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Pushed to the edges? Electivity patterns of urban stream homeless encampments in environmentally burdened areas

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ABSTRACT

Urban stream corridors in the San Francisco Bay Area have increasingly become locations for homeless encampments, yet little is known about the environmental conditions of these spaces. This study uses a geospatial electivity index to examine whether urban stream encampments in Santa Clara and Contra Costa counties are disproportionately located in census tracts with high pollution burdens, as measured by CalEnviroScreen 4.0. Findings show a statistically significant overrepresentation of encampments in census tracts in the top 25% of pollution and vulnerability scores, and a significant underrepresentation in lower-pollution areas. These results suggest that homeless individuals are being pushed toward environmentally hazardous areas, likely due to enforcement pressures, lack of viable alternatives, and land use patterns that concentrate polluting infrastructure and activities in low-resource areas. The findings have implications for environmental justice, public health, and urban policy, especially as CalEnviroScreen plays a central role in allocating state resources to disadvantaged communities.

KEYWORDS
Homelessness; pollution burden; geospatial analysis; disadvantaged communities; environmental justice

Introduction

California's homelessness crisis is among the most severe in the United States and is particularly acute in the San Francisco Bay Area, where chronic housing shortages, high costs of living, and the COVID-19 pandemic have left thousands of residents homeless (Streeter, 2022; Wright et al., 2021). While the structural drivers of homelessness—such as unaffordable housing, insufficient shelter capacity, the opioid crisis, and federal disinvestment in public housing and mental health—are well documented (Austin et al., 2021; Bassuk, 1984; Bay Area Council Economic Institute, 2021; Colburn & Aldern, 2022; Johnson & Chamberlain, 2008; Lyle, 2023; Rao & Brandeau, 2025), less attention has been paid to the environmental conditions experienced by homeless people and how geography shapes their exposure to environmental risks.

In recent years, local governments across California have increasingly adopted punitive responses to visible homelessness, including the enforcement of anti-camping laws and the forced removal of encampments from downtown and residential areas (City of San Jose, n.d.; Har, 2025; Karlamangla, 2025). The 2024 Supreme Court decision in *City of Grants Pass v. Johnson* has further enabled cities to clear encampments without providing alternative shelter options (Newsom, 2024; VanSickle, 2024). These legal and policy shifts have contributed to the displacement of homeless residents into parks and open spaces of cities, including along urban streams, floodplains, and other interstitial green spaces where enforcement is less aggressive and encampments are more likely to be tolerated (Herring, 2014).

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This study investigates a specific dimension of that displacement: whether urban stream encampments in the Bay Area are disproportionately located in areas with high environmental pollution burdens. Urban waterways offer some desirable features—shade, access to water, relative privacy, and ecological shelter—but may also expose residents to pollution risks, flooding, and public health hazards (Flanigan & Welsh, 2020; Hinds et al., 2024; Koprowska et al., 2020; Palta et al., 2016; Speer & Goldfischer, 2020; Verbyla et al., 2021). Yet, there is little empirical research on whether the locations of these encampments along urban streams correspond to areas already burdened by environmental injustice.

To address this gap, we used spatial analysis and an electivity index to examine the co-location of urban stream encampments with high-pollution census tracts, as defined by CalEnviroScreen 4.0. By focusing on Santa Clara and Contra Costa counties, this study offers evidence of a broader pattern in which homeless individuals—already among the most environmentally vulnerable populations (Bezgrebelna et al., 2021)—are concentrated in environmentally hazardous areas. Although the analysis is designed to identify spatial associations rather than explain the mechanisms that produce them, it contributes new insight to the literature on homelessness geography, environmental justice, and urban planning.

This paper makes an important contribution to the body of research on homelessness and the environment because it links homelessness not only to social marginalization but also to environmental marginalization. It shows that the geography of homelessness may amplify exposure to environmental harms in ways that are systematically patterned and policy-relevant. As California allocates billions in climate and environmental justice funding through tools like CalEnviroScreen, the CARB Cap-and-Trade program, and the CalEPA EJ Action Grants Program, understanding the location and vulnerability of urban stream homeless encampments is essential for equitable planning, public health response, and policy design. These findings may also inform other urban regions facing similar pressures, offering a replicable framework for analyzing how displacement policies and environmental burdens intersect in marginalized communities across the United States and beyond.

Background

Studies on the geography of encampments show that people experiencing homelessness have historically concentrated in areas near services, basic needs, income, safety, food. In cities this usually correlates with central business districts (Harrell, 2019; Lee & Price-Spratlen, 2004; Lee et al., 2010; Schor et al., 2003). However, over the past two decades, enforcement-based policies and land use regulations have increasingly pushed encampments into urban corridors, parks and open space areas of cities (American Public Health Association, 2023). City land use policies and "not in my backyard" (NIMBY) political pressure have also helped to concentrate homeless services away from residential areas into central, urban, often low-resource areas (Lee & Price-Spratlen, 2004). Opponents of anti-camping laws argue that enforcement through sweeps causes significant harm to residents by displacing them, disrupting social ties, and removing vital resources or possessions; relocation to more dangerous places; and potential victimization in continued homelessness (Darrah-Okike et al., 2018; Mayer et al., 2024; Robinson, 2019; Turner et al., 2018). Encampments persist, move, or re-form after abatement, and ultimately many cities are willing to tolerate encampments in areas where enforcement costs and public complaints are reduced (Herring, 2014).

In recent years, local governments, law enforcement, media, and service providers throughout the San Francisco Bay Area (hereafter referred to as "Bay Area") have anecdotally reported an increase in urban waterway encampments (Almendrala, 2020; Chu, 2024; Hubler et al., 2023; Kadah, 2024; Kendall, 2021). These locations—streams, creeks, and riparian corridors—may offer both physical refuge and social invisibility. The limited research on waterway encampments shows they provide such ecosystem services as shade and access to water (Palta et al., 2016). In a qualitative study, interviewees cited other benefits including privacy, avoiding the shelter system, and less harassment from authorities (Flanigan & Welsh, 2020). In addition to fulfilling basic needs for shelter, people experiencing homelessness appreciate urban green spaces for leisure, socializing, rest, privacy, and emotional connections with nature (Koprowska et al., 2020; Speer & Goldfischer, 2020). Mokos (2017), drawing on ethnographic research along the Ventura River in Southern California, argues that river-bottom encampments can function as "therapeutic landscapes" by providing privacy, a degree of safety, and restorative contact with nature, even as these same spaces are stigmatized and targeted for removal under public health and restoration rationales. These benefits may help explain why displaced residents often choose natural or interstitial spaces over sidewalks and crowded shelter systems. However, while the environmental risks and benefits of these locations have been noted, few studies have systematically analyzed whether streamside encampments are disproportionately located in environmentally burdened areas.

Waterway encampments may also experience ecosystem disservices, including pollution (Palta et al., 2016). Recent studies of waterway encampments found that the human fecal pollution load from encampments was not significant compared to the load from all human sources (Hinds et al., 2024) but also that anthropogenic sources of contamination were present in urban streams, and are potential risks if encampment residents were using river water (Verbyla et al., 2021). A recent literature review noted that, while homeless people are at the most risk of health impacts related to concurrent high heat and air pollution, research about people experiencing homelessness is still insufficient, despite the pressing human health implications (Van Tol et al., 2024). This highlights a critical research gap at the intersection of environmental exposure and homelessness.

