


# Rats and the COVID-19 pandemic: considering the influence of social distancing on a global commensal pest

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## Abstract

Rats contaminate foods and spread pathogens. Thus, changes in rat populations have consequences for society, especially in densely-populated cities. Following widespread social distancing and lockdown measures to curtail SARS-CoV-2, worldwide media outlets reported increased sightings of rats. To document possible changes in rat populations, we: (i) examined public service requests in the 6 years before, and during, 'lockdown' in New York City; (ii) used spatial analyses to identify calls in proximity to food service establishments (FSE); and (iii) surveyed pest-management companies. Over 6 years prior to the pandemic, we found a consistent moderate spatial association ( $r = 0.35$ ) between FSE and rat-related calls. During the early stages of the pandemic, the association between rat reports and food services did not decrease as would be expected by restaurant closures, but instead modestly increased ( $r = 0.45$ ). There was a 29.5% decrease in rat reports, overall. However, hotspot analysis showed that new reports were highly localized, yet absent in several industrial areas they were previously observed in, potentially masking a higher proportion of calls in neighborhoods near closed restaurants. Additionally, 37% of pest management companies surveyed reported that, unlike previous years, 50–100% of requests were from new clients and addresses. The finding that hotspots remained nearby dense clusters of restaurants does not support the common narrative that rats moved long distances. Rather, our results are consistent with rats finding nearby alternative food resources. Tracking these dynamics as the COVID-19 pandemic abates will be an important step to identifying how rats respond to society returning to normal activity patterns.

**Key words:** COVID-19, pandemic, rodent emergence, rodent surveillance, food service establishments, urban hygiene

## Introduction

Every year, commensal rats cost billions of dollars to society in the form of contaminated foods, the spread of disease-causing pathogens, infrastructure damage and fires from electrical short-circuits caused by gnawing (Pimentel et al. 2005). Thus, any changes in rat populations have consequences for human society, particularly in densely populated cities. One change to rat populations may have occurred during the early months of 2020, following social distancing and lockdown measures enacted to curtail the spread of SARS-CoV-2. We will define social distancing measures in the broadest sense, to include all business and event closures intended to keep people at a safe distance from one another. During this period, widespread reports from the media (Bedoya-Pérez et al. 2021) and pest management authorities (Harbison 2020) suggested increased sightings of rats. These reports included aggressive behaviors during daylight hours, and in close proximity to people (Harbison 2020; Sieg 2020). Additionally, less commonly observed behaviors such as lethal competition between rats (e.g. muricide) and cannibalism were routinely reported (CDC 2020).

While there few viable mechanisms to track changes in urban rat populations (Bedoya-Pérez et al. 2021), theoretically, any broad changes in human behavior could influence rats. As commensal organisms, rats adapt to human habits and circadian rhythms (Russell and Singer 1983; Stryjek et al. 2013). Even rats' taste preferences may reflect human food that is locally available and abundant (Parsons et al. 2019). Rats also form their burrows within, or near, human infrastructure where consistent food supplies are available (Himsworth et al. 2013). Examples include public parks, playgrounds and rubbish collection sites, where human wastes are consistently available. Dumpsters near restaurants and other food service establishments (FSE) are particularly important because they provide a year-round supply of food waste items (Bobby Corrigan, Department of Health and Mental Hygiene, NYC, pers. comm.) Once rats have found sufficient harborage, they may travel < 100 m from their burrows for the remainder of their lives (Byers et al. 2019a).

Thus, when social distancing measures led to the closures of businesses and changes in time spent outdoors in communal environments (e.g. municipal parks, outdoor theatres, sports venues), then commensal rats would have been forced to adapt to our new schedules. Some of the most overt changes by people that could affect rats include a sharp decrease in food produced by restaurants, and concomitant increases in food and trash produced from people cooking from home. Working and eating from home, in turn, could cause the production and storage of food wastes to be less centralized in respect to FSE. Other changes in human behavior that could impact rats included the purchase of an unprecedented number of pets (Vincent et al. 2020). Rats are highly attracted to homes with pets because pet food is highly aromatic and arousing to rats, and because pet wastes contain essential nutrients (Lambropoulos et al. 1999).

