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Research Article

Results of the Preliminary Survey on Mosquitos in the Coastal Wetlands in Libya

Ala Nuwayji[1], Hanan Aqeehal[2*], Mahmoud abuhajar[3], Ahmed Elgrari[4], Khaled Etayeb[5]

[1,2]National Centre for Disease Control, Ministry of Health, Libya
[3]Libyan Society for Birds (LSB), Libya
[4]Dept. of medical parasitology, Faculty of medicine, University of Tripoli, Tripoli, Libya
[5]Dept. of Zoology, Faculty of Science, University of Tripoli, Tripoli, Libya

**Corresponding Author:*

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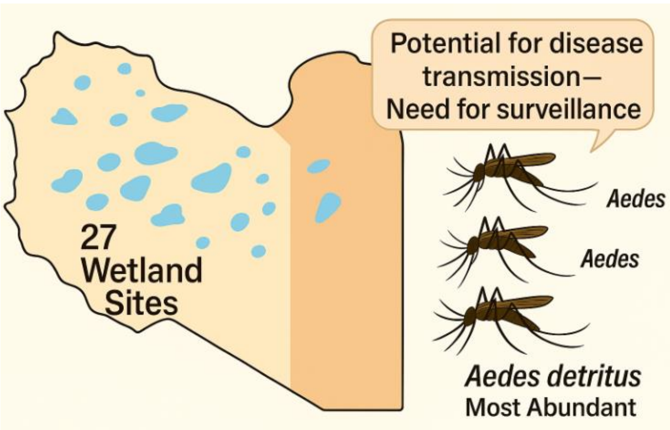
Abstract— Libya, despite its arid climate, possesses diverse wetland ecosystems that provide critical habitats for various organisms, including mosquitoes. These ecosystems have the potential to serve as breeding grounds for mosquitoes, which can act as vectors for various diseases. The primary objective of this study was to identify mosquito species present in 27 wetland sites across Libya to assess the potential risk of vector-borne disease transmission. A preliminary survey was conducted to collect mosquito samples from 27 wetland sites across Libya. Standard entomological techniques were employed to capture and identify mosquito species. Three species of Aedes mosquitoes were identified: *Aedes caspius, Aedes dorsalis,* and *Aedes detritus*. Among these, *Aedes detritus* was the most abundant species, found in all surveyed locations. These findings highlight the potential for disease transmission, especially considering the known vector status of these species. The study emphasizes the need for ongoing surveillance to monitor mosquito populations in order to implement effective control measures. Further research is necessary to explore the ecological factors influencing mosquito distribution and abundance, as well as the potential for the introduction of invasive species such as; *Aedes albopictus*.

Keywords— Mosquitoes, Vectors, Wetlands, Libya

Graphical Abstract-



This graphical abstract illustrates the key findings of a preliminary mosquito survey conducted across 27 wetland sites in Libya. It highlights the identification of three Aedes mosquito species: *Aedes caspius*, *Aedes dorsalis*, and *Aedes detritus*. Among them, *Aedes detritus* was found to be the most abundant and widespread across all surveyed locations. The visual emphasizes the potential for vector-borne disease transmission and underscores the urgent need for ongoing mosquito surveillance and control efforts in Libyan wetlands.

1. Introduction

Libya possesses a surprising variety of wetland ecosystems despite its predominantly arid and semi-arid climate. These wetlands, which include desert oases, salt marshes, coastal lagoons, wadis, and artificial reservoirs, play a crucial role in supporting regional biodiversity and sustaining ecological balance [1],[2]. Salt marshes, in particular, dominate the Libyan wetland landscape. These shallow basins, often dry or semi-dry for extended periods, occasionally connect to the Mediterranean Sea, forming dynamic ecological interfaces that fluctuate with seasonal and climatic variations. Along Libya's extensive coastline stretching more than 1,700 kilometers a diverse array of wetland habitats exists, ranging from coastal lagoons and bays to saline lakes and islands [3]. Despite their limited surface coverage, these wetlands provide essential habitats for aquatic and semi-aquatic organisms, functioning as key ecological nodes in an otherwise desert-dominated environment.

