

# Exploring Heat-Related 311 Service Requests as Indicators of Neighborhood Heat Burden in New York City

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## Research Article

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# Abstract

Extreme heat is the leading weather-related cause of death in New York City, yet vulnerability indices built from census and land-surface inputs capture where heat is present more readily than how residents experience and respond to it. We evaluated whether 311 service requests, a form of resident-generated social sensing, can serve as a complementary neighborhood-level indicator of heat burden. Daily 311 records for 2015–2025 were linked to heatwave days defined from the NOAA Central Park station ( $\geq 3$  consecutive days  $\geq 90^\circ\text{F}$ ), and nine candidate complaint categories (763,986 requests) were screened using Welch two-sample t-tests, with Poisson models as a sensitivity analysis for sparse categories. Hydrant-related requests showed the strongest heatwave signal (474.8 vs 59.1 mean daily requests), followed by power outage (39.9 vs 15.6) and ventilation requests (15.6 vs 8.4; all  $p < 0.001$ ). Aggregated to Modified ZIP Code Tabulation Areas, all three clustered spatially (Moran's I 0.507–0.674; all  $p < 0.001$ ), concentrating in the Bronx and Upper Manhattan, and all three were positively correlated with neighborhood poverty ( $r = 0.35$ – $0.66$ ). In spatial lag models, hydrant requests were independently associated with Hispanic population share, power outage requests with all sociodemographic predictors examined, and ventilation requests with poverty. In exploratory secondary analyses, ventilation requests corresponded most closely with heat-illness EMS dispatch rates, while cooling center density showed weak or no association with any category. Heat-related 311 requests appear to index distinct dimensions of heat burden, including informal cooling, infrastructure strain, and housing conditions, and may complement conventional heat metrics in targeting urban heat interventions.

## Background

Extreme heat is becoming a more urgent public health concern in New York City as climate change increases the intensity, duration, and frequency of heat events.<sup>1,2,3</sup> It raises the risk of dehydration, heat exhaustion, heat stroke, and death, while straining energy, transit, and communication systems across the city.<sup>1,2,4</sup> Extreme heat is now the leading cause of weather-related death in both New York City and the United States, and roughly 500 people die annually from heat in New York City<sup>5,6</sup>.

These risks are not evenly distributed. Heat-related illness and mortality are shaped by longstanding inequities in housing, neighborhood disinvestment, infrastructure, and access to cooling.<sup>7</sup> Heat-related mortality is higher in high-poverty neighborhoods, is concentrated among older adults and people with chronic illness, and disproportionately affects Black New Yorkers, whose heat-stress death rate is twice that of white residents.<sup>5</sup> Urban heat islands intensify these patterns, creating neighborhoods where heat-retaining surfaces, sparse vegetation, and poor-quality housing make hot days more dangerous and harder to escape.<sup>8,9</sup> This uneven geography has been documented through tools including the Heat Vulnerability Index (HVI), which highlights parts of Northern Manhattan, central Brooklyn, eastern Queens, and several neighborhoods in the Bronx.<sup>3,10</sup>

Existing tools for anticipating this harm, including the HVI, are constructed from relatively static inputs such as census-derived sociodemographic data, average land surface temperature, and housing

surveys.<sup>10,11</sup> While validated against mortality, their relationships with observed health outcomes are often modest.<sup>11</sup> Recent analyses further show that HVI rankings are sensitive to model specification: substituting key variables or incorporating comorbidity measures shifts neighborhood risk rankings, with only 12% of areas remaining stable across alternative specifications.<sup>12</sup> Comparisons between HVI scores and operational indicators such as heat-flagged emergency medical service (EMS) dispatches and hydrant-related 311 complaints likewise reveal weak correlations, raising questions about their utility for real-time decision-making.<sup>12</sup>

Beyond structural vulnerability metrics, conventional weather data provide critical warning signals but cannot fully explain how residents perceive, experience, and cope with extreme heat in everyday life.<sup>13,14</sup> Heat exposure is mediated by the conditions of daily life, including where people work, how they travel, housing quality, access to cooling, and the strategies people use to manage heat in their homes and neighborhoods.<sup>15,16</sup> Because the burdens of extreme heat are socially felt and socially stratified, they must also be measured through socially meaningful indicators.<sup>15</sup>