The stark contrast between the loss of food sources from FSEs and an increase in food sources from nearby residences could result in rats being seen more often in public, as well as facilitate increased competition between rats in public spaces (Peterson et al. 2020). We also acknowledge that changes in human behavior (being indoors working or outside away from work) can limit the amount of inference we can make about reported sightings of rats (for a full consideration of this aspect, see Parsons et al. 2020). However, despite the costs and risks of

rats to society, most cities do not have any direct forms of surveillance programs to detect changes in rats (Parsons et al. 2015; Byers et al. 2017; Desvars-Larrive et al. 2018). Additionally, there are no means to determine spatial risks of rodent-borne disease where abatement programs should be concentrated (Himsworth et al. 2013; Richardson et al. 2017). In order to document these occurrences, and mitigate risks, we must rely on indirect measures of rat activity such as public service calls (Murray et al. 2018) and requests to pest management authorities (Strand et al. 2019).

Therefore, in this preliminary study, we chose to first document any background association between rats and areas with a high density of FSEs. We then examined any changes in the association of rats and FSE during the early stages of the lockdown. If rats were moving long distances away from their typical FSE food resources because of COVID lockdowns, as had often been suggested by the media (e.g. rats move from the city to suburbs (Mannix 2020; Parsons 2020), then any putative association should subside as sightings decreased near restaurants and increased in areas with a lower density of FSEs. Additionally, pandemics are similar to other natural disasters in that they cause widespread social change including a higher mortality and loss of income. One of the principal research problems associated with natural disasters is the lack of studies in the early stages (Rael et al. 2018; Peterson et al. 2020). Thus, we focused on the initial period (March, April) of the pandemic because there is a need to understand the influence of natural disasters on rat populations in the early stages so that: (i) rat eradication programs can be better informed (Shiels et al. 2020) and (ii) to help fill a necessary research gap, because most studies on natural disaster occur years after an event (Rael et al. 2018; Peterson et al. 2020).

Given the abundance of data available, including the location of FSEs throughout New York City (NYC), we looked for observable shifts in public service reports (e.g. 311 calls), and any known spatial 'hotspots' of these reports, and if there is any signal of seasonality for these hotspots. Finally, while calls to 311 are free to report, calls reported to pest-management companies convey an added sense of urgency as they carry a monetary expense (Strand et al. 2019). Therefore, we also adapted the approach of (Strand et al. 2019), and utilized national pest control authorities. These agencies [the national pest management association of Fairfax, Virginia and the Canadian Pest Management Association (CPMA)] were already generating some of the reports to the media and the CDC, and had purview over most of the private pest control companies. We asked these pest management authorities to broadly distribute surveys to their front-line workers, as these professionals have direct knowledge of infestations and local rat populations.

## Methods

We analyzed public service requests (311 calls) from NYC Open Data (<https://opendata.cityofnewyork.us/>) on 3 May 2020 for the observation period beginning 1 January 2014 and ending 30 April 2020, inclusive of the lockdown phase which began on 23 March 2020. NYC was considered an appropriate region for analysis due to the high human population density, and the availability of robust, regularly updated and easily accessible reporting data. Reports to 311 are made when people file a complaint through phone, website or smartphone app. The selected