Recent interdisciplinary scholarship has emphasized the need for greater integration across environmental governance, public health, and urban studies when examining homelessness in natural resource contexts (Land & Derrien, 2025). This study helps address that gap by analyzing the spatial relationship between urban stream encampments and pollution exposure using CalEnviroScreen data. It contributes to both the literature on the geography of homelessness and the emerging study of encampments in ecologically sensitive or hazardous areas.

Research question and hypothesis

The purpose of this study is to evaluate whether a defined set of documented urban stream—adjacent encampment sites in Santa Clara and Contra Costa counties are disproportionately located in census tracts with high cumulative pollution burdens. This study focuses on a verified set of urban stream-adjacent encampment sites in Santa Clara and Contra Costa counties, as a spatially bounded and ecologically distinct subset of homeless encampments. The analysis, therefore, evaluates whether this defined subset of stream-corridor sites is disproportionately located within high-burden census tracts relative to their spatial availability within stream-adjacent urban land. Specifically, we examine whether observed stream-corridor encampment sites are more likely to be found in census tracts that fall within the highest quartile of environmental burden scores, as defined by the State of California. These census tracts—designated as Disadvantaged Communities—are already prioritized for environmental justice funding due to their elevated pollution exposure and population vulnerability.

We hypothesize that the documented stream-corridor encampment sites are disproportionately located in these high-pollution areas, even when accounting for the limited geography of stream-adjacent urban land. A finding of disproportionate representation would be consistent with broader patterns of spatial and environmental marginalization documented in prior research, though the mechanisms producing these patterns are not directly examined here. By testing this hypothesis, we aim to clarify whether a nonrandom spatial association exists between stream-corridor encampment locations and cumulative environmental burden. This provides an empirical foundation for future research examining how governance, land use, and environmental conditions may intersect in shaping the geography of homelessness and environmental exposure.

Research methods

This study uses a geospatial electivity index to examine whether homeless encampments along urban streams in Santa Clara and Contra Costa counties are disproportionately located in census tracts with high pollution burdens, as measured by CalEnviroScreen 4.0. This analysis evaluates a defined set of verified stream-adjacent encampment sites rather than attempting to enumerate all encampments within each county. The study is designed to assess whether this specific subset of stream-corridor sites is disproportionately located in high-burden census tracts relative to their spatial availability within stream-adjacent urban land.

Data collection and analysis

Urban stream encampment locations

This analysis is limited to encampment locations in Santa Clara County and Contra Costa County. Figure 1 illustrates the study area within the context of the greater San Francisco Bay Area. Santa

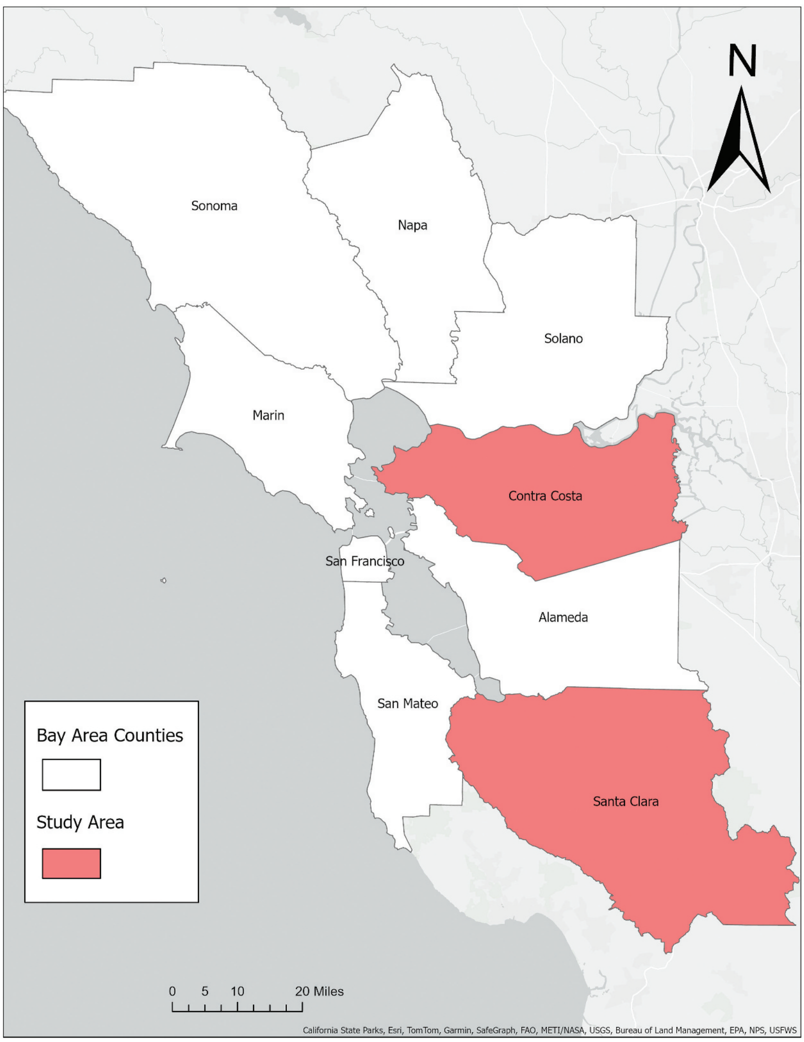

Figure 1. Map of the greater San Francisco Bay Area counties with study area counties highlighted.

Clara and Contra Costa counties were selected because project partners maintain ongoing stream stewardship, outreach, and restoration work in these areas, enabling consistent identification and verification of stream-corridor encampment sites. Both counties also contain extensive urban stream networks embedded within industrial, transportation, and mixed-use landscapes, making them suitable for examining how stream corridors intersect with cumulative environmental burden. This study prioritizes data reliability and site verification within these counties rather than attempting a region-wide census of encampments. Observed encampment locations represent documented sites during the study period and are analyzed as a cross-sectional snapshot. The analysis does not assume that encampments remained permanently fixed at these coordinates throughout the entire year, but evaluates spatial association based on verified site locations during data collection.

The focus on stream-adjacent encampments reflects a targeted research question about a recurring spatial context in which homelessness governance, environmental management, and land-use constraints intersect. This analysis is part of a broader research project examining environmental conditions and governance within urban stream corridors in the San Francisco Bay Area, and therefore concentrates specifically on encampments located within defined stream buffer zones.

Urban stream corridors represent a distinct land-use typology characterized by ecological sensitivity, jurisdictional fragmentation, limited formal development, and proximity to infrastructure networks. Prior research indicates that stream corridors and other interstitial green spaces are often locations where encampments persist following displacement from more visible urban areas and where enforcement pressures may be lower (Flanigan & Welsh, 2020; Herring, 2014). These corridors also overlap with infrastructure networks and environmentally burdened landscapes, making them a relevant setting for examining the spatial relationship between encampments and cumulative pollution burden (Palta et al., 2016). As such, this study treats stream-corridor encampments as a policy-relevant subset of sites rather than as representative of all encampments within each county.

By concentrating specifically on encampments located within defined stream buffer zones, this study isolates an ecologically bounded and policy-relevant subset of homeless encampments sites rather than attempting to represent all encampments within each county. This analytical focus enables systematic spatial comparison while maintaining conceptual clarity about the settlement typology under examination.