Along these lines, 311 data have increasingly been used as a form of urban social sensing, because they capture how residents notice, interpret, and act on neighborhood conditions through service-seeking behavior.<sup>18</sup> In New York City, 311 service requests have been used to study neighborhood distress and opioid use, urban blight, coronavirus-related concerns, school disruptions, and street flooding, among others.<sup>19–22</sup> In this sense, 311 data do not measure exposure directly; they capture the ways urban problems become visible, actionable, and reportable to residents. This makes them particularly useful for studying conditions experienced socially as much as they are measured physically.

While no prior study has systematically examined which 311 complaint types are sensitive to extreme heat, literature on heat coping behaviors suggests that heatwaves may increase reporting related to housing infrastructure strain, power outages, and cooling system failures.<sup>12,18</sup> Indoors, ventilation and air conditioning requests may reflect building-level thermal strain, as residents in poorly ventilated or inadequately cooled housing seek relief.<sup>23</sup> Power outage requests may increase as temperatures rise, reflecting grid strain from peak cooling demand.<sup>24</sup> Informally, the use of fire hydrants is a well-documented cooling behavior in dense urban neighborhoods where residents without air conditioning open hydrants for relief,<sup>12</sup> a practice routine enough that the city has enacted dedicated outreach and spray cap distribution efforts during heat emergencies.<sup>25</sup> Heat has also been commonly linked to odor complaints in popular media, though this has not been statistically examined.

This study evaluates whether 311 service requests can serve as a citywide signal of the social experience of extreme heat in New York City, and whether these patterns reflect both underlying spatial inequities and acute health outcomes. We ask: can 311 service requests be used to understand unequal exposure to heat stress in New York City? Our primary objectives were (1) to identify 311 service request categories showing a statistically meaningful association with extreme heat days; (2) to characterize their spatial distribution across neighborhoods at the Modified ZIP Code Tabulation Area (MODZCTA)

level; and (3) to examine whether these patterns are associated with neighborhood poverty, racial and ethnic composition, and age structure. As a secondary objective, we examined whether two existing components of the city's heat response, cooling centers and heat-related EMS dispatches, are spatially aligned with 311-derived indicators of neighborhood heat burden.

## Methods

### Data sources

We compiled heatwave data with 311 service requests to assess whether select complaint categories increased during periods of extreme heat. Heatwave data were obtained from the National Oceanic and Atmospheric Administration (NOAA) weather station in Central Park (USW00094728) for 11 consecutive full calendar years, 2015 through 2025, and calendar days were classified as heatwave versus non-heatwave days. Consistent with the New York City Panel on Climate Change, heatwaves were defined as three or more consecutive days with maximum temperatures of 90°F or above.<sup>26</sup> This yielded 106 heatwave days over the study period, ranging from 3 days in 2023 to 15 days in 2024; a full list of heatwave day distribution can be found in Supplementary Material S1.

We analyzed New York City 311 service request data from 2015 to 2025. Because the 311 platform separates records from 2010–2019 and 2020–present into two public datasets, heat-related complaints were compiled from both sources and harmonized prior to analysis. To identify requests plausibly related to heat exposure, adaptation, or heat-associated infrastructure stress, we used an iterative complaint selection process. We first reviewed the 311 data dictionary, examined prior literature, and explored the dataset through the NYC Open Data interface. Initial extraction by application programming interface was limited because relevant complaints were distributed across more than one field, particularly Problem (formerly Complaint Type) and Problem Detail (formerly Descriptor), and API filters could effectively target only one field at a time, risking undercapture of conceptually related complaints. We therefore shifted to a thematic extraction strategy using the web interface, manually filtering and downloading complaint categories across all available years, prioritizing inclusivity and conceptual consistency. Downloaded datasets were merged and curated in R, drawing on principles for open data curation described by Tussey and Yan.<sup>27</sup> Mixed data formats were resolved during preprocessing; final daily service request series contained no missing data attributable to parsing.

