

Spatial Misalignment of Micro-Environmental Hazards: How Containers Drive Mosquito Risk in New Orleans

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Abstract

Mosquito-borne risk in Gulf Coast cities is often attributed to broad environmental pressures, yet the extent to which parcel-level conditions drive standing water and larval habitats remains uncertain. This study analyzes environmental predictors of mosquito-relevant indicators across New Orleans using municipal inspection data from 951 residential parcels linked with district-level sociodemographic characteristics. Results show that while standing water was detected on 7.3% of parcels, larval habitats were rare (<1%), a pattern consistent with ecological expectations that only a small subset of water-holding sites support active mosquito development. Even with this low event frequency, container presence emerged as the dominant predictor of both outcomes, strongly associated with standing water ($p < .001$) and larval habitats ($p < .05$). Yard condition, property condition and water-feature maintenance showed no independent associations. More critically, district-level sociodemographic characteristics; income, racial composition and housing age were not significantly related to standing-water prevalence (all $p > .10$), revealing a mismatch between neighborhood-level structural disadvantage and the micro-environmental features that generate mosquito risk. The study contributes theoretically by demonstrating the primacy of micro-environmental variation, methodologically by integrating municipal inspections with multilevel modeling and practically by highlighting containers as the most actionable target for vector-control in New Orleans.

Introduction

Urban environments across the Gulf Coast present persistent challenges for mosquito control due to a combination of climatic, ecological and built-environment factors [1]. Warm temperatures, high humidity, and frequent rainfall support year-round mosquito activity in subtropical cities [2, 3, 4], while extreme weather events and seasonal precipitation patterns further amplify standing-water formation [5]. Dense housing, aging infrastructure and variable drainage contribute to localized water accumulation, with stormwater systems, underground storm-drain networks, and poorly maintained parcels serving as recurrent sources of mosquito production [6, 7, 8]. These dynamics are especially pronounced in New Orleans, where post-Katrina landscape changes, uneven redevelopment and persistent housing disrepair have shaped environmental [9] conditions across neighborhoods [10, 11].

Post-Katrina recovery produced highly uneven patterns of land-use change, environmental maintenance and neighborhood-level infrastructure investment [9, 14], creating a patchwork of parcel conditions that continue to influence drainage, standing-water accumulation and environmental risk [11,12]. Housing deterioration and environmental hazards have long been recognized as key public-health concerns in the region [14, 15, 16], underscoring the need to understand how parcel-level features contribute to mosquito-breeding risk in this context.

Mosquito production in cities is strongly influenced by microenvironmental conditions. Artificial containers, small water-holding structures and unmanaged yard features consistently serve as primary larval habitats for *Aedes* and *Culex* mosquitoes [17, 18]. Studies from Puerto Rico, India, Cambodia and multiple U.S. cities have shown that containers are among the most productive and persistent sources of mosquito larvae, regardless of broader neighborhood context [19, 20, 21, 22]. Container-breeding behavior is well documented in Gulf Coast mosquito species, with oviposition strongly tied to artificial water-holding structures [23]. However, less is known about how container presence interacts with other parcel-level characteristics, including housing condition, yard maintenance, property disrepair, and water-feature management, to influence environmental suitability for mosquito development in Gulf Coast cities. This gap limits the ability of municipal mosquito-control programs to identify the combinations of environmental conditions most strongly associated with habitat formation.

While mosquito abundance and arboviral transmission are important public-health outcomes, identifying environmental conditions that facilitate standing water and larval habitat formation represents a critical upstream component of mosquito-control programs. Consequently, parcel-level environmental surveillance can provide actionable information for targeting inspections and source-reduction activities before adult mosquito populations emerge.

Standing water is a critical precursor to mosquito development and its presence is shaped by both natural and built-environment factors. In New Orleans, post-disaster studies documented the rapid colonization of abandoned swimming pools and other water-holding structures following Hurricane Katrina [24, 11]. However, parcel-level predictors of standing-water accumulation remain poorly characterized, particularly in cities where frequent rainfall, aging drainage systems and heterogeneous yard maintenance practices and variable property conditions create highly localized environmental risks. Moreover, despite the widespread use of municipal inspection programs to identify mosquito-relevant environmental hazards, these operational datasets remain underutilized within urban mosquito ecology and public-health research. Municipal inspection data provide a unique opportunity to evaluate environmental risk indicators across diverse neighborhoods and housing conditions at a scale rarely captured through traditional ecological field studies. These inspections were conducted as part of a

broader municipal mosquito surveillance and source-reduction effort, providing an opportunity to examine environmental conditions relevant to operational vector-control decision making.

Broader sociodemographic and housing-quality indicators have also been linked to environmental health risks, including vector-borne disease exposure [14, 15, 25]. Several studies have documented higher mosquito densities in lower-income neighborhoods [20, 21], suggesting that structural inequities may shape mosquito-breeding risk. At the same time, emerging evidence indicates that local environmental conditions may exert a stronger influence on mosquito habitat formation than broader neighborhood characteristics. This distinction highlights an important scale mismatch in urban environmental health research: neighborhood-level indicators may not adequately capture the parcel-level conditions that directly create mosquito habitat. Understanding whether microenvironmental factors outperform broader sociodemographic measures in predicting mosquito-relevant conditions has important implications for municipal surveillance and intervention programs.