Overall, the research team was able to identify 17 homeless encampments along urban streams in Santa Clara County and 19 homeless encampments along urban streams in Contra Costa County (see Figures 2 and 3). The encampments were first located with the help of research partners—including local homeless service providers HomeFirst and the Bill Wilson Center in Santa Clara County and SOS Richmond in Contra Costa County, the North Santa Clara and Contra Costa Resource Conservation District (RCD), and creek cleanup and restoration groups such as Keep Coyote Creek Beautiful and South Bay Clean Creeks Coalition. All 17 encampments in Santa Clara County were visited by the research team between May 2024 and May 2025. Due to time and budgetary constraints, only 7 out of the 19 encampments in Contra Costa County were visited by the research team in June and July 2024. The exact location of the encampments used in this study were recorded by the research team during site visits. The exact location of the 12 encampments in Contra Costa County that the research team did not visit was confirmed by SOS Richmond and staff at Contra Costa RCD.

This spatial analysis is part of a larger interdisciplinary research project examining urban stream corridors and their social and ecological dynamics in the San Francisco Bay Area. The work involved in this study relies exclusively on geospatial site data and did not involve direct interaction with encampment residents for the purposes of this analysis. Location information was obtained through coordination with service providers and conservation organizations that maintain ongoing engagement with stream-adjacent encampments. Qualitative interviews with streamside encampment residents were conducted as part of the broader project under appropriate research ethics protocols and are analyzed in complementary work. Those findings are not presented here. The decision to focus this manuscript on spatial co-location patterns reflects

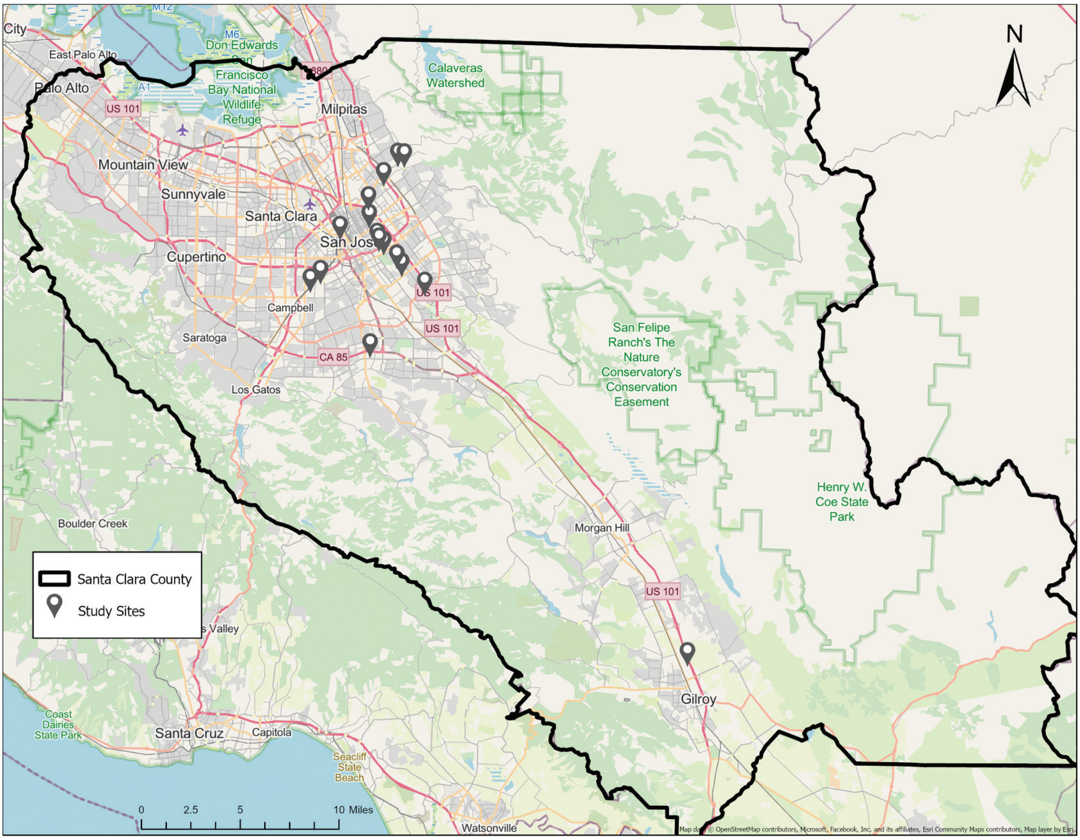

Figure 2. Map of encampment sites in Santa Clara County ($n = 17$).

a methodological choice to isolate geographic relationships between encampment sites and environmental burden measures rather than evaluate lived experience or individual decision-making.

Pollution burden data

CalEnviroScreen 4.0 is an index and mapping tool developed by the California Office of Environmental Health and Hazard Assessment to identify communities suffering from cumulative impacts of multiple pollutants. It is used to measure the combined impacts of pollution and vulnerability of a population to the effects of pollution, in every census tract in California. Pollution burden measures the direct exposure to pollutants and adverse environmental conditions caused by pollutants in a given area. Vulnerability measures the community socioeconomic factors and populations with physiological conditions that result in increased vulnerability to pollutants in a given area (California Office of Environmental Health Hazard Assessment and California Environmental Protection Agency, 2021). Every census tract receives an overall score, and then all tracts are organized into percentile rank to create a scale of relative pollution burden across the state. Data for CalEnviroScreen indicators was last updated in 2021. The percentiles have strong policy and funding implications as CA State Bill 535 (2012) directs investment of proceeds from the state's Cap-and-Trade Program to "disadvantaged communities," which are defined as census tracts ≥ 75th percentile of CalEnviroScreen 4.0 scores. Table 1 shows all data sources and analytical tools used for spatial analysis of urban stream corridors and encampment co-location.