Ecologically, Libyan wetlands hold immense importance for avifauna. They serve as vital stopover and wintering sites for numerous migratory bird species that travel between Europe, Asia, and sub-Saharan Africa [3]. Each year, large populations of waterbirds including flamingos, herons, and shorebirds depend on these wetlands for feeding and resting during their long migratory journeys. While Libya's arid climate might lead to the perception of limited biodiversity, its wetlands harbor a surprisingly rich assemblage of flora and fauna [1],[2],[4]-[7]. These areas thus represent not only ecological sanctuaries but also important components of regional and global biodiversity networks, linking continents through migratory flyways.

From a public health perspective, however, wetland ecosystems can also serve as favorable breeding grounds for mosquitoes. The presence of stagnant or slow-moving water, coupled with organic detritus and vegetation, provides ideal conditions for mosquito reproduction. Mosquitoes are not only an ecological component of wetland food webs but also notorious vectors of several significant diseases, including malaria, West Nile virus, Rift Valley fever, and other arboviral infections [8],[9]. The relationship between wetlands and vector-borne diseases is complex: while poorly managed or degraded wetlands may promote mosquito proliferation, well-functioning and biodiverse wetland ecosystems can naturally suppress mosquito populations through ecological regulation. Predatory insects, fish, amphibians, and other natural enemies of mosquito's help maintain population balance, highlighting the role of healthy ecosystems as natural barriers against disease transmission [9],[10],[11]. This balance underscores the importance of integrating ecological health into public health planning—a principle increasingly recognized in the context of the One Health approach.

Libyan wetlands are particularly vulnerable to environmental and anthropogenic changes. Climate variability, including alterations in precipitation patterns, prolonged droughts, and sporadic heavy rainfall events, directly influences wetland hydrology. Such fluctuations can transform temporary wetlands into persistent mosquito breeding sites or, conversely, dry them out, reducing suitable habitats [12],[13]. Human activities such as urban expansion, agricultural irrigation, wastewater discharge, and dam construction further modify the hydrological regime, often creating new artificial water bodies that can serve as mosquito habitats. These ecological and environmental transformations have the potential to shift mosquito species composition, increase the abundance of certain vector species, and consequently elevate the risk of mosquito-borne disease outbreaks in nearby human populations.

Understanding mosquito community structure in wetland ecosystems is therefore critical for assessing vector-borne disease risks and establishing targeted surveillance strategies. Wetlands serve as unique ecological interfaces where mosquitoes, avian hosts, and human populations intersect. Migratory birds, which frequent these wetlands seasonally, can act as reservoirs or carriers of arboviruses, facilitating the introduction of exotic pathogens into new regions. Resident bird species, on the other hand, may sustain local transmission cycles. Consequently, wetlands can function as "ecological bridges" linking vector species and vertebrate hosts, thereby playing a pivotal role in the circulation and maintenance of zoonotic arboviruses [14],[15].

Despite this significance, there is a scarcity of scientific information on mosquito fauna in Libya, particularly in wetland ecosystems. Most previous entomological studies have focused on malaria vectors or urban mosquito populations, leaving wetland-associated species largely undocumented [16]-[24]. The lack of updated data hampers effective vector control planning and weakens the national capacity to anticipate emerging disease threats. Recent environmental shifts—including increasing urbanization, climate change, and international mobility—further heighten the importance of understanding mosquito ecology in these sensitive habitats.

This study presents the results of a preliminary survey conducted across 27 wetland sites in Libya, aiming to identify mosquito species, assess their distribution, and establish baseline ecological data. To the best of our knowledge, this represents the first investigation of mosquito communities within Libyan wetland ecosystems. Special attention was given to detecting potential invasive species, notably *Aedes (Stegomyia) albopictus,* the Asian tiger mosquito, which has demonstrated remarkable adaptability and global spread potential.

By mapping the occurrence of mosquito species and characterizing their preferred habitats, this study provides foundational knowledge for future ecological and epidemiological research. Understanding mosquito diversity and distribution in wetlands is essential for designing integrated vector management programs, anticipating vector-borne disease risks, and conserving wetland ecosystem health. In doing so, this research bridges environmental science and public health, contributing to the growing recognition of wetlands as both ecological assets and critical components of disease surveillance frameworks in Libya.