To address these gaps, we analyzed municipal parcel-inspection data collected during a citywide mosquito surveillance and environmental assessment initiative conducted in New Orleans. The inspection protocol was designed to document observable environmental conditions associated with mosquito habitat formation, including standing water, evidence of larval breeding, container presence, yard maintenance, and housing characteristics. The protocol focused on observable environmental hazards and habitat indicators rather than direct measures of mosquito abundance, reflecting the operational objectives of the municipal inspection program. The inspections were conducted in areas prioritized by municipal mosquito-control operations and therefore provide insight into environmental conditions considered relevant for surveillance and source-reduction activities. Rather than measuring mosquito abundance directly, this study evaluates environmental indicators that represent conditions favorable for mosquito production and therefore serve as operational risk markers for vector-control programs.

Given the operational demands placed on municipal mosquito-control programs in New Orleans, identifying the parcel-level features that most strongly predict standing water and larval habitats is essential for prioritizing inspections and targeting limited resources. This study addresses these gaps by examining parcel-level and district-level environmental predictors of standing water and mosquito larval habitats across New Orleans using municipal inspection data. Specifically, we assess (1) which environmental and structural housing conditions are associated with standing-water presence on residential parcels; (2) which parcel-level environmental characteristics, including yard condition, property condition, container presence, and water-feature maintenance, are associated with evidence of larval habitat; and (3) whether neighborhood-level sociodemographic characteristics contribute to variation in these environmental mosquito-risk indicators.

These questions move from the immediate ecological precursor to mosquito development (standing water) to the conditions associated with larval habitat formation and finally to the broader neighborhood context that may influence environmental risk. By integrating parcel-level environmental observations with neighborhood demographic characteristics across nearly 1,000 municipal inspections, this study provides one of the most comprehensive evaluations of mosquito-relevant environmental conditions conducted using operational municipal surveillance data in a U.S. Gulf Coast city. The findings demonstrate how routinely collected municipal inspection data can be leveraged to identify actionable environmental risk factors, support targeted vector-control strategies, and strengthen community-level mosquito surveillance efforts.

Methods

Study design

This study employed a cross-sectional design conducted from March to June 2018 in New Orleans, Louisiana. The sampling frame consisted of six of the city's thirteen Planning Districts, encompassing 289 of 457 census block groups and 951 sampled properties. Neighborhoods were selected using a risk-based approach informed by documented West Nile virus (WNV) activity, historically high *Culex quinquefasciatus* counts and their public health importance as identified through routine municipal vector-surveillance operations. Selection criteria incorporated historical mosquito surveillance activities, including routine trap-based monitoring conducted by the New Orleans Mosquito, Termite and Rodent Control Board. Areas with documented WNV activity, elevated *Culex quinquefasciatus* trap and operational mosquito-control significance were prioritized for inspection. The sampling frame also included a tornado-impacted neighborhood in New Orleans East, where extensive debris, damaged structures and disrupted drainage systems following the February 2017 EF-3 tornado created environmental conditions conducive to mosquito proliferation.

A cross-sectional design was appropriate because the objective was to characterize environmental and structural conditions associated with suitability of mosquito habitat and environmental risk indicators during the onset of peak seasonal activity. This design was appropriate for characterizing environmental and structural conditions associated with mosquito habitat suitability and environmental risk indicators rather than direct measures of mosquito abundance. Because site selection was guided by risk-based criteria and operational feasibility rather than random sampling, the study used a non-probabilistic design and findings should be interpreted as representative of inspected areas rather than the entire city. These combined epidemiologic, ecological and structural considerations provided the rationale for selecting neighborhoods most likely to exhibit conditions associated with mosquito breeding and vector exposure. Only 2018 inspections were included in the analytic dataset because this was the first year in which field data collection was fully standardized using Survey123. Earlier datasets, including those collected during 2016 Zika response activities, utilized different data-collection platforms and workflows that were not methodologically comparable to the 2018 inspection protocol.

Study setting and data sources

This cross-sectional study was conducted from March to June 2018 in New Orleans, Louisiana, and used household inspection data collected by the New Orleans Mosquito, Termite and Rodent Control Board and the New Orleans Health Department as part of routine municipal mosquito-control operations.

The 2018 season represented the first year in which field data collection was fully standardized using mobile-friendly Survey123 forms developed by the City's GIS Department. Survey123 incorporated structured forms, standardized response options, skip logic and address-validation workflows designed to improve consistency in environmental observations and reduce variability in field documentation. These forms were designed to improve consistency in environmental assessments and were informed by refinements made during the city's 2016 and 2018 Zika mitigation initiatives, when the data-collection framework shifted from a map-centric to a form-centric system to reduce observer burden and enhance data quality. This transition enabled a more standardized assessment of parcel-level environmental conditions associated with mosquito habitat formation.