### Statistical analysis

Selected 311 categories were first screened for heat relevance using daily time-series comparisons of heatwave and non-heatwave days. Daily request counts were aggregated across the study period, including zero-count days, and compared using Welch two-sample t-tests. For low-volume categories, results were verified using Poisson regression as a sensitivity analysis. This step was an exploratory screening procedure rather than a definitive test of association. Service requests were not deduplicated by location or date, as the unit of analysis is the individual service request rather than the underlying

event; repeated reports of the same hydrant are treated as additional expressions of public concern rather than redundant records. Categories retained for subsequent analysis were selected on the basis of statistical patterns, volume, and interpretability as indicators of heat-related behavior, adaptation, or infrastructure strain.

To examine neighborhood-level spatial patterning, we aggregated complaint data to the MODZCTA level. MODZCTAs were developed by the NYC Department of Health and Mental Hygiene by consolidating low-population ZCTAs to improve the stability of estimates.<sup>28</sup> They were selected as the primary spatial unit because they balance spatial specificity with analytic stability: large enough to reduce sparsity in service request counts, yet still meaningful for neighborhood-level public health interpretation. Service requests with valid latitude and longitude were converted to spatial points, joined to MODZCTA polygons, and aggregated to neighborhood counts and rates per 1,000 residents. Records missing both coordinate and ZIP code data were excluded; where coordinates were missing but a ZIP code was available, records were retained and assigned to a MODZCTA via ZIP code lookup.

Pearson correlation coefficients were used to examine relationships among service request categories and bivariate relationships between request rates and neighborhood sociodemographic characteristics. Area-level poverty, racial/ethnic composition, and age structure were derived from U.S. Census Bureau American Community Survey estimates and merged to the MODZCTA analytic file. Multivariable linear regression models then examined the independent associations of poverty, Black population share, Hispanic population share, and older adult population share with hydrant, power outage, and ventilation request rates.

To account for potential spatial autocorrelation among neighboring MODZCTAs, we conducted an exploratory spatial data analysis using Moran's I to test for spatial clustering in each outcome. Lagrange Multiplier diagnostics were used to determine whether a spatial lag or spatial error specification was more appropriate; results indicated spatial lag was the better-fitting specification across all three outcomes. Spatial weights were constructed using a queen contiguity matrix with row-standardized weights (style = "W"), in which neighboring MODZCTAs were defined as those sharing a boundary point. One MODZCTA (Roosevelt Island) had no contiguous neighbors under this definition and was retained with zero spatial weight (zero.policy = TRUE), consistent with standard practice for isolated geographic units. Spatial lag models were estimated for each of the three retained outcome categories using maximum likelihood estimation, with model fit compared to the corresponding ordinary least squares (OLS) models using the Akaike information criterion (AIC).

## Secondary analysis

To illustrate potential avenues for extending the utility of 311 data as a real-time signal of heat burden, we examined how heat-related request rates corresponded with two external indicators: heat illness EMS dispatches and the spatial distribution of cooling centers. Heat illness EMS dispatch data were obtained from the NYC Emergency Medical Services incident dataset and filtered to confirmed heat-related calls

(final call type = HEAT) between 2015 and 2025. Individual incidents were linked to MODZCTAs via ZIP code using the MODZCTA boundary file; 70 incidents (0.8%) could not be matched and were excluded. Incidents were aggregated to the MODZCTA level and expressed as a rate per 100,000 residents. Because of right skew driven by low-population MODZCTAs, particularly in lower Manhattan where daytime population substantially exceeds residential population, EMS rates were log-transformed prior to analysis. Cooling center data were obtained from the NYC Cool Options Finder ([nyc.gov/coolingcenters](https://nyc.gov/coolingcenters), accessed June 2026); facilities designated as pools or spray showers were excluded, retaining 602 indoor cooling centers and other indoor cool options, which were spatially joined to MODZCTAs and expressed as a rate per 100,000 residents. Spearman rank correlations were calculated between each external indicator and each of the three 311 service request categories.