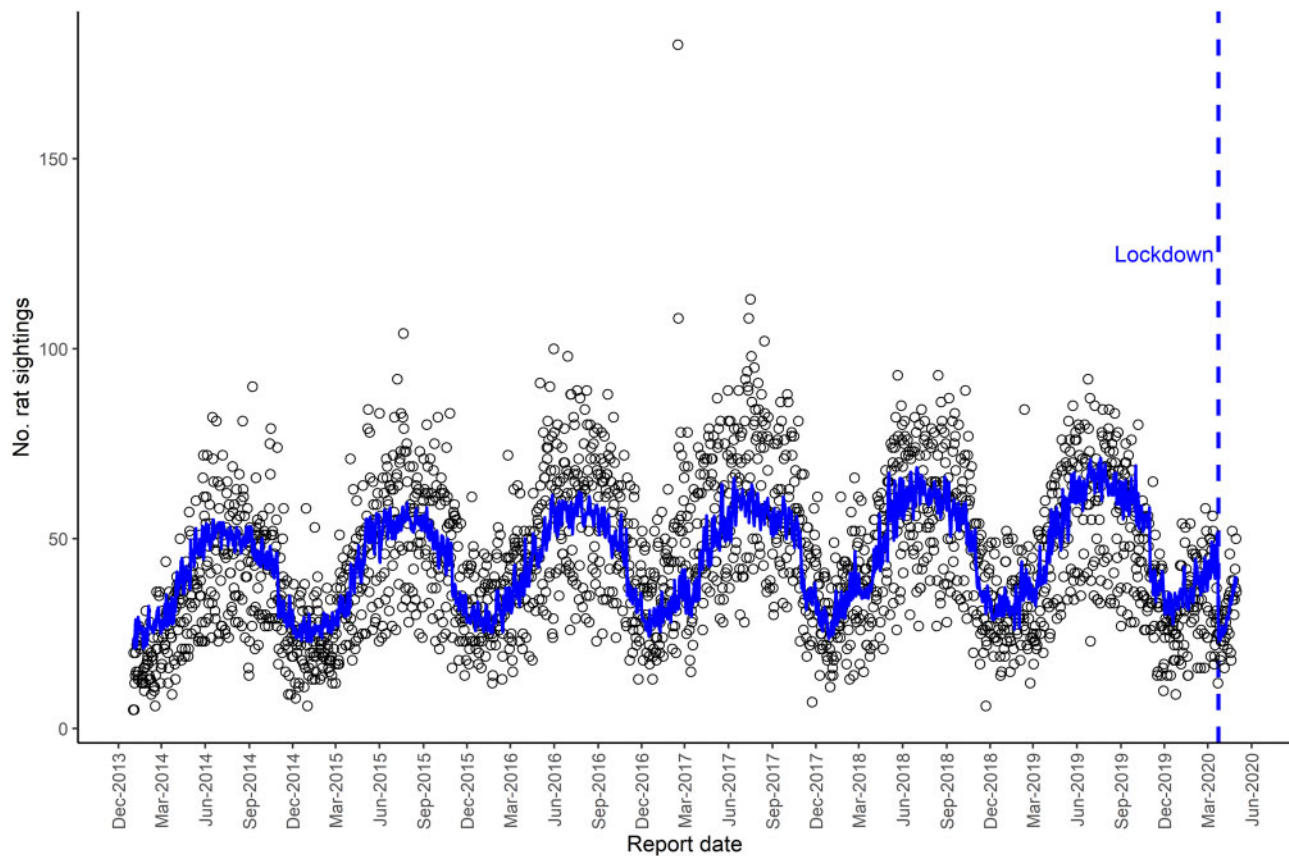


Figure 1: Distribution of daily rat sightings (open circle) during the observation period (1 January 2014 to 30 April 2020) overlaid with the model estimates from the Poisson regression (blue line). The vertical blue line shows the date of lockdown, 23 March 2020

time interval was chosen because it allows a before-and-after treatment analysis to be considered alongside annual seasonal changes. Rodent-related 311 calls are classified into five categories: signs of rodents, conditions attracting rodents, rat sighting, mouse sighting and rodent bites. For this study, we limited our analysis to the 'rat sighting' category.

Pest control interventions offer a means to determine relative prevalence of rats (Strand et al. 2019). Thus, we created a survey with the help of industry professionals. The survey covered at least a 30-day period from lockdown to post-lockdown. Three primary questions were posed: (i) whether there had been changes in overall rat-related calls from customers; (ii) what proportion of post-lockdown customers were new customers (which may account for customers in new residences, or areas, not previously infested); and (iii) whether the number of new customers was different from the number of new customers during the same period the previous year. Respondents were not required to disclose personally identifiable information.

The survey was distributed through pest control channels Canadian Pest Control Association (CPCA) in Canada on 5 May 2020 and the USA via Pest Control Magazine (Harbison 2020). We also distributed to pest management professionals as well as via social media through Twitter and LinkedIn.

## Statistics

### 311 calls

We used R (R Core Team 2020) to perform the generalized linear model analysis with a Poisson distribution to model the number

of rat sightings, and ggplot2 (Wickham 2016) to plot the distribution of daily rat sightings and Poisson regression estimates against the report date. We used Poisson regression to assess the association between daily rat sightings before and after the lockdown phase. The lockdown phase was included in the model by using a binary indicator with a value of 0 for dates before the lockdown (1 January 2014 to 22 March 2020) and 1 for dates after the lockdown (23 March 2020 to 30 April 2020). We expressed the results as adjusted relative rates (aRR) and corresponding 95% confidence intervals. The aRR has a non-negative distribution where  $aRR > 1$  indicates a positive association,  $aRR < 1$  indicates a negative association and  $aRR = 1$  indicates no association. We then used descriptive statistics to report the survey findings.