1.1 Objective of the Study

This study aimed to (1) identify mosquito species present in Libyan coastal wetlands, (2) assess their distribution across different habitats, understanding mosquito diversity in these ecosystems is crucial for developing targeted surveillance and control strategies.

2. Related work

Mosquitoes inhabiting wetland ecosystems are of both ecological and epidemiological importance, yet their study in

Libya has been largely neglected. Historically, research in Libya has concentrated primarily on malaria vectors or urban mosquito populations, leaving wetland-associated species underexplored [12]–[20]. This knowledge gap is significant, given the critical role that wetland mosquitoes play in maintaining arbovirus transmission cycles and acting as bridge vectors between avian and human populations. Despite the paucity of local data, regional research from North Africa and the broader Mediterranean offers valuable insights into the composition, ecology, and public health implications of wetland-associated mosquito species, which are likely relevant to the Libyan context.

Several studies in North Africa have documented the predominance of species such as Aedes caspius, Aedes dorsalis, and Aedes detritus in brackish and freshwater habitats [14],[27],[28]. These species exhibit remarkable ecological plasticity, enabling them to adapt to a wide range of environmental conditions, including fluctuations in salinity, water depth, and temperature, which are characteristic of coastal wetlands. For instance, *Aedes caspius* has been reported to tolerate highly saline environments, while Aedes dorsalis is often associated with temporary freshwater pools created during seasonal flooding events. Aedes detritus, a member of the detritus complex, is commonly found in semi-permanent wetlands with abundant organic matter, where it exploits the nutrient-rich sediments for larval development.

The ecological adaptability of these mosquitoes has important implications for their distribution and abundance across North Africa. Surveys conducted in neighboring countries such as Tunisia, Algeria, and Morocco consistently report the presence of these species in similar coastal and inland wetland habitats [22]–[24]. These findings suggest that mosquito assemblages in Libya are likely to follow comparable ecological patterns, given the continuity of Mediterranean and Saharan biogeographical zones across political boundaries. Moreover, the environmental drivers influencing mosquito distribution—such as water salinity, vegetation cover, hydrological fluctuations, and anthropogenic disturbance—are broadly comparable throughout this region, further supporting the extrapolation of regional data to the Libyan context.

Taxonomic complexity is a notable challenge in the study of wetland mosquitoes. The detritus complex, which includes morphologically similar but genetically distinct species such as Aedes detritus and Aedes coluzzii, exemplifies this difficulty [25]–[28]. Morphological identification alone is often insufficient to distinguish cryptic species within the complex, particularly at immature stages. Molecular techniques, such as polymerase chain reaction (PCR) and internal transcribed spacer 2 (ITS2) sequencing, have become essential tools for accurate species delineation. Correct identification is critical not only for ecological studies but also for understanding vector competence, as different species within the same complex can vary significantly in their ability to transmit arboviruses. This complexity underscores the importance of integrating molecular approaches into entomological surveys, particularly in regions like Libya where baseline species data are scarce.

In addition to native wetland species, invasive mosquitoes represent a growing public health concern in North Africa. The Asian tiger mosquito (Aedes albopictus), in particular, has attracted attention due to its rapid expansion in the Mediterranean Basin and North Africa [29]–[32]. This species exhibits remarkable ecological flexibility, colonizing both natural and artificial water bodies, including containers, tires, irrigation channels, and temporary pools. Its ability to exploit urban, peri-urban, and rural habitats has facilitated its establishment in previously uncolonized areas. The public health implications of Aedes albopictus colonization are significant, as it is a competent vector for dengue, chikungunya, and Zika viruses. Reports of its establishment in Tunisia, Algeria, and Morocco raise concerns about its potential introduction into Libyan ecosystems, particularly in coastal wetlands that may serve as initial points of entry. Continuous surveillance is therefore crucial to detect early invasions and to implement timely vector control measures.

Regional studies have also highlighted the ecological and epidemiological importance of mosquito diversity in wetland habitats. Wetlands serve as ecological interfaces where mosquitoes interact with a range of vertebrate hosts, including migratory and resident birds, reptiles, and mammals. Migratory birds, in particular, can act as reservoirs or carriers of arboviruses, introducing exotic pathogens into local mosquito populations and potentially initiating transmission cycles. Resident bird populations can maintain these cycles locally, creating a persistent risk of zoonotic spillover. Consequently, wetlands function as ecological hubs for vector–host interactions, with direct implications for the emergence and maintenance of mosquito-borne diseases [29],[30]. Understanding the species composition and abundance of mosquito populations in wetlands is therefore critical for predicting disease risk and informing integrated vector management strategies.