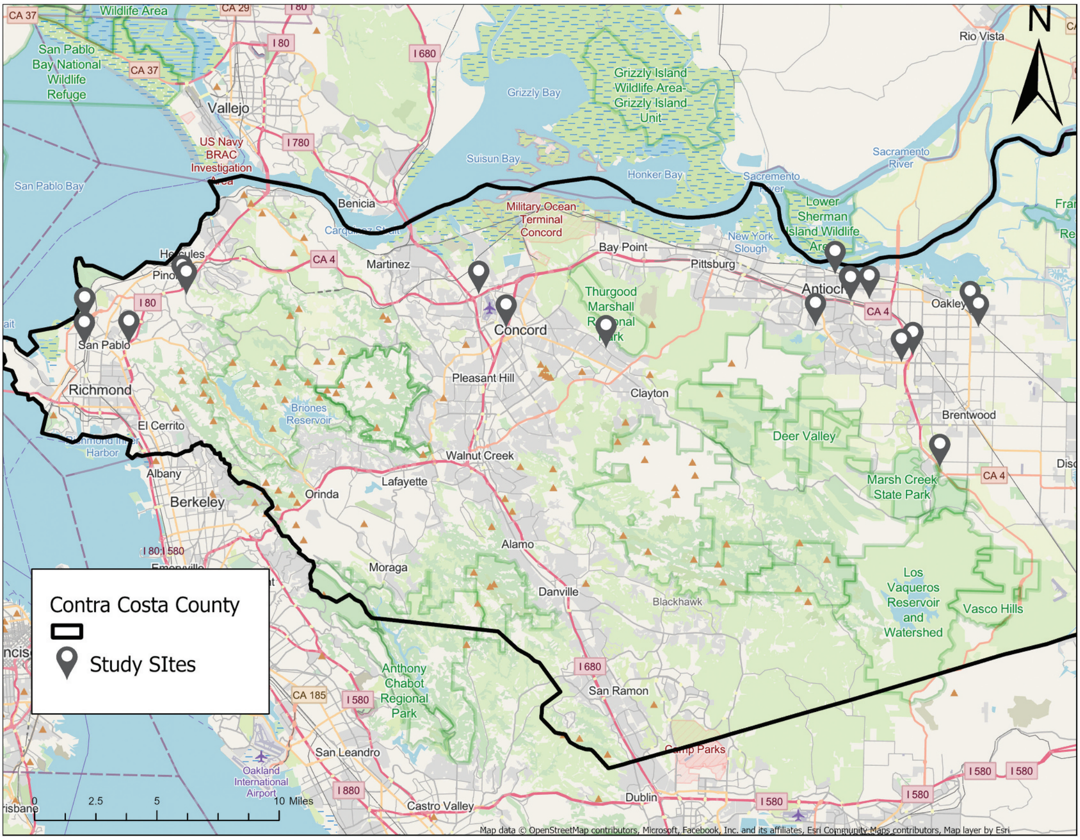

Figure 3. Map of encampment sites in Contra Costa County ($n = 19$).

Table 1. Data sources and analytical tools used for spatial analysis of urban stream corridors and encampment co-location.

Dataset / Tool	Source	Application
National Hydrography Dataset (NHD)	U.S. Geological Survey (USGS) accessed June 7, 2024.	Identified stream networks to delineate urban stream corridors and generate buffer zones
CalEnviroScreen 4.0	California Office of Environmental Health Hazard Assessment (OEHHA), accessed June 7, 2024.	Provided pollution burden scores at the census tract level for environmental classification
Encampment Location Data	Field observations by research team and nonprofit partners	Geolocated unsheltered encampments used to evaluate spatial co-location with environmental hazards
California Cities and Town Boundaries	U.S. Census Bureau 2023 MAF/TIGER via California Open Data Portal	Defined urban boundaries to constrain study area and support contextual spatial analysis
ArcGIS Pro 3.3	Esri	Conducted spatial processing, buffering, overlay analysis, and mapping
ArcPy (Python, Jupyter Notebooks)	Python library for ArcGIS automation	Automated bootstrapping workflow and electivity index calculations

Integration of CalEnviroScreen and encampment data in ArcGIS Pro

In this study an Electivity Endex (EI) was used to determine if urban stream campsite locations in two counties are significantly co-located with high-pollution census tracts based on CalEnviroScreen percentile scores. The electivity index is a use—availability ratio commonly applied in ecological and spatial analysis to evaluate whether observed site occurrences are over- or underrepresented relative to their proportional availability in the landscape (Kammel et al., 2016). An EI value of 1 indicates proportional occurrence, values greater than 1 indicate overrepresentation relative to availability, and values less than 1 indicate underrepresentation. In this study, EI allows assessment of whether encampments occur in high-pollution census tracts at rates exceeding what would be expected based solely on the relative land area of those tracts within the study region.

First, CalEnviroScreen 4.0 was selected as a standard measure of pollution burden across the state. Shapefiles are available that contain the percentile score for each census tract. The CalEnviroScreen shapefiles from (July 6, 2024) were used in ArcGIS Pro to create polygons for each census tract. Tracts ≥ 75th percentile are assigned a red color; all other tracts were assigned a gray color. This data is then clipped to the boundaries of Santa Clara County and Contra Costa County to limit analysis to the study area. The locations of urban stream encampments in Santa Clara and Contra Costa counties, as recorded by the research team and local partners, were added to a new layer in ArcGIS Pro (see Figures 2 and 3). The Spatial Join action was performed in ArcGIS Pro to join the layer of encampment locations to the layer showing CalEnviroScreen scores (see Figures 4 and 5).

ArcGIS Pro was used to count the number of encampment sites in both counties and categorize them into two classes: sites in tracts with scores at or above the 75th percentile of CalEnviroScreen scores, and sites in tracts with scores below the 75th percentile. The figures are combined to create a single dataset for the study area, shown in Table 2.

The relative availability of census tracts at or above the 75th percentile was calculated in ArcGIS Pro by dividing the total land area of tracts in each class (≥75th percentile and <75th percentile) by the

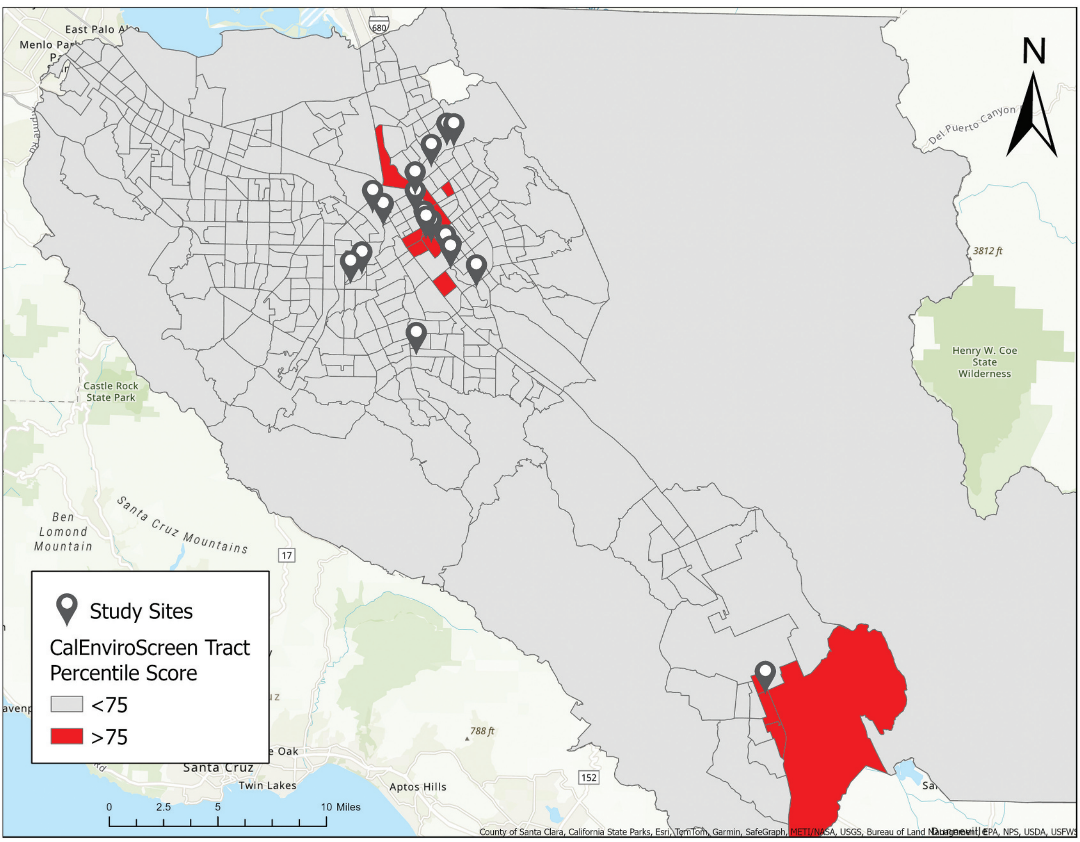

Figure 4. Map of Santa Clara County showing CalEnviroScreen census tracts percentile score by color, and location of observed urban stream encampments.