## Results

### Which 311 categories are heat-related?

A total of 763,986 311 service requests across nine screened categories were assembled and reviewed for inclusion. Categories were identified through review of the 311 data dictionary and thematic exploration of the dataset, drawing primarily on the Problem and Problem Detail fields. In some cases records were grouped across both fields to capture conceptually related complaints; for example, hydrant-related activity was compiled from multiple complaint types and descriptors that collectively reflect heat-related public cooling behavior. Categories retained for evaluation included New Tree Request, Beach/Pool complaints, Air Conditioning, Hydrant-related complaints, Power Outage, Ventilation, Hose, Cooling Tower, and Odor. Supplementary Table S2 presents these categories with their associated descriptors and record counts.

In exploratory analyses, hydrant-related complaints showed the strongest association with heatwave days (mean 474.8 vs. 59.1 complaints per day), followed by power outage, ventilation, and air conditioning complaints (all  $p < 0.001$ ). Beach/Pool complaints were also significantly higher on heatwave days ( $p < 0.001$ ), though the volume in this category was low (1,921 requests over 11 years), limiting interpretability. Cooling Tower complaints likewise differed significantly ( $p = 0.021$ ) but were rare overall (232 records), warranting caution. As a sensitivity analysis, low-volume categories were re-examined using Poisson and quasi-Poisson regression on daily counts, with consistent conclusions. Hose and Odor complaints showed no clear heatwave pattern ( $p = 0.83$  and  $p = 0.38$ , respectively). New Tree Requests appeared more frequent on heatwave days, but this difference was not statistically significant ( $p = 0.066$ ), and further exploration revealed anomalies suggesting that some records may reflect administrative batching or other non-urgent service processes. Table 1 presents these results.

Table 1

Exploratory screening of candidate 311 service request categories by heatwave status, New York City, 2015–2025.

| <b>Category</b>  | <b>Mean/day<br/>non-heatwave</b> | <b>Mean/day<br/>heatwave</b> | <b>Total<br/>non-heatwave</b> | <b>Total<br/>heatwave</b> | <b>Welch t-test<br/>p-value</b> |
|------------------|----------------------------------|------------------------------|-------------------------------|---------------------------|---------------------------------|
| Air Conditioning | 12.8                             | 22.1                         | 50,134                        | 2,344                     | 6.06e-05                        |
| New Tree Request | 45.2                             | 51.4                         | 176,857                       | 5,446                     | 0.066                           |
| Odor             | 36.1                             | 37.3                         | 141,037                       | 3,959                     | 0.376                           |
| Ventilation      | 8.4                              | 15.6                         | 32,932                        | 1,658                     | 3.61e-15                        |
| Power Outage     | 15.6                             | 39.9                         | 60,990                        | 4,233                     | < 2.2e-16                       |
| Hydrant          | 59.1                             | 474.8                        | 231,241                       | 50,324                    | < 2.2e-16                       |
| Beach/Pool       | 0.5                              | 1.4                          | 1,773                         | 148                       | 3.61e-10                        |
| Cooling Tower    | 0.1                              | 0.1                          | 217                           | 15                        | 0.021                           |
| Hose             | 0.2                              | 0.2                          | 661                           | 17                        | 0.826                           |

Although the broad Air Conditioning category was significantly associated with heatwave days (12.8 vs. 22.1 mean daily requests), it was dominated by noise complaints about air conditioning and ventilation equipment (90.3% of the category). These complaints are filed by individuals disturbed by operating equipment, and their association with heat therefore likely reflects increased equipment use during hot weather rather than unmet cooling needs. While elevated noise may in part indicate aging or malfunctioning units, this cannot be distinguished from routine operation in the 311 record. Because this category indexes the presence and operation of cooling equipment rather than its absence, it was retained in exploratory analyses (Table 1) but excluded from the final analytic dataset.