Inspection teams recorded observable environmental and structural conditions associated with mosquito habitat formation, including standing water, evidence of mosquito breeding, adult mosquito activity, container presence, yard condition, building condition, air-conditioning status, and other water-holding

features. The protocol focused on observable environmental hazards and habitat indicators rather than direct measures of mosquito abundance, reflecting the operational objectives of the municipal inspection program. Because property access varied across neighborhoods, inspections ranged from full parcel assessments to partial visual assessments conducted from the property perimeter or public right-of-way. Property-owner reluctance, resident absence, safety concerns, physical barriers, and limited visibility occasionally restricted access to portions of a parcel. Consequently, observations reflected visible environmental conditions and may have underestimated the prevalence of mosquito habitat features located in backyards, enclosed spaces, or other inaccessible areas.

Of the 951 parcels included in the inspection frame, 634 received an inspection, consisting of 300 full inspections and 334 partial inspections, while 317 parcels were inaccessible, declined participation, or otherwise did not receive a completed inspection (**Figure 1**). Analyses were restricted to records containing the variables required for model estimation, resulting in differing analytic sample sizes across outcome measures. The inspection protocol focused on habitat indicators rather than entomological sampling. Mosquito specimens were not collected and species-level identification was not performed during parcel inspections. As a result, the study evaluates environmental suitability for mosquito habitat formation rather than species-specific mosquito abundance. Accordingly, findings

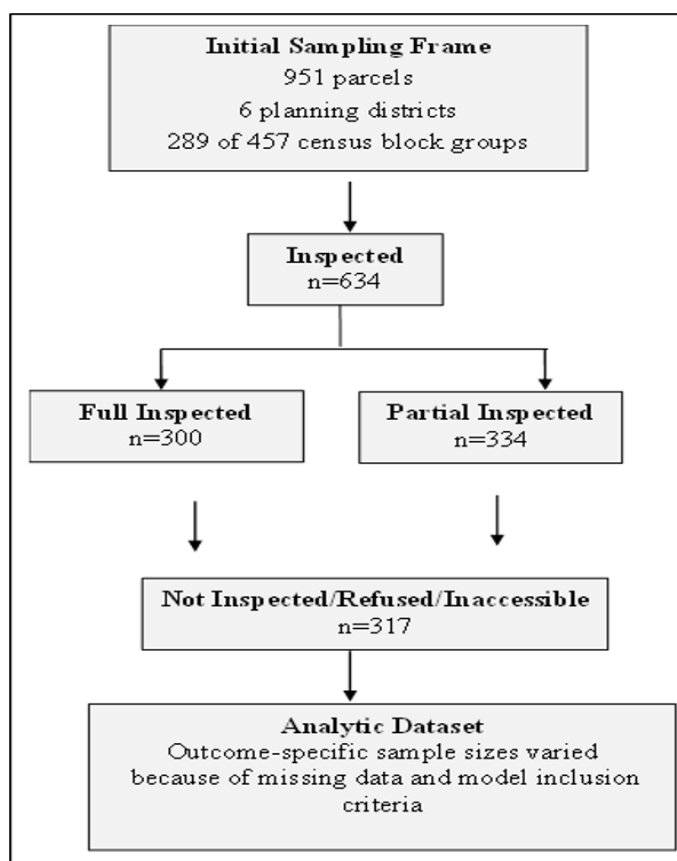


Figure 1. Sampling flow diagram for the 2018 New Orleans municipal mosquito inspection study. The initial sampling frame included 951 parcels across six planning districts and 289 census block groups. Of these, 634 parcels received an inspection, including 300 full inspections and 334 partial inspections, while 317 parcels were inaccessible, declined participation, or otherwise did not receive a completed inspection. Outcome-specific analytic sample sizes varied based on data completeness and model inclusion criteria.

should be interpreted as indicators of environmental mosquito risk rather than direct measures of vector population density.

Demographic data were obtained from the U.S. Census Bureau 2018 American Community Survey (ACS) 5-year estimates and included total population, racial composition, median household income and housing age. Racial composition was converted to percentages for White, African American, Asian, and a combined “other race” category to align with ACS reporting conventions. Housing age was calculated as the proportion of units built within three ACS-defined construction periods (1940–1969, 1970–1989, and 1990 or later), which reflect major shifts in housing infrastructure and building materials relevant to mosquito ecology. ACS construction-year categories do not distinguish post-Katrina reconstruction from pre-Katrina structures; therefore, homes rebuilt after Hurricane Katrina could not be identified.

Measures

Environmental and structural indicators were assessed through direct observation for each inspected parcel, including residential, commercial, paved and vacant lots. Inspection teams used a standardized Survey123 instrument to document observable environmental conditions associated with mosquito habitat formation as part of routine municipal vector-control operations. All environmental variables including standing water, larval habitats, adult mosquito presence, container presence, yard condition, property condition and water-feature maintenance were coded as binary indicators (present = 1, absent = 0) because inspectors documented only whether each condition was observed.

The inspection protocol focused on environmental hazard identification and habitat assessment rather than entomological sampling. Consequently, mosquito specimens were not collected, species-level identifications were not performed, and no direct measures of mosquito abundance were recorded. Findings should therefore be interpreted as indicators of environmental suitability for mosquito habitat formation rather than species-specific measures of mosquito production. Adult mosquito presence was recorded solely through visual confirmation and was treated as an observational indicator rather than a biological measure of abundance. Similarly, evidence of larval habitat was documented through field observation of breeding activity and water-holding environments considered suitable for mosquito development. Larval habitats were infrequently observed, a pattern consistent with ecological expectations that only a minority of water-holding sites support active mosquito development; this rarity reflects biological processes rather than measurement error.