Despite the insights gained from regional research, Libya remains an understudied context. The limited entomological surveys conducted within the country have primarily targeted malaria vectors, leaving gaps in knowledge regarding wetland-associated species and their ecological dynamics [16]–[20]. This paucity of data hampers risk assessments and constrains the development of targeted public health interventions. Moreover, environmental changes—including climate variability, urban expansion, and water management practices—may alter mosquito habitats and influence species composition. For example, rising temperatures and irregular rainfall patterns can extend mosquito breeding seasons and create new temporary habitats, while anthropogenic modifications such as irrigation, dam construction, and urbanization can inadvertently generate artificial breeding sites. These environmental changes have the potential to reshape mosquito community structure, increase vector abundance, and amplify disease transmission risk.

In the broader North African and Mediterranean context, studies have emphasized the value of continuous mosquito monitoring in wetlands as a proactive measure for vector-borne disease prevention. For instance, longitudinal surveys in Tunisia and Morocco have demonstrated that wetland mosquito assemblages can shift seasonally, with certain species dominating under specific hydrological and climatic conditions [22]–[24]. Such findings illustrate the dynamic nature of mosquito populations and the importance of temporal monitoring to capture changes in species composition and vector density. Applying these insights to Libya, a similar approach can yield critical information on species occurrence, distribution, and ecological preferences, forming the basis for evidence-based surveillance and control strategies.

Furthermore, molecular and ecological studies in neighboring countries have advanced understanding of vector competence, highlighting that species within the same genus can vary considerably in their capacity to transmit pathogens. For example, different members of the Aedes detritus complex exhibit variation in feeding behavior, host preference, and viral susceptibility [25]–[28]. These findings reinforce the importance of precise taxonomic identification in epidemiological assessments, as misidentification could lead to inaccurate evaluations of disease risk. Integrating morphological and molecular approaches is therefore essential for accurately characterizing mosquito communities in Libyan wetlands and for informing targeted vector control efforts.

The invasive potential of Aedes albopictus further underscores the necessity of robust surveillance. This species' rapid spread across the Mediterranean region has been facilitated by its ecological versatility, anthropogenic transport, and adaptability to a wide range of climatic conditions [29]–[32]. Its ability to establish populations in both natural wetlands and human-modified habitats poses significant challenges for public health authorities. Early detection in Libyan wetlands could enable preemptive interventions, preventing establishment and mitigating potential outbreaks of arboviral diseases. This is particularly relevant in coastal wetlands, which may serve as first points of colonization due to trade and transportation activities.
In summary, the regional literature emphasizes several key points relevant to mosquito ecology in Libyan wetlands. First, native species such as Aedes caspius, Aedes dorsalis, and Aedes detritus dominate North African coastal and inland wetlands, exhibiting remarkable adaptability to fluctuating environmental conditions. Second, taxonomic complexity within cryptic species groups necessitates molecular tools for accurate identification, which is critical for understanding vector competence and disease risk. Third, invasive species such as Aedes albopictus pose emerging threats due to their ecological flexibility and capacity to transmit significant arboviruses. Finally, environmental variability, both natural and anthropogenic, influences mosquito distribution, abundance, and seasonal dynamics, highlighting the need for continuous surveillance and ecological monitoring.

Given the limited data on Libyan wetlands, the present study addresses an important knowledge gap. By systematically documenting mosquito species across 27 wetland sites, the research establishes baseline information on species composition, abundance, and habitat associations. This foundational data is crucial for future ecological research, integrated vector management, and public health interventions aimed at mitigating the risk of mosquito-borne diseases. Moreover, it aligns Libya with regional efforts to monitor mosquito fauna in North Africa and the Mediterranean, facilitating comparative studies and collaborative disease prevention initiatives.

previous research across North Africa and the Mediterranean provides valuable insights into wetland mosquito ecology and public health relevance, yet Libya remains largely unexplored. Understanding the diversity, distribution, and ecological determinants of mosquito populations in Libyan wetlands is therefore both scientifically and epidemiologically imperative. The present study represents the first systematic effort to fill this gap, providing a critical foundation for ongoing surveillance, ecological research, and vector-borne disease prevention strategies in the region.