### Spatial analysis

To investigate changes in the spatial distribution of rats in NYC over the study period, we mapped 311 rat calls in GIS and applied hot spot analyses. Both ArcMap 10.6 (ESRI, 2011) and QGIS 3.10 (QGIS Development Team, 2011) were used for these analyses. We first divided 311 calls from NYC by month and year and imported these as separate data layers in GIS. We then conducted an optimized hot spot analysis in ArcMap using the Mapping Clusters toolbox. This analysis evaluates areas with more or fewer point occurrences than expected at random, and applies a Getis-Ord  $G_i^*$  statistic to assess significant deviations from a random distribution. We used the NYC borough outline as the bounding polygon for this analysis, and a fishnet pattern was used to generate sampling polygons across the study area,

**Table 1:** Adjusted Poisson regression with adjusted relative risk (aRR) of daily rat sightings

Variables	aRR	Robust SE	95% CI	P-values
Intercept	2.97	0.53	2.10–4.21	<0.001
Calendar date	1.00	0.00001	1.00–1.00	<0.001
Lockdown phase	0.69	0.09	0.54–0.89	<0.001
Days since lockdown	1.02	0.004	1.01–1.02	<0.001
Max. temperature (°C)	1.01	0.001	1.01–1.02	<0.001
Calendar month				
January	1 (ref)			
February	1.11	0.05	1.02–1.21	0.012
March	1.12	0.04	1.04–1.20	0.002
April	1.30	0.05	1.20–1.40	<0.001
May	1.42	0.06	1.31–1.55	<0.001
June	1.43	0.06	1.31–1.56	<0.001
July	1.39	0.07	1.26–1.53	<0.001
August	1.36	0.07	1.23–1.49	<0.001
September	1.34	0.06	1.23–1.46	<0.001
October	1.36	0.05	1.26–1.47	<0.001
November	1.04	0.04	0.97–1.13	0.255
December	0.93	0.03	0.86–0.99	0.026
Lockdown × max. temperature	0.98	0.009	0.96–0.99	0.023
Lockdown × April	0.79	0.09	0.63–0.99	0.041

as recommended for this tool. Finally, we created kernel density raster layers of both the FSE (using NYC Open Data on inspections) and rat 311 calls by month, and used the Band Collection Statistics toolbox to calculate correlation coefficients between each raster dataset. To visualize changes in rat activity through space and time, we generated a time series of 311 rat calls in QGIS by creating a heatmap and working within the Time Manager plugin.

## Results

### 311 calls

Daily rat sightings in NYC follow a seasonal pattern (Fig. 1) and was significantly associated with maximum daily temperature (aRR: 1.01; 95% CI: 1.01–1.02) (Table 1). This indicates that for every 1°C increase in temperature, the rate ratio of rat sightings would be expected to increase by a factor of 1.01. The interaction terms with the lockdown phase indicator and calendar month shows that the relative rate of rat sightings in the month of April during the lockdown was significantly lower compared with prior years (aRR: 0.79; 95% CI: 0.63–0.99). Although the relative rate of rat sightings in April 2020 was significantly lower compared with the same month in prior years, there was a significant increase in relative rates of rat sightings for each additional day since the lockdown (aRR: 1.02; 95% CI: 1.01–1.02).

### Spatial relationship with FSE

There was a positive correlation between the kernel density estimates of FSE and location of 311 calls in all of the months assessed (Table 2; Fig. 2). The spatial association between FSE and location of rat-related 311 reports actually increased between the pre- and post-lockdown periods ( $r$  of 0.35–0.36 during January/February 2020 compared with 0.44–0.45 during March/April 2020). Additionally, the Getis-Ord analysis identified hotspots of 311 complaints within NYC (Fig. 2). The correlation analysis (Table 2) also showed a high correlation among 311

calls throughout the three years 2018–20 ( $r=0.83$ – $0.95$ ), which indicates that the locations of the rodent complaints were generally consistent across all years and months analyzed (Supplementary Fig. 1), with a modest increase after the lockdown. As opposed to the period before the shutdown (Fig. 2A, B), there were no visibly detectable hotspots in areas away from clusters of FSE. Whereas several areas that prominently fostered hotspots prior to the pandemic (e.g. around the northern part of Prospect Park and around Gowanus canal) no longer expressed the same spatial relationship (Fig. 2C).