Property condition was categorized as “good or great” versus “decent or poor” based on visible structural integrity, exterior maintenance, and evidence of deterioration. Yard condition was categorized as “maintained” versus “blighted or unmaintained,” reflecting vegetation overgrowth, debris accumulation, and general upkeep. These categories reflect standard municipal vector-control practice, and inspectors received routine training on their application as part of operational field protocols.

Container presence included any water-holding container, including tires. Examples included buckets, coolers, toys, planters, watering cans, tarps, trash receptacles, lawn furniture, tire piles, and other artificial containers capable of retaining water. Because inspectors documented only the presence or absence of containers rather than individual container counts, analyses focused on the existence of potential breeding habitats rather than container abundance. Water-feature maintenance was coded as maintained or not maintained.

Air-cooling systems were categorized as no air conditioning, window unit, or central air based on external observation. Homeowner presence was recorded to document access and observational com-

pleteness, as sidewalk-only assessments occasionally constrained the precision of environmental observations. Homeowner presence was documented because access to private property and inspection completeness were influenced by resident availability and consent. This variable provided additional context for interpreting differences in inspection coverage across parcels. Inspection completeness varied because access to private property was not always possible. Some observations were conducted from the property perimeter or public right-of-way when homeowners were unavailable, access was restricted, or safety concerns limited entry. Consequently, environmental assessments reflect observable conditions and may underestimate the presence of concealed breeding habitats located in backyards or otherwise inaccessible areas. Environmental indicators were observed during inspections and subsequently coded as binary presence/absence variables for analysis.

A total of 951 parcels were included in the field sampling frame. Inspection teams completed 300 full inspections and 334 partial inspections. Partial inspections occurred when access limitations, homeowner absence, physical barriers, or safety concerns restricted observation of portions of a property. An additional 317 parcels could not be fully assessed because of refusal, inaccessibility, or other operational constraints. Figure 1 presents the parcel selection and inspection-completion workflow used in the study.

Data quality, completeness and missingness

Data completeness for the 2018 inspection dataset was high because the digital form required inspectors to complete all observational fields before submission. The use of standardized forms, structured response options and built-in validation procedures reduced data-entry errors and improved consistency across inspection teams. Only 0.8% of inspection records had missing environmental indicators, and these were excluded from analysis.

Missingness in ACS variables reflected standard Census suppression patterns and affected fewer than 2% of block-group records. Missing demographic values were handled using listwise deletion in IBM SPSS Statistics version 29 (IBM Corp., Armonk, NY) as missingness was low and not systematically associated with environmental outcomes. No imputation procedures were used.

A total of 951 parcels were included in the study frame. Of these, 634 parcels received an inspection, consisting of 300 full inspections and 334 partial inspections, while 317 parcels were inaccessible, declined participation, or otherwise did not receive a completed inspection. The binary inspection variable identified whether a parcel received any inspection, whereas inspection completeness (full versus partial) was maintained separately to document field coverage. Analytic sample sizes therefore varied across models based on data availability and outcome-specific inclusion criteria. Earlier inspection years (e.g., 2016) were excluded because they were collected using different field tools and workflows and were not methodologically comparable to the standardized 2018 Survey123 dataset. The 2018 season represented the first fully standardized implementation of the municipal inspection protocol and was therefore selected as the primary analytic dataset.

Spatial data management

Spatial data management was conducted in ArcGIS 10.5 [26]. Block-group demographic attributes were spatially joined to inspection locations using the intersection tool. Parcel inspection locations were geocoded using addresses and GPS coordinates collected during field operations. While standardized address-entry procedures improved spatial accuracy, occasional GPS variability and address verification issues required routine quality-control review during data processing.

For research question 3, residential parcel-level environmental indicators and ACS sociodemographic variables were aggregated to the planning-district level, which represented the smallest neighborhood unit consistently available across the 2018 dataset. District-level aggregation reduced parcel-level clustering and allowed examination of ecological associations between neighborhood characteristics and standing water prevalence. Because neighborhood demographic characteristics were available only at aggregate geographic scales, district-level analyses were intended to evaluate broader ecological relationships rather than infer individual household-level socioeconomic effects. This approach allowed comparison of parcel-level environmental observations with larger neighborhood patterns relevant to municipal planning and vector-control operations.

Data analysis

All statistical analyses were performed in IBM SPSS Statistics version 29 [27]. Analyses were structured around three research questions: (1) which property-level environmental and structural conditions were associated with the presence of standing water; (2) which property-level factors predicted the presence of larval habitats; and (3) how neighborhood-level sociodemographic characteristics related to environmental mosquito-risk indicators. Logistic regression was used for each research question because all outcomes were binary. Because standing water and larval habitat observations were relatively uncommon, outcome prevalence was examined prior to model fitting to ensure sufficient events for logistic regression analyses. Categorical predictors, including air-cooling system type, were entered as indicator (dummy-coded) variables using SPSS's automatic reference-category coding. For logistic regression models, results are presented as odds ratios (ORs) with 95% confidence intervals (CIs).