The final dataset included Ventilation, Power Outage, and hydrant-related service requests. Power outage requests ( $n = 64,999$ ) rose sharply on heatwave days, from an average of 15.6 to 39.9 daily requests, while ventilation requests ( $n = 34,482$ ) nearly doubled, from 8.4 to 15.6. Hydrant-related complaints emerged as the clearest and most persistent signal of extreme heat, increasing from an average of 59.1 to 474.8 requests per day and standing out as a recurring feature of hot-weather days across the study period.

Given the strength of the hydrant signal, we conducted a descriptor-level review to identify which subcategories to retain. “Remove Hydrant Locking Device” was infrequent and appeared to reflect maintenance activity, while “Request to Open a Hydrant” appeared to capture a formal access mechanism rather than everyday heat-related hydrant use and was inconsistently represented over time. We therefore retained Fire Hydrant Emergency (FHE), Hydrant Running, Hydrant Running Full, and Illegal Use of a Hydrant. These descriptors do not measure identical phenomena: hydrant running requests may

reflect visible public hydrant use and can include repeated reports of the same hydrant, whereas FHE requests appear more closely tied to the municipal response itself.<sup>29</sup> On some heatwave days there are no hydrant running requests but large numbers of FHE requests, and vice versa, suggesting the descriptors are complementary rather than interchangeable: one captures public reporting, the other the city's response. Combined, they capture a broader pattern of hydrant-related cooling activity during extreme heat.

## **Spatial analysis at the MODZCTA level**

Spatial joins between complaint point data and MODZCTA polygons were highly complete: only 28 hydrant complaints (0.01%), 1 power outage complaint (< 0.01%), and 0 ventilation complaints failed to match. Complaints were aggregated to totals by MODZCTA and standardized by estimated population to create rates per 1,000 residents. MODZCTAs with zero estimated population were left unshaded in rate maps because population-standardized rates could not be calculated.

Choropleth maps showed that the three retained request types were not randomly distributed across the city (Fig. 1). Hydrant-related rates were especially concentrated in parts of the Bronx and Upper Manhattan, with comparatively lower rates across much of Staten Island, southern Brooklyn, and eastern Queens (Fig. 1A). Power outage rates also concentrated in Upper Manhattan and a wider portion of the Bronx, as well as selected areas of central Brooklyn (Fig. 1B). Ventilation rates were spatially patterned but somewhat more diffuse, with concentrations in Central and Upper Manhattan, parts of the Bronx, and selected areas of Staten Island and central Brooklyn (Fig. 1C).

Tested statistically, MODZCTA-level rates were positively correlated across the retained categories, although the strength of association varied. Hydrant-related and power outage rates were moderately to strongly correlated ( $r = 0.60$ ), suggesting these two indicators cluster in some of the same neighborhoods (Supplementary Figure S3). Ventilation rates were more weakly related to hydrant activity ( $r = 0.21$ ) and only modestly related to power outage rates ( $r = 0.31$ ), indicating that ventilation may capture a different dimension of neighborhood heat-related conditions.

## **Sociodemographic analysis**

At the MODZCTA level, higher neighborhood poverty was associated with higher rates of all three retained request types. The strongest relationship was for power outage rates ( $r = 0.66$ , 95% CI: 0.567–0.735), followed by hydrant-related rates ( $r = 0.55$ , 95% CI: 0.436–0.644) and ventilation rates ( $r = 0.35$ , 95% CI: 0.218–0.477; all  $p < 0.001$ ). Heat-related request patterns were therefore concentrated in economically vulnerable neighborhoods.

In multivariable models including poverty, racial/ethnic composition, and age structure, neighborhood sociodemographic composition remained strongly associated with request rates (Table 2). Hydrant-related rates were most strongly associated with Hispanic population share ( $\beta = 0.658$ ), while poverty was only marginally associated after adjustment. Power outage rates showed the strongest overall

model fit ( $R^2 = 0.649$ ) and were positively associated with poverty, Black population share, and Hispanic population share, with a modest negative association with the proportion of residents aged 65 and older. Ventilation rates were positively associated with poverty but negatively associated with Hispanic population share and older age composition. Variance inflation factors were low across all models (all VIFs < 2), suggesting that overlap among poverty, race/ethnicity, and age composition did not meaningfully distort coefficient estimates.