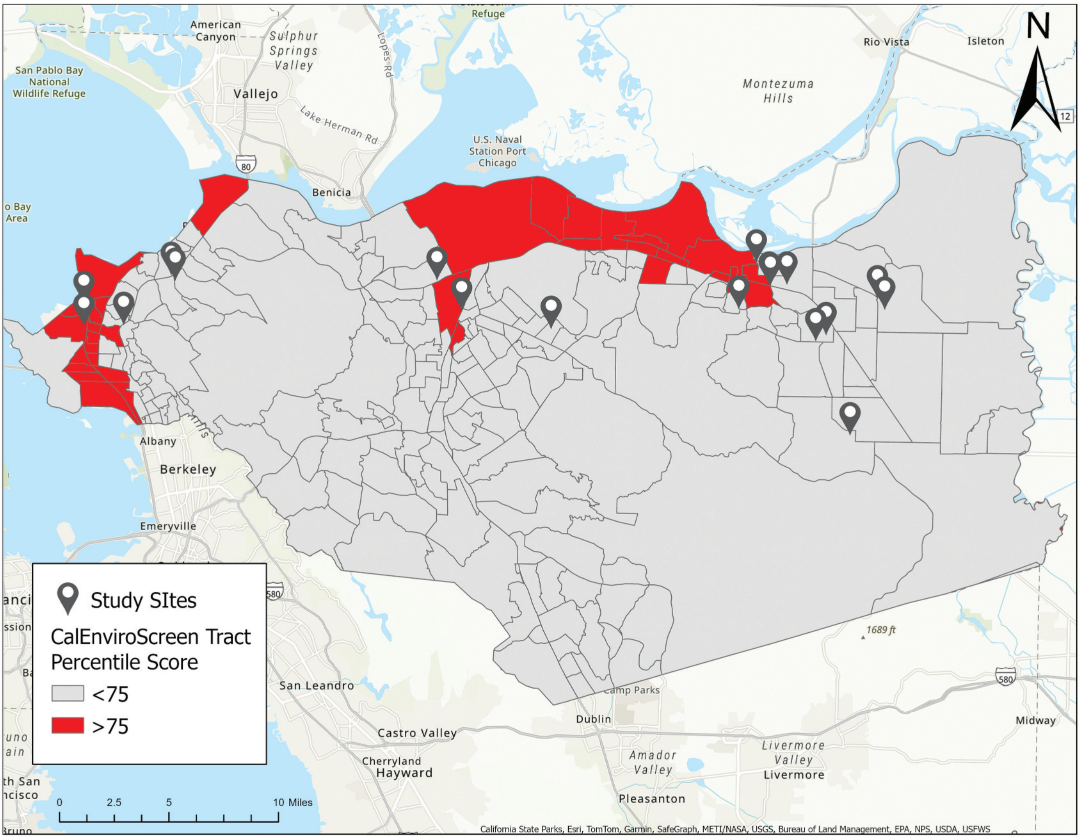

Figure 5. Map of Contra Costa County showing CalEnviroScreen census tracts percentile score by color, and location of observed urban stream encampments.

Table 2. Number of urban stream encampments observed in each CalEnviroscreen percentile class in the study area.

CalEnviroScreen Percentile Class	Observed encampments in class
Below 75th	26
≥75th percentile	10

Table 3. Electivity index values for observed encampments by CalEnviroScreen percentile class.

CalEnviroScreen Percentile	Observed encampments in class	Percent occurrence of observed encampments found in class	Percent availability of class within study area	Electivity Index
Below 75th	26	72.22	92	0.79
≥75th percentile	10	27.78	8	3.47

total land area of the study site. This yielded the "percent availability" of each class, as presented in Table 3, Column 4.

Similarly, the relative occurrence of encampments within each class was calculated by dividing the number of encampments in each percentile group by the total number of observed encampments. This produced the "percent occurrence" values shown in Table 3, Column 3.

Lastly, ArcGIS Pro is used to calculate the EI score for encampments in tracts above the 75th percentile and those below the 75th percentile, by dividing the percent occurrence of each class by the percent availability of encampments in each class, as shown in Table 3, Column 5.

Testing spatial significance

Generating bootstrapped data

To determine if the EI of the observed urban stream encampment site locations is statistically significant, a comparison set of randomly generated points was generated to calculate a "bootstrapped" standard deviation of the EI value in each class, which could then be compared to the observed values.

The location of the randomly generated sites was limited to similar urban stream locations as the observed encampments. The research team only collected location information for stream encampments in urban areas. Comparing the locations of observed encampments to the USGS National Hydrography Dataset (NHD) layer in ArcGIS Pro revealed that all were situated within 300 meters of a stream. In ArcGIS Pro the study area was cropped to census tracts defined as "urban" by the U.S. Census and the Buffer tool was used to generate a 300 m buffer around all NHD streams in those tracts. The Generate Random Points tool was then used in ArcGIS Pro to generate a random set of points within the resultant area (see Figure 6). The number of random points generated was equal to the number of observed encampments.