The first model examined associations between property-level characteristics and the presence of standing water. The logistic regression model took the form:

$$\begin{aligned} \text{Logit} (P (\text{StandingWater}_i = 1)) \\ = \beta_0 + \beta_1 (\text{YardCondition}_i) + \beta_2 (\text{PropertyCondition}_i) + \beta_3 (\text{ContainerPresence}_i) \\ + \beta_4 (\text{WaterFeatureNotMaintained}_i) + \beta_5 (\text{ACType}_i) \end{aligned}$$

The second model evaluated predictors of larval habitat presence and included standing water as a predictor because it is a necessary precursor for larval development:

$$\begin{aligned} \text{logit}(P(\text{LarvalHabitat}_i = 1)) = \alpha_0 + \alpha_1(\text{StandingWater}_i) + \alpha_2(\text{ContainerPresence}_i) + \alpha_3(\text{YardCondition}_i) \\ + \alpha_4(\text{PropertyCondition}_i) + \alpha_5(\text{WaterFeatureNotMaintained}_i) \end{aligned}$$

Adult mosquito presence was examined descriptively but excluded from regression models because it was an observational outcome rather than a determinant of environmental conditions and lacked standardized measurement. Because species-level mosquito identification was not conducted during inspections, analyses focused on environmental indicators of habitat suitability rather than species-specific mosquito ecology.

The third model assessed whether district-level sociodemographic characteristics were associated with the proportion of parcels containing standing water. Parcel-level environmental indicators and ACS variables were aggregated to the planning-district level, and linear regression was used because the outcome, district-level standing-water prevalence was continuous. Planning districts represented the most consistent administrative geography available across the municipal inspection dataset and aligned with operational mosquito-control planning boundaries. Predictors included median household income, percent Black residents, mean housing-age category, and total population. All predictors were

standardized to district-level means prior to analysis. The linear regression model took the form:

$$\text{Standing Water Prevalence}_d = \gamma_0 + \gamma_1(\text{Median Income}_d) + \gamma_2(\text{Percent Black}_d) + \gamma_3(\text{Housing Age}_d) + \gamma_4(\text{Population}_d) + \epsilon_d$$

where each predictor represents the district-level mean or total for district d . This ecological analysis was intended to evaluate broader neighborhood patterns and was not used to infer individual household-level relationships. Because district-level analyses were based on six planning districts, findings from these models should be interpreted as exploratory and hypothesis-generating. Model fit was evaluated using R^2 and adjusted R^2 , and confidence intervals were derived from model-based standard errors.

Model diagnostics were conducted in SPSS to assess multicollinearity, influential observations and overall model fit. Variance inflation factors were examined to evaluate collinearity among predictors. Standardized residuals and Cook's distance were used to identify influential cases. Model fit was assessed using the Hosmer–Lemeshow goodness-of-fit test and the area under the receiver operating characteristic curve. Statistical significance was defined as $p < 0.05$.

Results

Characteristics of inspected parcels

A total of 951 parcels were included in the study frame, encompassing residential, commercial, paved, and vacant lots. Of these, 634 received an inspection, including 300 full inspections and 334 partial inspections, while 317 parcels were inaccessible, declined participation, or otherwise did not receive a completed inspection (**Figure 1**). Inspection outcomes were evenly distributed, with 31.5% receiving a full inspection, 35.1% partial inspections, and 33.3% recorded as no inspection or refusal.

Most parcels were residential (57.8%), while commercial properties and paved or vacant lots represented a small proportion of the sample. Air conditioning units were observed at 47.1% of parcels, whereas 52.8% had no visible AC. Property conditions were generally favorable, with 91.3% rated as good or great and nearly all yards (98.8%) were maintained.

Environmental indicators were infrequently observed: standing water (7.2%), containers (12.8%), tire piles (2.1%), adult mosquitoes (2.6%) and larval habitats (4.0%). The relatively low prevalence of larval habitats is consistent with the expectation that only a subset of water-holding environments support active mosquito development at any given time. Consistent with the study design, the sampling frame was concentrated in districts prioritized through municipal mosquito-surveillance activities, including areas with historical West Nile virus activity and elevated *Culex quinquefasciatus* trap counts.

Parcels were distributed across all planning districts, with the largest share located in Algiers (34.9%) and Uptown/Carrollton (20.2%). Sociodemographic characteristics reflected substantial variation across block groups, with a mean household income of \$30,925 (SD = 10,854) and an average population of 831 residents (SD = 524). **Table 1** presents the full distribution of parcel characteristics, environmental observations and contextual block group indicators.