Because request rates and several predictors are likely spatially autocorrelated, we re-estimated each model using spatial lag regression. Moran's I confirmed significant spatial autocorrelation in all three outcomes (hydrant I = 0.573, power outage I = 0.674, ventilation I = 0.507; all  $p < 0.001$ ). Lagrange Multiplier diagnostics indicated a spatial lag specification was appropriate across all three outcomes, with the adjusted LM-lag statistic significant (hydrant  $p = 0.041$ , power outage  $p = 0.001$ , ventilation  $p = 0.005$ ) and the adjusted LM-error statistic non-significant in each case (all  $p > 0.05$ ). Spatial autocorrelation was significant across all three models (hydrant  $p = 0.361$ , power outage  $p = 0.406$ , ventilation  $p = 0.538$ ; all  $p < 0.001$ ), and spatial lag models improved fit in all cases (AIC: hydrant 378 → 359; power outage 326 → 300; ventilation 473 → 426). After accounting for spatial structure, the substantive pattern of findings largely held. For hydrant-related requests, Hispanic population share remained independently associated ( $\beta = 0.462$ ,  $p < 0.001$ ), while poverty and Black population share remained non-significant. For power outage requests, all four sociodemographic predictors remained significant, reinforcing this as the most robust and broadly patterned association across models. For ventilation requests, poverty ( $\beta = 0.312$ ,  $p < 0.001$ ) and Hispanic population share ( $\beta = -0.160$ ,  $p = 0.025$ ) remained significant, while Black population share and age 65 + did not.

Table 2

Multivariable OLS and spatial lag regression models for heat-related 311 service request rates at the MODZCTA level (standardized coefficients).

| Outcome      | Model              | $R^2$ / $\rho$       | AIC   | $\beta$ Poverty | $\beta$ Black | $\beta$ Hispanic | $\beta$ Age 65+ |
|--------------|--------------------|----------------------|-------|-----------------|---------------|------------------|-----------------|
| Hydrant      | OLS                | 0.592                | 378.1 | 0.127           | 0.017         | 0.658***         | -0.072          |
|              | <i>Spatial Lag</i> | $\rho = 0.361^{***}$ | 359.3 | 0.078           | -0.013        | 0.462***         | -0.031          |
| Power Outage | OLS                | 0.649                | 326.3 | 0.297**         | 0.449***      | 0.311***         | -0.117*         |
|              | <i>Spatial Lag</i> | $\rho = 0.406^{***}$ | 299.8 | 0.186**         | 0.302***      | 0.194**          | -0.092*         |
| Ventilation  | OLS                | 0.201                | 473.3 | 0.481***        | -0.073        | -0.292***        | -0.209*         |
|              | <i>Spatial Lag</i> | $\rho = 0.538^{***}$ | 425.7 | 0.312***        | -0.021        | -0.160*          | -0.075          |

\* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ .

## Secondary analysis

We explored how heat-related requests corresponded with two additional indicators of heat burden: heat illness EMS dispatches and cooling center distribution (Supplementary Figures S4–S5). Ventilation requests showed the strongest spatial correspondence with heat illness EMS dispatch rates ( $\rho = 0.670$ ,  $p < 0.001$ ), followed by hydrant-related requests ( $\rho = 0.298$ ,  $p < 0.001$ ) and power outage requests ( $\rho = 0.239$ ,  $p = 0.001$ ). Borough-level patterns were visually distinct: Bronx and Brooklyn MODZCTAs clustered toward higher hydrant and power outage rates relative to their EMS burden, while Manhattan MODZCTAs showed higher EMS and ventilation rates, driving the overall ventilation correlation. Cooling center density (per 100,000 residents) across 177 MODZCTAs showed no meaningful association with power outage rates ( $\rho = 0.064$ ,  $p = 0.398$ ) and only weak associations with hydrant ( $\rho = 0.213$ ,  $p = 0.004$ ) and ventilation rates ( $\rho = 0.269$ ,  $p < 0.001$ ).