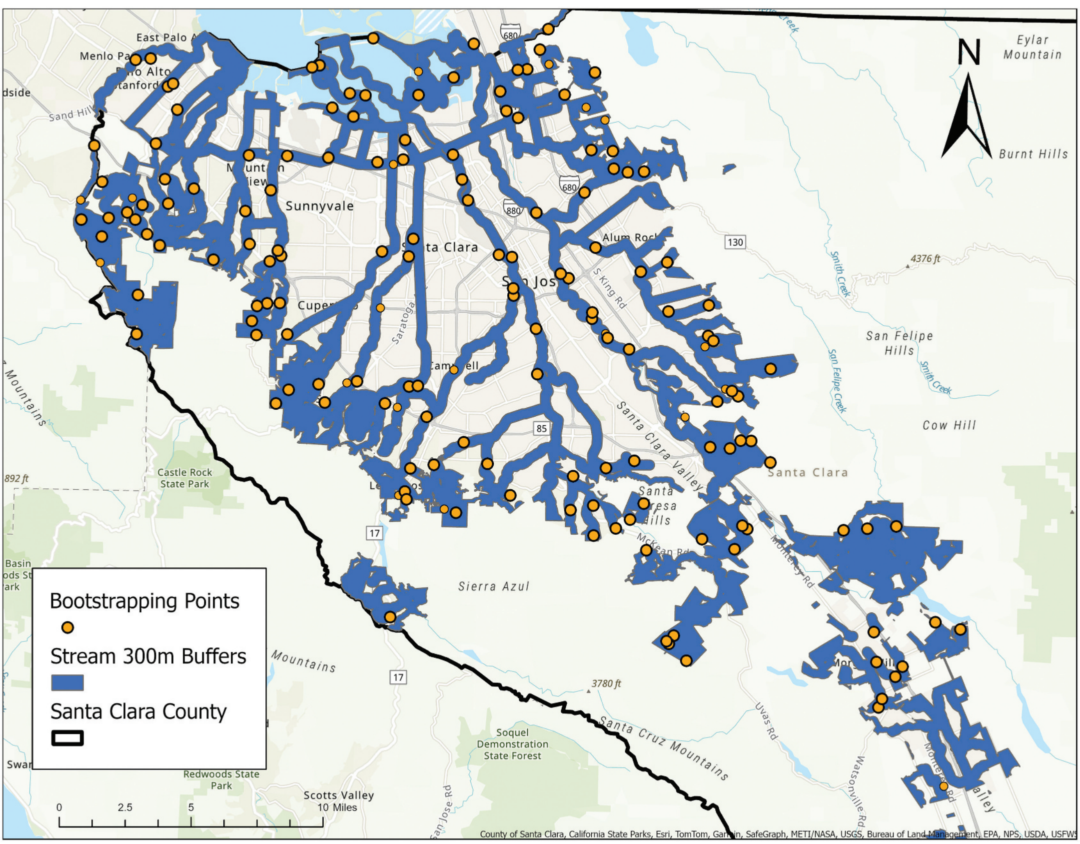

Figure 6. Detail of Santa Clara County showing the randomly generated points within stream buffers.

Table 4. Using the electivity index values from ten sets of 32 randomly generated points within the 300 m urban stream buffer area to create a bootstrapped standard deviation for each percentile group.

	Electivity index values for 10 iterations of randomly generated points										
CalEnviro-Screen Percentile	Rand. 1	Rand.2	Rand. 3	Rand.4	Rand. 5	Rand. 6	Rand.7	Rand. 8	Rand. 9	Rand. 10	SD
Below 75	0.91	1.02	0.98	1.02	0.91	1.05	0.98	0.95	0.95	1.05	0.05
75 and above	1.24	0.83	1.24	0.83	2.06	0.41	0.83	1.65	0.83	0.41	0.56
*(Null)	14.92	0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.92	2.98

*Note: The "Null" category includes census tracts that have no associated CalEnviroScreen values, typically due to being unpopulated areas.

Table 5. Comparing the observed electivity index values to the thresholds of 95% confidence for co-location and non-colocation.

CalEnviro-Screen Percentile	Standard Deviation	Co-location threshold (high)	Co-location threshold (low)	Observed Electivity Index Value	Electivity Index Residual	Significance
Below 75	0.05	1.10	0.90	0.79	−0.11	*non-colocation
75 or above	0.45	2.11	−0.11	3.47	1.36	*co-location
*(Null)	2.98	6.96	−4.96	0.000	0.00	none

*Note: The "Null" category includes census tracts that have no associated CalEnviroScreen values, typically due to being unpopulated areas.

The EI ratio calculation was performed for each CalEnviroScreen percentile group in each set of random points generated, and exported to a table in Excel. This process of generating random points and EI calculation was repeated a total of 10 times to serve as a minimum standard for statistical reasoning. In the resultant Excel table the STAD P function was used to calculate the bootstrapped standard deviation of the EI in each class (Table 4).

Bootstrapped threshold comparison for electivity index residuals

The standard deviation values created for each class from the bootstrapped data were used to create thresholds of 95% confidence that co-location is occurring above random chance, and the inverse, that nonco-location is occurring less than random chance.

These high and low thresholds were calculated for each CalEnviroscreen percentile group and included in a table, and then compared with the observed EI values (Table 5).

To assess whether encampments were disproportionately located in areas of environmental burden, we applied a 95% confidence threshold based on the distribution of EI values from bootstrapped random points. For each CalEnviroScreen percentile group, high and low thresholds were calculated as 1 plus or minus two standard deviations from the mean (i.e., $1 + 2 \times$ SD and $1 - 2 \times$ SD, respectively), representing the bounds within which co-location would be expected by chance. These thresholds are reported in Table 5 and were compared to the observed EI values for encampments.

For each environmental burden class, a residual was calculated to indicate the degree of over- or under-representation. If the observed EI exceeded the upper threshold, the class was considered significantly overrepresented, and the residual was computed as:

$$Residual = EI_{observed} + (1 + 2\sigma)$$

If the observed EI fell below the lower threshold, the class was considered significantly underrepresented, and the residual was computed as:

$$Residual = EI_{observed} - (1 - 2\sigma)$$

If the observed EI fell between these thresholds, it was considered not significantly different from random, and the residual was set to zero.

If the residual is a positive value, it shows statistically significant co-location or non-colocation of encampments with that class. If the residual is less than zero, then it takes a value of zero.

Findings

Figures 4 and 5 and Table 3 show that highly polluted census tracts represent a very small land area within each county. Despite the low availability of these areas, the maps and table show that they are a common location for urban stream encampments. Indeed, 28% of the observed encampments were in disadvantaged community census tracts, even though these make up only 8% of the study site area.

If the location of encampments were randomly distributed across the entire study area, we would expect the percentage of sites to match the percentage availability of each class, leading to an EI ratio of approximately 1:1, or a value close to zero.

A high EI value means that encampments tend to co-locate with that class, despite its limited availability within the study site. The inverse is also true: when classes have a low EI value, there is a lower percentage of the overall occurrence of encampment sites in that class, even though that class is widely available within the study area.

Table 4 shows non-zero electivity indices in both disadvantaged community census tracts, and in the lower-scoring census tracts. The data show a tendency for encampments to co-locate with census tracts that have a high pollution burden, despite their relative scarcity. It also shows that for tracts below the 75th percentile, there is a tendency for encampments *not to* co-locate with those areas, despite their relative abundance.

Table 5 shows that the co-location of observed encampment locations in Santa Clara and Contra Costa counties with census tracts with CalEnviroScreen 4.0 scores in the 75th and above percentile range (i.e., high pollution tracts) was statistically significant. It also shows that the non-collocation of observed encampment locations in Santa Clara and Contra Costa counties with census tracts with scores below the 75th percentile (i.e., low-pollution tracts) was statistically significant. The EI result of 3.47 for high-pollution tracts significantly exceeds the ±1 standard deviation threshold, resulting in a final residual of 1.36. This indicates a clear and statistically meaningful overrepresentation of encampments in high-pollution areas, reinforcing the hypothesis that their spatial distribution is statistically nonrandom with respect to environmental burden classifications. Conversely, the final residual for low-pollution tracts was −0.11, reflecting a slight but consistent underrepresentation of encampments in these areas relative to their availability. Together, these values demonstrate a statistically asymmetrical distribution of encampments across pollution burden classes within the study area.

This analysis reveals a statistically significant relationship between the locations of urban stream encampments and environmental pollution burdens in Santa Clara and Contra Costa counties. Using CalEnviroScreen 4.0, we found that observed stream-corridor encampments in the study area are disproportionately located in census tracts within the top 25% of pollution and vulnerability scores—areas already identified by the state as environmentally disadvantaged. These high-scoring tracts represent a relatively small portion of the study area, yet account for a disproportionately large share of observed encampment sites.

Conversely, encampments are significantly underrepresented in census tracts below the 75th percentile, which make up the majority of land in both counties. This pattern of over- and under-representation was confirmed through an EI analysis and bootstrapped comparisons with randomly generated site data, indicating that the observed spatial distribution is unlikely to be due to chance. The consistent underrepresentation in lower-pollution tracts indicates that encampment locations are not distributed in proportion to land availability across pollution classes. These patterns demonstrate a statistically disproportionate spatial association between stream-corridor encampments and census tracts classified as having elevated cumulative environmental burden.