Parcel-level bivariate associations with larval habitat presence

Larval habitats were detected on 4.0% of inspected parcels, with strong and statistically significant differences across several environmental indicators (**Table 2**). Parcels with standing water showed markedly higher larval positivity (45.6%) compared with parcels without standing water (0.8%; $p < 0.001$). Container presence was also strongly associated with larval habitats, with 27.0% of container-positive parcels harboring larvae compared with only 0.6% of container-negative parcels ($p < 0.001$). Yard con-

Table 1. Descriptive Characteristics of Inspected Properties in New Orleans (n = 951)

Variable	n	Percent
Inspection Status		
Full Inspection	300	31.5
Partial Inspection	334	35.1
No Inspection or Refusal	317	33.3
Property Type		
Residence	550	57.8
Commercial	4	0.4
Paved or Vacant Lot	12	1.3
Not Available	385	40.5
Air Conditioning		
AC Type Observed (Central or Window Unit)	448	47.1
AC Type Not Observed	502	52.8
Not Available	1	0.1
Property Condition		
Decent or Poor	83	8.7
Good or Great	868	91.3
Yard Condition		
Blighted or Unmaintained	11	1.2
Maintained	940	98.8
Environmental Indicators		
Standing Water		
Yes	68	7.2
No	883	92.8
Containers Present		
Yes	122	12.8
No	829	87.2
Tire Piles Present		
Yes	20	2.1
No	931	97.9
Adult Mosquitoes Present		
Yes	25	2.6
No	926	97.4
Larval Habitats Present		
Yes	38	4
No	913	96
Planning District		
Algiers	332	34.9

Uptown/Carrollton	192	20.2
New Orleans East	163	17.1
Gentilly	135	14.2
Lower Ninth Ward	128	13.5
Central City/Garden	1	0.1

Note. All percentages are calculated using the full analytic sample ($n = 951$). Property and yard condition variables were dichotomized based on municipal inspection ratings. Environmental indicators represent observed presence of potential mosquito habitats or adult mosquitoes at the time of inspection. Planning district categories reflect municipal administrative boundaries. Sociodemographic characteristics represent block group means derived from the 2018 American Community Survey (ACS 5-year estimates). The 'Not Available' category reflects parcels where inspectors could not observe the property type due to access limitations, obstructions, or refusals; these parcels were retained in the dataset because environmental indicators were still recorded. Because inspection completeness varied across parcels, some environmental observations were based on full inspections while others reflected partial assessments conducted from property perimeters or public rights-of-way.

dition demonstrated a pronounced gradient: 54.5% of parcels rated as blighted or unmaintained were larval-positive, compared with 3.4% of maintained parcels ($p < 0.001$). Property condition showed a similar pattern, with 10.8% of parcels in decent or poor condition exhibiting larval habitats versus 3.3% of parcels in good or great condition ($p = 0.002$). Water-feature maintenance was not significantly associated with larval presence in bivariate analysis ($p = 0.46$). These findings indicate that standing water, container presence, and indicators of poor yard or property maintenance are strongly associated with larval habitat presence and therefore warrant inclusion in multivariable models. Because these observa-

Table 2. Bivariate Associations with Larval Habitat Presence

Predictor	Larvae Present (n)	Larvae Absent (n)	Larvae Present (%)	p-value (Chi-square)
Standing Water				
No	7	876	0.80%	<0.001
Yes	31	37	45.60%	<0.001
Containers Present				
No	5	824	0.60%	<0.001
Yes	33	89	27.00%	<0.001
Yard Condition				
Blighted or Unmaintained	6	5	54.50%	<0.001
Maintained	32	908	3.40%	<0.001
Property Condition				
Decent or Poor	9	74	10.80%	0.002
Good or Great	29	839	3.30%	0.002
Water Feature Maintenance				
No	10	214	4.50%	0.46
Yes	20	622	3.10%	0.46

Note: Percent larvae present reflects the proportion of parcels within each category that were positive for larval habitats. Chi-square tests compare category-specific distributions of larval presence and absence.

tions represent environmental habitat indicators rather than species-specific mosquito measurements, findings should be interpreted as predictors of environmental suitability for mosquito development.

Parcel-level multivariable predictors of mosquito larval habitat presence

Standing water on a parcel remained the strongest predictor of larval habitat presence after adjustment for other parcel-level characteristics. Despite the relatively low prevalence of observed larval habitats (4.0%), several parcel-level environmental factors demonstrated strong independent associations with larval habitat presence. Parcels with standing water had 18.45 times higher odds of containing larval habitats (95% CI: 4.86–70.39, $p<0.001$). Container presence was also a strong independent predictor; parcels with containers had 15.90 times higher odds of larval habitat presence (95% CI: 4.11–61.47, $p<0.001$). Yard condition showed a borderline association, with blighted or unmaintained parcels exhibiting 7.90 times higher odds of larval habitat presence (95% CI: 0.93–67.10, $p=0.058$). Property condition and water-feature maintenance were not statistically significant predictors in the adjusted model. Overall model fit was acceptable (Pseudo- $R^2 = 0.148$), indicating that parcel-level environmental features meaningfully contributed to predicting larval habitat presence. Standing water and container presence emerged as the dominant environmental predictors, underscoring the importance of source-reduction strategies targeting water-holding containers and unmanaged breeding habitats.