3. Methodology

3.1 Study area

The survey was carried out in collaboration with the Libyan Society for Birds (LSB) during the International Waterbird Census (IWC) of 2024, conducted between January 11 and 30. The team surveyed all major wetlands and waterbird sites along the Libyan coast, spanning from Ras Jdair in the west to Tobruk in the east. (Table1, Figure 1).

Table 1. Visited sites during the IWC 2024

City	Location	Date
Zuwarah	Sabkhat Malita, Al-Manqoub, Qam Al-Wadd, Island of Farwa, Sabkhat Abu Kamash	January 11-13, 2024
Sabratha	Telil	January 13, 2024
Zliten	Wadi Ka'am Dam, Ain Ka'am	January 14, 2024
Misrata	Kawf Dakhil, Qasr Ahmad, Sewage Treatment Plant, Saso	January 15, 2024
Tawargha	Ain Tawargha	January 16, 2024
Sirte	Al-Hayshah, Al-Wushkah, Shatt Bumrim, Sabkhat Sultan	January 17-19, 2024
Derna	Wadi Khabtah, Wadi Hamisa, Umm Hafin, Ras al-Tin, Al-Qasbiya, Al-Tamimi Port, and Sabkhat Al-Tamimi	January 20-21, 2024
Al-Marj	Ain Al-Zarqa, Ain Al-Shiqiqa, and Marj Al-Qadima	January 22, 2024
Benghazi	Jaliyata, Buzira, Lake Tibesti, Ain Ziana, Sabkhat and Landfill of Qanfuda, Sabkhat Karkoura, and Al-Breiga	January 23-25, 2024
Al-Qarbulli	Wadi Tarat	January 26, 2024
Jebel Nafusa	Wadi Zart Dam, Ain Taqaddit, Wadi Majanin Dam, and Ain an	January 27, 2024

Tripoli	Maitika Navigation (Mellaha), Shatt Tajoura, Al-Nadi Al-Bahri, Al-Midaa, Shatt Qarqarsh, Sewage Treatment Plant Al-Hadhba, and Biyara Al-Najila	January 28-30, 2024

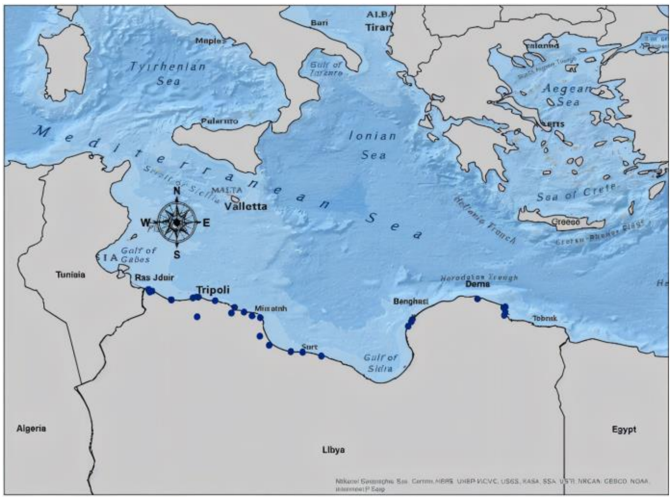


Figure 1. Map showing Geographic location of the surveyed sites

3.2 Larval sampling

Larval surveys were conducted from January 11 to 30, 2024, across 27 wetland sites. Samples were collected using a 400 ml dipper, with 3-5 water scoops taken from both the edges and center of each habitat. The collected samples were then sent to the Parasitology and Vector-Borne Diseases Laboratory at the National Center for Disease Control (NCDC). Third and fourth instar mosquito larvae were preserved in 70% ethanol and identified using the MosKeyTool[21]. To facilitate identification, larvae were cleared in Nesbitt's solution for three hours and mounted on slides using Puri's medium. For specimens with siphons, the larvae were sectioned at the end of the sixth abdominal segment to allow for horizontal placement of the siphon under the coverslip. First and second instar larvae were reared until they reached the third or fourth instar stage, at which point they were processed using the same methods as described above.