### Survey data

There were 50 respondents from 47 cities across North America. Several responses had to be excluded because one responded ‘prefer not to answer’ to the first question whether there has been changes in number of rat-related calls from customers. There were three no-responses to the second question on ‘whether the majority of post-lockdown customers’ were new customers, and five no-responses to the third question on ‘whether the number of new customers for rat jobs was different’ to the number of new customers during the same period the previous year.

### Volume of rat-related calls or jobs

More than half of the respondents (55%, Fig. 3A) indicated they received an increase in the volume of rat-related calls or jobs. More than half of the respondents (Fig. 3B, 53%) reported they have more calls from new clients for rat-related jobs as compared with the previous year.

### Proportion of rat-related jobs from new clients

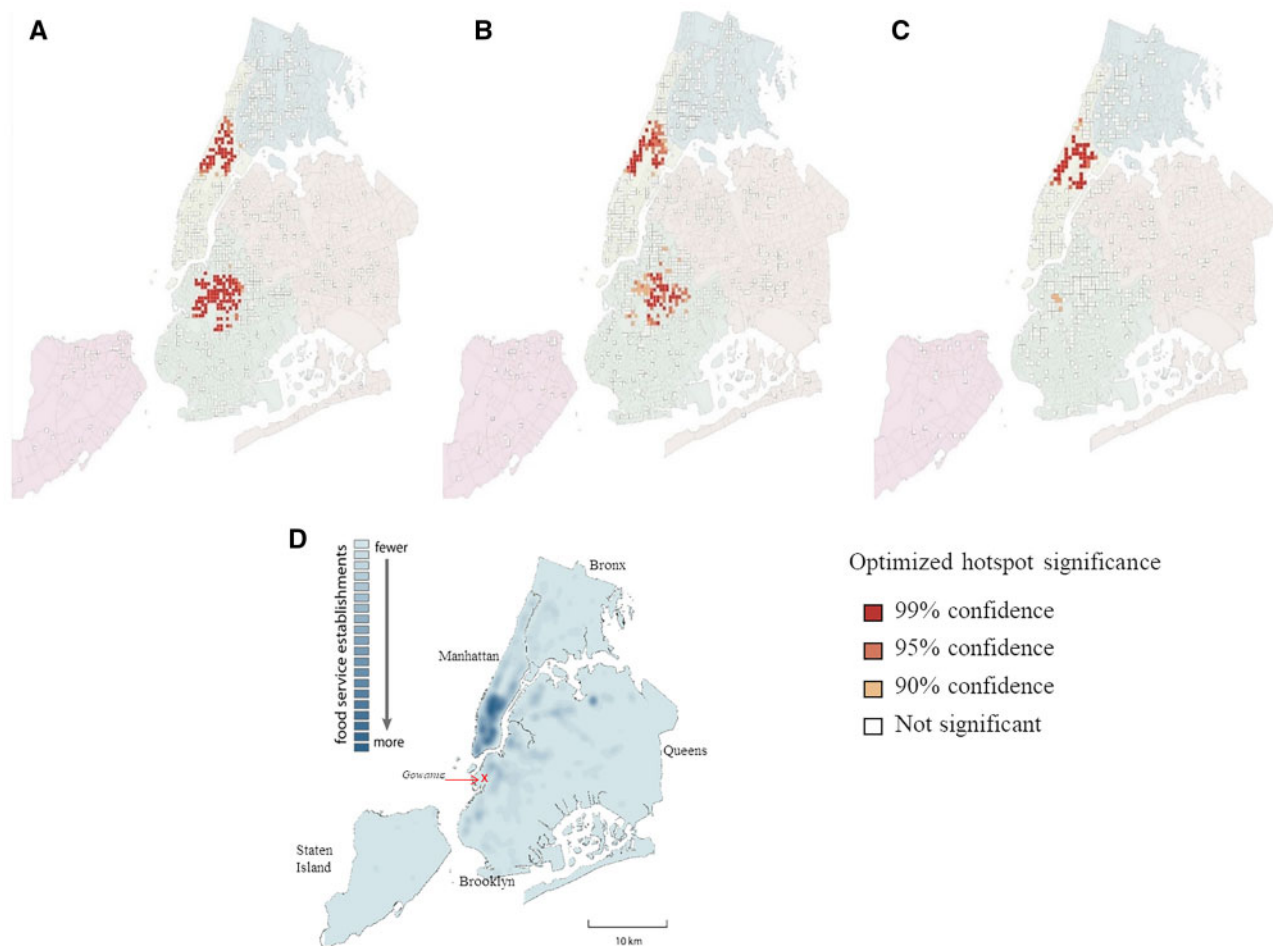
When asked how many of the rat-related calls or jobs were from new clients, 13% of respondents indicated that all of their rat-related jobs were for new clients (Fig. 3C); 32% of the respondents indicated that the proportion of rat-related jobs from new clients were very low, 1–25%. Among the 24 respondents who experienced an increase in rat-related calls or jobs, 21 (88%) indicated that they have acquired more new clients for rat-related jobs compared with the same time last year, while the remaining 3 (12%) responded that the relative volume is about the same.