Table 3. Multivariable Logistic Regression Predicting Larval Habitat Presence Across Parcels (n = 501)			
Predictor	Adjusted OR	95% CI	p-value
Standing water present	18.45	4.86–70.39	<0.001
Containers present	15.9	4.11–61.47	<0.001
Yard condition: blighted/ unmaintained	7.9	0.93–67.10	0.058
Property condition: decent/poor	2.39	0.63–9.09	0.203
Water-feature not maintained	0.54	0.04–7.32	0.644

Note: Odds ratios are adjusted for all predictors listed. Parcel-level variables were coded as binary indicators based on field inspection data. Model fit: Log-likelihood = -40.65; Deviance = 81.29; Pseudo- R^2 (Cragg-Uhler) = 0.148. ORs were computed as $\exp(\text{coef})$, and confidence intervals were computed as $\exp(95\% \text{ Wald intervals})$. Results should be interpreted as associations with observed larval habitat indicators rather than direct measures of mosquito abundance because species-level mosquito surveillance was not conducted during parcel inspections.

Parcel-level predictors of standing water presence

Container presence was the only statistically significant predictor of standing water on residential parcels (Table 4). Parcels with containers had 19.96 times higher odds of having standing water compared to parcels without containers (95% CI: 8.69–45.99, $p<0.001$). Yard condition, property condition, and water-feature maintenance were not significantly associated with standing water in the adjusted model. The model explained a modest proportion of variance (Pseudo- $R^2 = 0.091$), indicating that container presence is the primary parcel-level environmental factor associated with standing water accumulation. The strong association between containers and standing water supports the operational value of container-focused inspection and source-reduction activities within municipal mosquito-control programs.

Table 4. Multivariable Logistic Regression Predicting Standing Water Presence Across Parcels

Predictor	Adjusted OR	95% CI	p-value
Containers present	19.96	8.69–45.99	<0.001
Yard condition: blighted/unmaintained	0.51	0.05–5.13	0.565
Property condition: decent/poor	1.26	0.51–3.12	0.61
Water-feature not maintained	1.91	0.17–21.38	0.6

Note. Odds ratios reflect adjusted associations between parcel-level environmental indicators and the presence of standing water. All predictors were coded as binary indicators. Model fit was assessed using the Cragg–Uhler (Nagelkerke) Pseudo- R^2 .

Neighborhood-level sociodemographic predictors of standing water prevalence

Planning district-level sociodemographic characteristics were not significantly associated with the proportion of parcels containing standing water (**Table 5**). Median household income, percent Black residents, mean housing age, and total population showed no meaningful adjusted associations with standing water prevalence across the six districts included in the 2018 sample (all $p > 0.49$). Although the model explained a substantial proportion of variance ($R^2 = 0.774$), the adjusted R^2 was negative, reflecting the small number of districts and limited statistical power. Overall, neighborhood-level sociodemographic indicators did not demonstrate clear ecological associations with standing water in this sample. Because analyses were based on only six planning districts, these findings should be interpreted cautiously and viewed as exploratory rather than definitive evidence of an absence of neighborhood-level effects.

Table 5. Linear Regression Predicting District-Level Standing Water Prevalence ($n = 6$)

Predictor	β Coefficient	95% CI	p-value
Median household income	0.000007	–0.000010 to 0.000025	0.561
Percent Black residents	–0.152	–2.024 to 1.721	0.491
Mean housing age (numeric)	0.002	–0.352 to 0.356	0.956
Total population	-2.3×10^{-7}	-4.2×10^{-6} to 3.7×10^{-6}	0.59

Note: Parcel-level environmental indicators were aggregated to the district level. Coefficients represent ecological associations and should not be interpreted as parcel-level effects. Confidence intervals were computed from model output, and all predictors were standardized to district-level means. Wide confidence intervals and the negative adjusted R^2 reflect the small number of planning districts ($n = 6$) and limited statistical power. Accordingly, these results should be considered exploratory and hypothesis-generating rather than conclusive.

Discussion

This study provides new evidence on parcel-level environmental conditions associated with mosquito larval habitats and standing water across New Orleans. Urban mosquito ecology is shaped by fine-scale environmental heterogeneity, and our findings reinforce the importance of micro-environmental features in determining mosquito-breeding risk in dense urban settings, consistent with prior work demonstrating the complexity of mosquito dynamics in cities [3, 4]. Importantly, this study focused on environmental indicators of mosquito habitat suitability rather than direct measures of mosquito abundance or arboviral transmission. Although larval habitats were infrequently detected during routine municipal inspections, several parcel-level indicators demonstrated strong associations with both larval presence and standing-water accumulation.

Standing water and container presence emerged as the most influential predictors of larval habitat presence. Parcels with standing water had markedly higher odds of harboring larvae, aligning with long-standing evidence that artificial containers and small water-holding structures are primary breeding sites for *Aedes* and *Culex* mosquitoes [17, 18]. Container presence was similarly associated with larval habitats, reinforcing findings from Puerto Rico, India and Cambodia that containers consistently drive mosquito productivity across diverse ecological contexts [19, 22]. Indicators of poor yard or property condition showed weaker associations, suggesting that specific water-holding features may be more consequential than general parcel upkeep in New Orleans, a pattern also observed in Baltimore and Washington, DC [20, 21].

Container presence was also the only significant predictor of standing water in the parcel-level model, highlighting its dual role as both a water-accumulation point and a larval development site. This finding is consistent with post-Katrina studies documenting the rapid colonization of water-holding structures including abandoned swimming pools by mosquitoes in New Orleans [24, 11]. Yard condition, property condition and water-feature maintenance were not independently associated with standing water, suggesting that container management may offer the most direct and actionable target for reducing water accumulation during routine inspections. From an operational perspective, these findings support the continued prioritization of container-focused surveillance, source reduction and community outreach activities within municipal mosquito-control programs.