4. Results and Discussion

4.1. Survey Findings and Species Composition

The preliminary entomological survey conducted across 27 wetland sites in Libya during the winter of 2024 revealed active mosquito breeding habitats in five locations, representing 18.5% of the surveyed sites. This relatively low detection rate may be attributed to the seasonal timing of the survey during winter, when mosquito breeding activity is typically reduced in Mediterranean climates. A total of 56 mosquito larvae were collected from these positive sites, all of which were successfully identified to species level using morphological characteristics.

The results confirmed the presence of three species from the genus Aedes: *Aedes caspius*, *Aedes dorsalis*, and *Aedes detritus*. The distribution and abundance of these species revealed distinct patterns (Table 2). Aedes detritus was the most abundant and geographically widespread species, constituting 59% (n=33/56) of the total collection and being the only species present at all five positive breeding sites. Aedes dorsalis was the second most prevalent species, representing 38% (n=21/56) of the larvae and found at four of the five sites. In contrast, *Aedes caspius* was the least abundant and widespread, comprising only 4% (n=2/56) of the total collection and being restricted to a single location (Ain Al-Shaqiqa in Al-Bayda).

Table 2. Mosquito larvae species collected during the Preliminary survey

City	Location	Number of mosquitoes	Mosquito species		
			Aedes caspius	***Aedes dorsalis***	***Aedes detritus***
Al-Bayda	**Ain Al-Shaqiqa**	5	2	2	1
Derna	**Umm Hafin**	16	-	2	14
Zliten	**Ain Ka'am**	24	-	14	10
Benghazi	**Ain Ziana**	5	-	2	3
Tripoli	**Almallaha in Mitiga airport**	6	-	1	5

The spatial distribution of species abundance is further visualized in Figure 2, which illustrates the proportional representation of each species across the positive breeding sites. The chart clearly demonstrates the numerical dominance of *Aedes detritus* across all locations where larvae were found, followed by Aedes dorsalis, while *Aedes caspius* was only present at one site in low numbers.

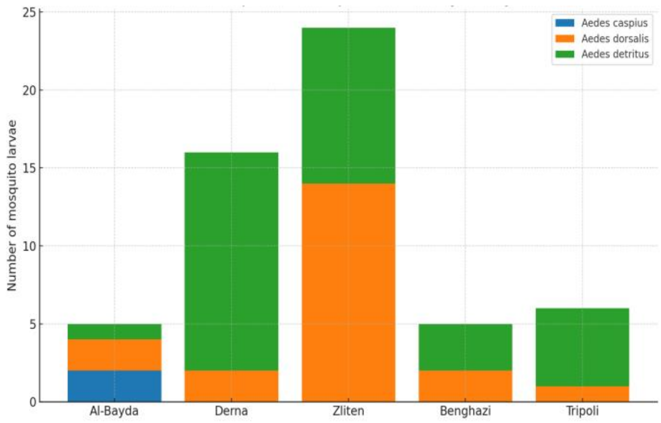


Figure 2. Distribution of mosquito larvae species across surveyed Libyan wetlands

4.2. Ecological Adaptability and Habitat Preferences

The ecological profiles of the positive breeding sites varied but were predominantly characterized as brackish or freshwater environments. Sites included natural springs (Ain Ka'am, Ain Ziana, Ain Al-Shaqiqa), coastal marshes (Umm Hafin, Almallaha), and other wetland types that provide suitable breeding conditions for these mosquito species. The prevalence of Ae. detritus across all these habitats underscores its superior adaptability to the varying environmental conditions present in Libyan wetlands, which often experience fluctuating salinity levels and periodic drying. This finding aligns with the well-documented halophilic and euryhaline (tolerant of varying salinity) nature of these Aedes species [14], [27], [28].

The life history strategy of these mosquitoes, particularly their ability to lay desiccation-resistant eggs that remain viable in dry sediments and hatch en masse following rainfall or flooding events [28], explains their success in these temporary or semi-permanent wetlands. The high larval abundance at Ain Ka'am (n=24) and Umm Hafin (n=16) suggests these sites represent particularly stable and productive breeding grounds, possibly due to consistent water availability, suitable water chemistry, and adequate organic matter that supports larval development. These locations should be prioritized for future monitoring and targeted control efforts.