These findings support the hypothesis that documented stream-corridor encampments are disproportionately located in census tracts with elevated cumulative environmental burdens. While urban streams may offer shade, privacy, and relative leniency from law enforcement, their co-location with environmental hazards raises critical concerns about cumulative disadvantages and the spatial expression of environmental injustice. Although the analysis does not identify the mechanisms producing this distribution, it demonstrates that stream-adjacent encampments are not randomly distributed across the landscape and are disproportionately concentrated in areas already characterized by high pollution burdens and population vulnerability. These findings provide an empirical foundation for future research examining the social, environmental, and governance processes that may contribute to this pattern.

Discussion

This study identifies a statistically significant spatial association between documented urban stream—adjacent encampment sites and census tracts with high cumulative pollution burdens and elevated population vulnerability indicators. Encampment sites are disproportionately located in the highest-scoring CalEnviroScreen tracts within Contra Costa and Santa Clara counties, even though those tracts constitute a relatively small share of total land area. Conversely, encampments are comparatively rare in lower-scoring tracts that comprise a larger portion of the counties' geography.

These results indicate a pattern of spatial concentration in environmentally burdened areas rather than proportional distribution across the landscape. While this pattern is consistent with prior research on spatial marginalization, the present analysis does not identify the mechanisms producing this distribution, including potential roles of enforcement practices, land-use constraints, regulatory environments, or settlement dynamics (Darrah-Okike et al., 2018; Herring, 2014; Robinson, 2019).

These findings contribute to broader discussions in urban policy and planning scholarship on the governance of marginalized urban spaces and the production of spatial inequality. The concentration of encampments in environmentally hazardous stream corridors reflects not only physical displacement but also a form of regulatory marginalization, wherein urban policies—such as anti-camping ordinances, cleanup operations, and redevelopment pressures—systematically push homeless populations into less visible, less regulated, and more ecologically vulnerable areas, such as riparian floodplains and infrastructure-adjacent landscapes characterized by elevated pollution burdens and environmental hazard exposure (Goodling, 2020; Palta et al., 2016). This dynamic parallels scholarship on spatial marginality and informal settlement regulation, where state action (or inaction) both constrains and defines where vulnerable groups can exist in the urban fabric (Gibson, 2019; Goodling, 2020). Importantly, the absence of coordinated land use, environmental, and homelessness planning responses exacerbates these conditions. Environmental justice research has documented how environmental harms are unevenly distributed across marginalized communities and shaped by political and regulatory decisions (Pellow, 2025). In this context, environmental injustice refers not only to where pollution is located, but also to the institutional processes that influence who is exposed to it. Viewing stream encampments through this lens allows us to examine whether spatial patterns of homelessness intersect with existing patterns of environmental burden. Thus, beyond highlighting environmental injustice, the findings point to governance gaps—where fragmented institutional responsibility and weak interagency coordination perpetuate cycles of displacement and exposure. Addressing these challenges requires an integrated governance approach that accounts for both environmental risk and the basic rights of homeless residents to safe, stable shelter.

Literature-based explanations for structural and environmental factors potentially shaping encampment geography and directions for future research

The present study identifies a statistically significant spatial association between stream-corridor encampments and environmentally burdened census tracts but does not identify the mechanisms producing this pattern. Prior research suggests several plausible processes that may influence encampment geography, including enforcement practices, land-use constraints, service accessibility, environmental amenities, and individual decision-making. The discussion below is intended to highlight potential explanations documented in the literature and to identify priorities for future research rather than to explain the observed pattern in the present study.

While this study cannot determine the decision-making processes that shape encampment location, research on this topic suggests several structural dynamics that may contribute to these observed patterns. The literature suggests that there are a mix of "push" and "pull" factors that could cause encampments to form along urban streams. Encampments may form in urban streams because they are far enough away from law enforcement to be tolerated, close enough to basic resources for residents, and offer some positive ecosystem services (Darrah-Okike et al., 2018; Mayer et al., 2024; Robinson, 2019; Turner et al., 2018). Enforcement pressure and anti-camping laws can effectively push homeless individuals away from more visible, central locations—such as downtowns and residential neighborhoods—into urban stream spaces where enforcement is lighter and visibility is lower. These spaces often coincide with polluting infrastructure, including industrial zones, freeways, railroads, and waste facilities.

Encampment sweeps, interactions with law enforcement, and home and business owners harassing or reporting people experiencing homelessness in central business districts and residential areas are a major deterrent for encampments (Goldshear et al., 2023). This may have the effect of pushing homeless community members away from residential and business areas to the same edge places where cities already tolerate undesirable, polluting, or other "nuisance" land uses, such as industrial zones, sanitation and wastewater facilities, and transportation infrastructure. The literature shows that encampments are correlated with areas that provide basic needs, so even within these edge areas, encampments are likely to form within reasonable travel distance to resources like basic needs, public transit, jobs, and services (Chamard, 2015).

At the same time, urban green spaces—especially urban stream corridors—offer tangible benefits such as privacy, proximity to nature, and access to shade and water. In studies, encampment residents cited their preference for living in nature, and the benefits of shade and privacy as reasons for living in waterways and urban green spaces (Flanigan & Welsh, 2020; Koprowska et al., 2020; Palta et al., 2016; Speer & Goldfischer, 2020). Many people experiencing homelessness express fear of the shelter system or find its lack of privacy and restrictions on lifestyle inadequate for their or their family's needs, and choose to live outside instead (Hepler, 2025). Thus, streamside encampments may simultaneously reflect displacement and strategic choices within severely constrained options.

While the present study demonstrates a statistically significant spatial association between stream-corridor encampments and environmentally burdened census tracts, future research is needed to identify the mechanisms underlying this pattern. Longitudinal analyses could examine how encampment locations shift in response to policy and enforcement changes, while comparative studies across different encampment types could assess whether exposure to environmental burdens varies by settlement context. Qualitative research with encampment residents could further explore how environmental conditions, service accessibility, safety concerns, and governance practices influence location decisions. Such work would help clarify the processes that shape encampment geography and environmental exposure.

Implications for environmental justice policy and urban planning

The concentration of encampments in areas with high CalEnviroScreen scores raises public health concerns. CalEnviroScreen pollution exposures include high concentrations of ozone and PM2.5, diesel emissions, drinking water contamination, pesticide use, toxic releases from facilities, and traffic impacts. Many people experiencing homelessness have underlying health conditions that make them at risk for the effects of extreme heat and air pollution, and living unsheltered can compound exposures (Van Tol et al., 2024).

CalEnviroScreen also measures adverse environmental conditions caused by pollution from toxic cleanup sites, groundwater threats, hazardous waste facilities, impaired waterways, and solid waste sites and facilities. Further research is needed to understand the role of encampments as a source of pollution and their potential contribution to the CalEnviroScreen indices. Some local water agencies attribute the majority of trash and debris in urban streams to encampment discharges (Santa Clara Valley Water District, n.d.), but more data is needed to disaggregate between illegal dumping and encampment-generated waste. Recent literature has established that waterway encampments are not significant contributors to anthropogenic sources of contamination in urban streams; however, residents using river water may be at risk (Hinds et al., 2024).