## Discussion

Resident-generated 311 service requests appear to capture dimensions of extreme heat that are not fully represented by conventional heat metrics. Rather than measuring exposure alone, these requests reflect how residents experience, respond to, and seek relief from extreme heat. Different categories capture distinct dimensions of this social experience: hydrant-related complaints reflect informal cooling practices, power outage requests capture infrastructure strain, and ventilation complaints point to chronic housing conditions that become consequential during extreme heat.<sup>23,30</sup> Socioeconomic vulnerability appears to shape both residents' adaptive responses and the infrastructural challenges they face, and these dynamics are visible through 311.

The spatial and sociodemographic patterns we observed are consistent with existing evidence on the distribution of heat burden in New York City. The concentration of hydrant and power outage complaints in the Bronx and Upper Manhattan aligns closely with the geography identified by the HVI and the broader literature.<sup>7,9,10</sup> Heat-related illness and death disproportionately affect high-poverty neighborhoods and Black and Hispanic communities, reflecting longstanding structural barriers to cooling.<sup>3–5</sup> Hydrant activity in particular was most strongly associated with Hispanic neighborhood composition, consistent with prior evidence that opened hydrants function as an informal cooling strategy in underserved communities.<sup>25,29</sup> Ventilation complaints followed a somewhat different pattern: although poverty remained their strongest predictor, their weaker sociodemographic model fit and persistent spatial clustering suggest they may be shaped by housing conditions or building infrastructure.<sup>31,32</sup> The correspondence between ventilation complaints and heat illness EMS dispatches is the most striking finding of the secondary analysis. Ventilation requests showed the strongest correlation with EMS burden ( $\rho = 0.670$ ) despite the weakest sociodemographic model fit in the primary analysis, suggesting they may capture dimensions of indoor environmental vulnerability not well explained by neighborhood composition alone.<sup>30</sup> This makes ventilation-related requests a potentially valuable indicator of neighborhoods where heat stress is translating into measurable health burden, and

where targeted building inspection, code enforcement, or public health outreach might have the greatest impact.<sup>33</sup>

These findings support a social sensing framework for understanding urban heat inequity. Conventional metrics such as land surface temperature and vulnerability indices describe where heat is present and who is structurally vulnerable, but are less able to capture how heat is lived, responded to, and managed in everyday settings.<sup>17</sup> Incorporating information on how communities experience and respond to heat could improve the design and placement of cooling centers, shade infrastructure, greening projects, and outreach efforts.<sup>34</sup> Our cooling center analysis provides suggestive evidence: associations between cooling center density and heat-related requests were weak and inconsistent across all three categories, indicating limited alignment between existing cooling infrastructure and neighborhoods exhibiting higher reported heat burden.

Several directions for future research emerge. Preliminary analyses suggest hydrant-related requests have increased differentially across boroughs since approximately 2021; this requires formal longitudinal investigation to determine whether it reflects changes in heat exposure, neighborhood vulnerability, reporting behavior, or municipal response. Similar questions apply to ventilation and power outage requests, where trends may be shaped by shifts in the built environment. Characteristics such as tree canopy coverage, proximity to highways, and housing quality may structure both indoor and outdoor heat exposure and could help explain spatial patterns beyond sociodemographic composition.<sup>35</sup> Finally, complementary qualitative research examining coping practices, organizational responses, and residents' perceptions of gaps in formal heat mitigation infrastructure would provide important context.

**Limitations.** Several limitations warrant consideration. First, 311 data are subject to differential reporting: residents' willingness and ability to file complaints vary by neighborhood, language, familiarity with city services, and historical relationships with municipal agencies. Request rates may therefore reflect reporting behavior as well as underlying heat burden, and some populations or neighborhoods may be systematically underrepresented. Reporting may also vary by complaint type; ventilation complaints may be influenced by housing tenure and concerns about landlord retaliation, while the absence of signals for other heat-related concerns may reflect the existence of alternative reporting or service channels rather than an absence of need. Second, hydrant-related complaints are shaped by policing and enforcement dynamics, as whether a running hydrant generates a request depends not only on its presence but on who observes it, who reports it, and how enforcement is distributed across neighborhoods. Finally, because our analysis was conducted at the ecological (MODZCTA) level, associations between neighborhood sociodemographic characteristics and request rates should not be interpreted as individual-level relationships.