4.3. Taxonomic Considerations and Public Health Implications

A critical consideration in interpreting these results is the taxonomic complexity within the detritus complex. This group includes morphologically similar but genetically distinct species, particularly *Ae. detritus* and *Ae. coluzzii*, which can only be reliably differentiated using molecular tools [25]-[28]. While all specimens in this study were morphologically identified as Ae. detritus, the potential presence of cryptic species in Libya cannot be ruled out without genetic verification. Molecular confirmation using techniques such as PCR and ITS2 sequencing represents a crucial next step for precise taxonomic resolution, which has significant implications for understanding vector competence, insecticide resistance profiles, and ultimately for designing effective vector control strategies.

From a public health perspective, the predominance of these species is of considerable importance. All three identified species are recognized vectors of medical and veterinary concern. *Ae. dorsalis* and *Ae. caspius* are known vectors of West Nile virus and Rift Valley fever virus, while Ae. detritus is a competent vector for Tahyna virus and has been implicated in the transmission of other arboviruses [14], [33]. The coexistence of these mosquitoes with diverse migratory and resident waterbirds in Libyan wetlands creates a critical ecological interface for the enzootic circulation and potential amplification of arboviruses. Migratory birds can introduce exotic pathogens, while resident species can maintain transmission cycles, creating conditions suitable for potential spillover to human populations.

4.4. Regional Context and Surveillance Imperatives

The growing global expansion of the invasive Aedes albopictus (Asian tiger mosquito) presents a significant future concern for Libya and other North African countries [29]-[32]. This species, a highly efficient vector for dengue, chikungunya, and Zika viruses, has already established populations in several Mediterranean countries. Its remarkable ecological plasticity allows it to exploit both natural and urban habitats, particularly artificial containers commonly found in human settlements. Although not detected in this survey, its absence cannot be assumed given the increasing reports from neighbouring regions and the extensive trade and travel networks connecting Libya to countries where this species is established.

The ongoing environmental changes in Libya, including climate variability, urbanization, and modifications to water management practices [32]-[35], can create new breeding sites and facilitate the establishment of invasive species. Rising temperatures may extend mosquito breeding seasons [34]-[37], while changing precipitation patterns can create more ephemeral water bodies that Favor certain Aedes species [35]-[38]. Therefore, the implementation of a robust, long-term mosquito surveillance program in Libyan wetlands is not merely an academic exercise but a fundamental component of public health preparedness [39]. Such a program should be designed to monitor native species population dynamics, serve as an early warning system for invasive species, and provide data for targeted vector control interventions to mitigate the risk of emerging mosquito-borne disease [40]-[43].

4.5 Recommendations

To strengthen mosquito surveillance and vector control in Libya, several strategic measures should be considered. First, the establishment of a comprehensive national entomological surveillance program that targets both coastal and inland wetlands is crucial. This program would systematically track changes in species distribution, detect the introduction of invasive mosquitoes, and provide timely data for public health decision-making. Incorporating environmental and climatic data, including rainfall, temperature, and vegetation indices, into predictive models can enhance the understanding of mosquito population dynamics and allow authorities to anticipate seasonal peaks in vector activity. Strengthening laboratory capacity for accurate morphological and molecular identification of mosquito species, particularly those with known arboviral transmission potential, is essential for implementing evidence-based control strategies. Furthermore, fostering regional collaboration with neighbouring North African countries can facilitate the sharing of surveillance data, harmonize vector monitoring protocols, and establish early warning systems for emerging mosquito-borne pathogens. Lastly, active engagement with local communities and municipalities through environmental management and public awareness campaigns is vital to reduce mosquito breeding sites, minimize human–mosquito contact, and ensure the sustainability of control efforts. Collectively, these measures provide a strategic framework for evidence-based interventions that can reduce the risk of mosquito-borne diseases and enhance public health preparedness in Libya.

5. Conclusion and Future Scope

This preliminary investigation provides the first dedicated documentation of mosquito species inhabiting Libyan coastal wetlands, establishing a crucial baseline for future research and public health intervention. The findings confirm that *Aedes detritus*, *Aedes dorsalis*, and *Aedes caspius* are the predominant species in these ecosystems, with Ae. detritus demonstrating the greatest abundance and widest distribution. The presence of these known vector species in ecologically sensitive wetland areas, which also serve as key habitats for migratory birds, underscores a potential risk for the circulation of arboviruses. The ecological adaptability of these species to both brackish and freshwater environments highlight the potential of Libyan wetlands to support stable mosquito populations throughout the year.

