were found to support *Culex* breeding, albeit at lower levels compared to organically polluted urban sites [20, 21]. The productivity of these habitats is often subject to seasonal variations in rainfall and water flow, which can limit their stability and reliability as larval habitats throughout the year. The relatively low productivity of discarded tyres in this study contrasts with findings from Port Harcourt, where tyres accounted for a higher proportion of breeding, likely due to more frequent rainfall and pervasive indiscriminate waste disposal practices [22].

The distribution pattern uncovered in Minna reflects broader ecological trends observed across sub-Saharan Africa. For instance, research in Lagos reported that gutters and stagnant drains were the most common habitats for *Culex quinquefasciatus* [23]. Similarly, a study in Accra, Ghana, revealed that urban drains supported high larval densities, indicating that *Culex* mosquitoes effectively exploit polluted water habitats that are a common feature of rapidly expanding cities [24]. Conversely, in more rural settings, such as rice-growing communities in The Gambia and Côte d'Ivoire, irrigated fields were identified as the dominant breeding sites, often linked to seasonal transmission cycles of lymphatic filariasis and arboviral infections [25, 26]. The parallels between Minna and these diverse regions highlight the dual and interconnected role of agricultural practices and urban development in shaping mosquito ecology.

From a public health perspective, the abundance of *Culex* larvae in rice fields and gutters is a finding of considerable concern. *Culex* mosquitoes are established vectors of lymphatic filariasis in West Africa, a neglected tropical disease that remains endemic in several Nigerian states [27]. They are also competent vectors for arboviruses such as West Nile virus and Rift Valley fever, which are of growing concern in Africa [28, 29]. The persistence of these highly productive breeding sites in Minna suggests a sustained and potentially escalating risk of disease transmission, particularly in peri-urban communities where human settlement, agricultural activity, and vector habitats intersect, leading to frequent human-vector contact.

Furthermore, the marked adaptation of *Culex* mosquitoes to organically polluted habitats like gutters underscores their significant ecological plasticity and resilience. This adaptability enhances their survival in diverse and challenging environments and may also be linked to the development of physiological resistance to commonly used insecticides, presenting a compounded challenge for control programs [30].

These findings collectively underscore the urgent need for targeted larval source management to form a central pillar of integrated vector control in Minna. Based on the evidence, intervention programs should prioritize rice fields and drainage gutters. Practical strategies may include:

- Environmental management: Improving the design and maintenance of drainage systems to ensure water flow and prevent stagnation.
- Agricultural practices: Implementing intermittent irrigation schemes and water-level management in rice fields to disrupt the mosquito breeding cycle.
- Larviciding: The targeted application of biological larvicides, such as *Bacillus thuringiensis israelensis* (Bti), in identified high-risk habitats to reduce larval populations in an environmentally sensitive manner.
- Community participation: Mobilizing communities for regular environmental sanitation exercises to clear blocked drains and remove artificial water-holding containers.

Evidence from previous successful interventions, for example, in Tanzania and Kenya, has demonstrated that habitat-targeted larval control can significantly reduce *Culex* breeding densities and subsequently lower the risk of disease transmission [31, 32]. Implementing a similarly focused strategy in Minna could therefore yield substantial public health benefits and contribute to reducing the local burden of *Culex*-borne diseases.

While this study provides valuable baseline ecological data, it is important to acknowledge its limitations. The research was confined to six selected habitats within Minna and did not assess seasonal variations in breeding patterns, which can be significant. Future studies should adopt a longitudinal surveillance design to capture these temporal dynamics across different seasons. Furthermore, incorporating molecular identification techniques would allow for precise species complex discrimination and better linkage of specific ecological patterns with actual disease transmission potential. Integrating insecticide resistance monitoring would also provide a more holistic understanding of the factors influencing *Culex* vector capacity in the region.

5. Conclusion

This study has demonstrated that *Culex* mosquitoes in Minna, North-central Nigeria, exploit a diverse range of natural and artificial habitats for breeding. However, rice fields and drainage gutters emerge as disproportionately productive sites, highlighting their exceptional ecological suitability and the strong influence of human activities—both agricultural and urban on vector proliferation. Given the established role of *Culex* species as vectors of lymphatic filariasis and various arboviruses, these findings have direct and serious implications for public health. Therefore, to be effective, vector control efforts in Minna and similar settings must prioritize the management of rice fields and urban drainage channels as key larval sources.

Recommendations

Based on the findings of this study, the following actions are recommended:

- Public health authorities should implement targeted larval source management programs that focus explicitly on rice fields and gutters as priority habitats for intervention.
- Community-based sanitation initiatives should be promoted and supported to improve overall waste management and reduce the prevalence of stagnant water in residential and urban areas.
- Integrated Vector Management (IVM) strategies should be formally adopted, combining environmental management with other control methods for sustainable impact.

Compliance with ethical standards

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Ethical Approval and Consent

This study involved the collection of mosquito larvae from various aquatic habitats. This study did not involve the use of human participants, formal ethical approval and informed consent were not required. Access to public drainage system and pre-urban areas was conducted in accordance with local guidelines.

Animal welfare

The study utilizes mosquito larva and adults. Rearing and morphological identification of adult mosquitoes are in standard entomological procedures and are not subjected to specific animal welfare regulations for invertebrates in Nigeria.

Disclosure of conflict of interest

The authors declare that they have no competing interests.

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Authors' contributions

TJO conceived the study. AI and TJO participated in the design and quality assessment of the study. OU and TJO took part in the selection and extraction of the plant samples used. AI and TJO, AOO, STG and HAA drafted the manuscript, with significant input from TJO. All authors proofread the manuscript and made inputs. All authors approved the final manuscript for publication.

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