The findings indicate that encampments are disproportionately represented in the highest percentile CalEnviroScreen tracts. At the same time, homeless people are likely not captured in CalEnviroScreen's population characteristics. The socioeconomic factors used as indicators of increased vulnerability to pollutants in CalEnviroScreen 4.0 include educational attainment, housing-burdened low-income households, linguistic isolation, poverty, and unemployment (California Office of Environmental Health Hazard Assessment and California Environmental Protection Agency, 2021, p. 20).

The pollution effects of encampments are also not currently captured in CalEnviroScreen. Indicators that cause adverse environmental effects include toxic cleanup sites, groundwater threats from leaking underground storage sites and cleanups, hazardous waste facilities and generators, impaired water bodies, and solid waste sites and facilities (California Office of Environmental Health Hazard Assessment & California Environmental Protection Agency, 2021, p. 19). It also uses contamination levels of drinking water as an indicator of pollution exposure (California Office of Environmental Health Hazard Assessment & California Environmental Protection Agency, 2021, p. 54).

The academic literature has established that homeless populations are among the most environmentally vulnerable populations (Bezgrebelna et al., 2021). In this way, homelessness may meet CalEnviroScreen's selection criteria for Socioeconomic Factor Indicators, as it is a "widespread concern" related to population characteristics, and one "known to modify vulnerability to impacts of pollution" (California Office of Environmental Health Hazard Assessment and California Environmental Protection Agency 2021, 17–18), though it may be challenging to find reliable data on homelessness at the census tract level. The role of urban stream encampments in contributing to trash and pollution remains a topic of debate among policymakers and scholars, and likely more research is needed to establish its effects before it could be included as an indicator in CalEnviroScreen.

Given the funding implications of CalEnviroScreen scores, these findings raise questions about how homeless populations are accounted for in cumulative vulnerability assessments. This analysis evaluates the spatial distribution of documented stream-adjacent encampment sites rather than the number of individuals residing within them. Because encampment population sizes vary and were not systematically enumerated for this study, the results do not establish the total number of homeless individuals residing in high-scoring census tracts. However, local Point-in-Time (PIT) estimates indicate that both counties have several thousand homeless residents annually, suggesting that stream-adjacent sites represent a nontrivial component of broader regional homelessness.

As CalEnviroScreen plays a central role in guiding California's environmental justice investments, future iterations of the tool could consider whether and how highly mobile or homeless populations are incorporated into cumulative vulnerability metrics. Incorporating indicators that better reflect the geography of homeless encampments—while methodologically challenging—may improve the tool's responsiveness to populations experiencing environmental exposure outside conventional residential housing classifications.

These findings reinforce the need to treat homelessness as not only a housing and social services crisis but also an environmental justice issue. Homeless individuals are disproportionately burdened by cumulative spatial disadvantages: exclusion from central urban spaces, limited access to services, and exposure to hazardous environmental conditions.

This has significant implications for state and local policy. As California channels climate and environmental justice funding through tools like CalEnviroScreen and the CalEPA EJ Action Grants Program, recognizing the environmental exposures faced by homeless populations becomes essential for equitable resource allocation. Urban planners and public health officials must also coordinate across sectors to ensure that responses to homelessness do not inadvertently deepen spatial and environmental inequalities.

Furthermore, this study provides a replicable methodology for examining the intersection of environmental injustice and homelessness in other metropolitan regions. By combining geospatial analysis with indices like CalEnviroScreen, researchers and planners can better understand how policy, land use, and enforcement practices shape the environmental conditions of homeless community members. To further support decision-making, local agencies could integrate environmental risk assessments into encampment response strategies, prioritizing pollution mitigation near high-risk zones, and incorporating stream health into cost-benefit analyses for policies to address homelessness. The use of spatial tools such as spatial analysis can guide resource allocation by identifying areas where homeless populations face disproportionate environmental burdens. While this study is observational and does not establish causation, the consistent spatial associations underscore the need for interdisciplinary planning approaches that account for both social vulnerability and environmental health. Future research integrating qualitative interviews and lived-experience data would be necessary to evaluate the relative roles of agency, structural constraint, and environmental preference in shaping encampment geography.

Conclusions

This study contributes to the growing literature on the spatial dynamics of homelessness and environmental justice by demonstrating a statistically significant relationship between urban stream encampment locations and census tracts with high pollution burdens in the San Francisco Bay Area. Using an electivity index and bootstrapped spatial analysis, we find that encampments in Santa Clara and Contra Costa counties are significantly overrepresented in the top 25% of CalEnviroScreen pollution and vulnerability scores and significantly underrepresented in less polluted areas.

These findings suggest that residents of the observed encampments are disproportionately located in urban areas with good access to jobs and amenities but are also disproportionately exposed to environmental hazards—such as poor air quality, proximity to toxic sites, and impaired waterways. These are areas already burdened by polluting land uses and historically underserved by public health infrastructure. The results underscore that homelessness is not only a housing and public safety issue but also an environmental justice concern, wherein homeless residents are pushed into geographies of cumulative disadvantage.

The role of urban stream encampments in contributing to trash and pollution remains a topic of debate among policymakers and scholars. While homeless residents are often blamed for environmental degradation at these sites, this study offers a more nuanced perspective. Encampments are already disproportionately located in areas with high pollution burdens, making them recipients of environmental harm rather than primary sources. Moreover, the visibility of encampments may attract illegal dumping by individuals unaffiliated with them, further exacerbating pollution in these areas (Zimmer, 2025).

This spatial pattern of environmental marginalization has urgent policy relevance. As California and other jurisdictions expand investments in environmental justice, climate resilience, and homelessness interventions, the co-location of homeless populations in high-pollution areas should inform both the allocation of resources and the design of cross-sectoral responses. The methodology used here can also be applied in other metropolitan regions to identify where homelessness and environmental burden intersect, providing planners and policymakers with a framework for incorporating environmental exposure considerations into homelessness, public health, and environmental justice planning.

This study has several limitations due to the transient nature of encampments. The research team relied on local outreach groups to provide information on encampment locations, so some smaller or less visible camps may have been missed. Additionally, some of the encampment locations included in this study have since been abated and have likely shifted to other sites due to recent efforts on the part of local officials to clear homeless encampments (Contra Costa Health, 2024; Walker, 2025) following the Supreme Court's *Grants Pass v. Johnson* ruling and a subsequent executive order from Governor Newsom. Increased enforcement, including the establishment of No Encampment Zones, has resulted in rapid displacement and relocation. As a result, the analyzed encampment locations represent a snapshot in time and may not fully reflect longer-term patterns, thereby limiting the generalizability of the findings. While this study employs randomized null models and bootstrapped comparisons to demonstrate systematic differences between observed encampment locations and chance expectations, the analysis remains observational in nature. The patterns we identify should therefore be understood as evidence of consistent, nonrandom spatial associations rather than causal relationships. These associations nonetheless have clear implications for policy: they suggest that enforcement practices, zoning, and land use decisions constrain the geography of homeless residents, funneling them into environmentally hazardous spaces. Further research is needed to examine how evolving legal and enforcement landscapes shape the spatial distribution, environmental exposure, and transit accessibility of homeless populations over time.

Additionally, because the study focuses exclusively on stream-adjacent encampments, the findings cannot be generalized to all encampment typologies within the counties. Comparative analysis across different settlement forms would be necessary to determine whether pollution burden exposure differs by encampment type.

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