To build upon these findings and effectively translate them into public health action, the following research and surveillance priorities are identified:
Molecular Entomology and Taxonomic Clarification: Future work must employ molecular tools (e.g., PCR, DNA barcoding, ITS2 sequencing) to confirm the morphological identifications, resolve potential cryptic species within the detritus complex, and build a reference DNA barcode library for Libyan mosquitoes. This taxonomic precision is essential for accurate risk assessment and targeted control.

Comprehensive Seasonal and Spatial Monitoring: This study was a winter snapshot. A comprehensive surveillance program should involve year-round, longitudinal sampling across a wider geographic range to understand seasonal population dynamics, identify key breeding seasons, and map species distribution shifts in response to environmental drivers. This should include both larval and adult mosquito collections to better understand transmission risk.

Pathogen Surveillance and Vector Incrimination: To directly assess disease risk, future studies should integrate mosquito collection with pathogen screening. Testing mosquito pools for arboviruses like West Nile virus, Rift Valley fever virus, and others using molecular or virological techniques is essential to determine their role in local transmission cycles and assess the potential for outbreaks.

Ecological and Climatic Modeling: Research should move beyond descriptive surveys to predictive modeling. Integrating entomological data with GIS-based ecological data (e.g., salinity, vegetation, water permanence) and climatic parameters can help model and predict suitable habitats for both native and invasive mosquito species under different climate change scenarios, enabling proactive rather than reactive vector control.

Integrated Vector Management and Public Health Policy: Finally, strengthening collaboration between entomologists, ecologists, and public health authorities is paramount. The data generated from enhanced surveillance should directly inform the design of integrated vector management strategies, focusing on environmentally sensitive control of larval habitats in and around wetlands, and raising public awareness about personal protection measures.

By establishing a sustainable, long-term monitoring framework that combines entomological, molecular, and ecological approaches, Libya can significantly enhance its preparedness for mosquito-borne disease threats, safeguard public health, and contribute valuable data to regional and global vector surveillance networks. This proactive approach is particularly important in the context of climate change and increasing global connectivity, which continue to alter disease transmission dynamics worldwide.

By establishing a long-term monitoring framework that combines entomological, ecological, and molecular approaches, Libya can enhance its preparedness for potential mosquito-borne disease outbreaks and contribute valuable data to regional and global vector surveillance networks.

Author's Statements

Conflict of Interest-The authors declare that there are no conflicts of interest related to this study.

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Author Contributions-All authors contributed equally to the study conception, design, data collection, analysis, and manuscript preparation.

Data Availability-The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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AUTHORS PROFILE

Ala Nuwayji earned his Master's degree in Zoology – Evolutionary Biology (Life Sciences) in 2025. He currently works at the National Centre for Disease Control in the Parasitology and Vector-Borne Diseases Laboratory and is also a member of the Libyan Society for Birds (LSB). He has published two research papers and has three years of research experience.

Hanan Aqeehal earned his Master's degree in Zoology -(Basic Sciences) in 2018.She is currently working at the National Centre for Disease Control and the head of Parasitology and Vector-Borne Diseases Laboratory. she has published 21 research papers and has 11 years of research experience.

Mahmoud abuhajar He is enrolled in a Master's program in Zoology – Environmental Sciences. He currently a member of the Libyan Society for Birds (LSB). He has published one research papers and has three years of research experience.

Ahmed Elgrari earned his PhD degree in community medicine in 2025. He is currently working at Tripoli university- medical parasitology department and the National Centre for Disease Control and the head of Zoonotic diseaes control administration. He has published four research papers and has 13 years of research experience.

Khaled Etayeb- Professor at the Department of Zoology, Faculty of Science, University of Tripoli since Jan. 2023. PhD. in Ornithology and Urban Ecology 2011 from Sheffield University, UK. He has more than 60 of scientific publications. In term of civic and volunteering activities, he holds the position of head of the Libyan Society for Bird (LSB).