## Conclusion

Resident-generated 311 service requests offer a complementary source of information for understanding urban heat inequity. Different categories captured distinct dimensions of residents'

experiences during extreme heat, reflecting informal cooling practices, infrastructure strain, and housing-related vulnerabilities, while revealing spatial patterns that closely align with socioeconomic inequities across New York City. While temperature and heat vulnerability indices remain essential for characterizing exposure, they cannot fully capture the social realities of extreme heat. Integrating resident-generated data alongside conventional metrics may help cities better identify vulnerable communities and develop heat mitigation strategies that are more responsive to residents' lived experiences.

## Declarations

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Conflict of interest

The authors declare that they have no competing interests.

Ethics approval

This study used publicly available, de-identified data which is determined to be exempt from human subjects research requirements by the Institutional Review Board of the City University of New York (CUNY).

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Data availability

The data analyzed in this study are publicly available through the NYC Open Data platform.

Code availability

The code used for data processing and analysis is available from the corresponding author upon reasonable request.

## Authors' contributions

Conceptualization: JNS, MJH, KS, CM, RPL; Methodology: JNS, MJH, KS, RPL,CM; Formal analysis: JNS, KS; Data curation: JNS, MJH; Investigation: JNS, KS, MJS; Writing – original draft: JNS; Writing – review & editing: JNS, MJH, KS, CM, RPL; Visualization: JNS, KS; Supervision: RPL; Project administration: JNS, RPL; Funding acquisition: RPL.

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## Figures

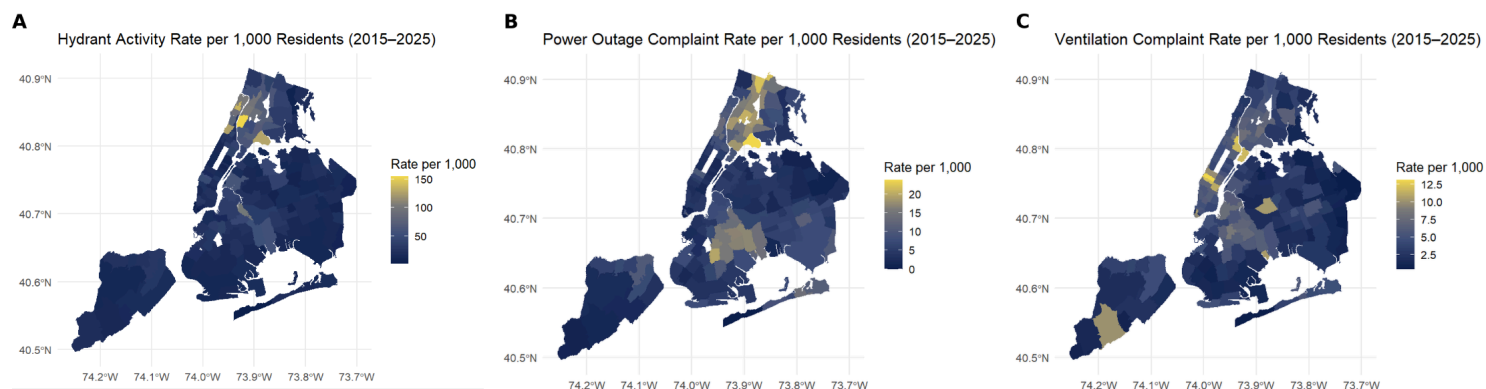


**Figure 1**

Heat-related 311 service request rates per 1,000 residents by Modified ZIP Code Tabulation Area, New York City, 2015–2025. (A) Hydrant activity. (B) Power outage complaints. (C) Ventilation complaints. MODZCTAs with zero estimated population are unshaded.

## Supplementary Files

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