At the neighborhood scale, sociodemographic characteristics were not significantly associated with district-level standing-water prevalence. Although the model explained substantial variance, the small number of districts limited statistical power and likely contributed to wide confidence intervals. The absence of clear ecological associations suggests that parcel-level environmental features may be more important drivers of standing water than broader neighborhood sociodemographic patterns in this context, even though prior work has documented links between housing conditions, environmental disrepair and vector-borne disease risk [14, 15, 25]. These findings indicate that micro-environmental conditions may overshadow neighborhood-level structural inequities in shaping mosquito-breeding risk, at least within the scope of municipal inspections. However, because district-level analyses were based on only six planning districts, these findings should be interpreted cautiously and viewed as exploratory rather than definitive evidence of an absence of neighborhood-level effects.

This study has several strengths, including the use of systematically collected municipal inspection data, integration of parcel-level and district-level indicators and the application of multivariable models to isolate independent predictors of mosquito-relevant environmental conditions. The study areas were selected based on municipal priorities that included historical mosquito-surveillance activities,

documented arboviral concerns, and operational vector-control needs, enhancing the practical relevance of the findings for real-world mosquito-control programs. This study has several strengths, including the use of systematically collected municipal inspection data, integration of parcel-level and district-level indicators, and the application of multivariable models to isolate independent predictors of mosquito-relevant environmental conditions. The study areas were selected based on municipal priorities that included historical mosquito-surveillance activities, documented arboviral concerns, and operational vector-control needs, enhancing the practical relevance of the findings for real-world mosquito-control programs. The study also leveraged data collected through routine municipal surveillance and source-reduction activities, demonstrating the value of operational public-health datasets for evaluating environmental mosquito risk at a scale rarely achieved through traditional ecological field studies.

Several limitations should be considered. Larval habitats were rare, which may have reduced power to detect associations with less common parcel-level indicators. Inspection completeness varied and some environmental features may have been under reported. District-level analyses were constrained by the small number of planning districts, limiting the ability to detect neighborhood-level effects. An additional limitation is that drainage-system and stormwater-infrastructure characteristics were not available for analysis. Previous studies have shown that underground storm-drain systems can serve as important larval habitats for *Culex quinquefasciatus* and may contribute substantially to urban mosquito production [8]. Because these habitats were not systematically assessed during parcel inspections, the present study may not fully capture all environmental sources of mosquito habitat within the urban landscape.

Because inspectors conducted assessments from the sidewalk or parcel perimeter, visibility of backyard features, small containers, or shaded water-holding structures was sometimes limited. These access constraints likely produced conservative estimates of environmental hazards and may partially explain the low prevalence of larval habitats. Property-owner reluctance, resident absence, and physical access barriers further affected inspection completeness and may have limited the identification of concealed breeding habitats.

The inspection protocol was designed to identify environmental mosquito hazards rather than conduct entomological surveillance. Consequently, mosquito specimens were not collected and species-level identification was not performed. Because habitat preferences differ among mosquito taxa, particularly between *Aedes* and *Culex* species, the observed associations should be interpreted as indicators of environmental suitability for mosquito breeding rather than species-specific measures of mosquito abundance or vector production. An additional limitation is the age of the dataset. The inspections were conducted in 2018, and environmental conditions may have changed because of redevelopment, infrastructure improvements, changing land-use patterns, and ongoing mosquito-control activities. Nevertheless, the findings remain valuable because they identify persistent parcel-level environmental conditions associated with mosquito habitat formation and demonstrate a framework for integrating municipal inspection data into operational vector-control planning.

Finally, the cross-sectional design precludes causal inference. Despite these limitations, the results highlight clear opportunities for targeted mosquito-control interventions. Container removal and management represent actionable strategies that can be integrated into routine inspections to reduce both standing water and larval habitat formation, consistent with global recommendations for integrated vector management. Strengthening container-focused outreach and enforcement may yield meaningful

reductions in mosquito breeding potential at the parcel scale in New Orleans. Future studies should integrate parcel-inspection data with trap-based mosquito surveillance, species-specific entomological monitoring, drainage-system characteristics, weather patterns, and longitudinal observations to better understand the pathways linking environmental conditions to mosquito abundance and disease risk.

In conclusion, this study demonstrates that parcel-level environmental features, particularly container presence, are the primary drivers of standing water and larval habitat presence in New Orleans. Neighborhood-level sociodemographic characteristics did not meaningfully predict standing-water prevalence, emphasizing the importance of micro-environmental conditions in shaping mosquito-breeding risk. While the study does not directly measure mosquito abundance, it identifies environmental conditions most strongly associated with habitat suitability and therefore provides actionable information for surveillance and source-reduction programs. These findings support targeted, parcel-level interventions as a central component of integrated vector management and provide a foundation for refining municipal mosquito-control strategies in urban settings.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statement

The data supporting the findings of this study are available from the corresponding and last author upon reasonable request.

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