## Discussion

If rats were moving significant distances during the pandemic, then we would have expected a decreased association between rodent complaints and FSE. Instead, we found a strong association between the location of rodent complaints and FSE that has remained consistent over the last 3 years across all seasons and months (with a modest increase from 0.35 to 0.44 in the early stages of the pandemic; Table 2; Fig. 2). During the early stages of the pandemic, the association between rats and FSE actually increased (Table 2), indicating calls near FSE increased slightly, while calls overall went down by 29.5%. This finding is similar to what occurred during the stay-at-home order in Chicago, USA, whereby increased rat sightings was positively associated with proximity to restaurants (Murray et al. 2021). The Getis-Ord analysis also supports this finding, as it indicates there were no new hotspot clusters away from FSE. Thus, even after restaurants were impacted, calls were generated from very close to the same areas, almost certainly within the same neighborhoods. Additionally, while the Getis-Ord showed pre-existing hotspots near FSE remained consistent, other hotspots away

**Table 2:** Correlation matrix between the food service establishment (FSE) kernel density raster and monthly 311 calls kernel density raster in New York City, USA

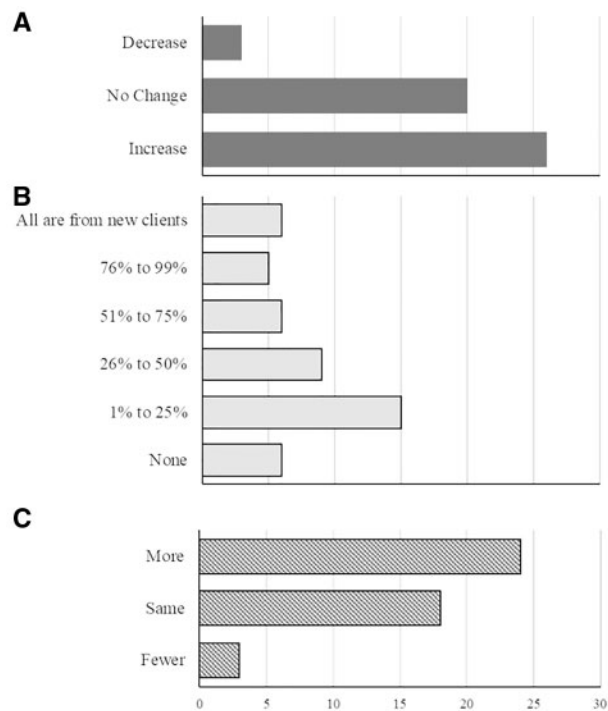
	FSE	March 2018	April 2018	March 2019	April 2019	January 2020	February 2020	March 2020	April 2020
FSE	1								
March 2018	0.40	1							
April 2018	0.33	0.95	1						
March 2019	0.42	0.88	0.89	1					
April 2019	0.44	0.90	0.92	0.93	1				
January 2020	0.36	0.90	0.92	0.91	0.92	1			
February 2020	0.35	0.83	0.87	0.88	0.91	0.91	1		
March 2020	0.44	0.88	0.91	0.90	0.92	0.92	0.90	1	
April 2020	0.45	0.84	0.89	0.90	0.90	0.91	0.89	0.95	1

**Figure 2:** Results of optimized hotspot analysis (Getis-Ord  $G_i^*$ ) of 311 calls in New York City, USA. (A) April 2018; (B) April 2019; (C) April 2020; and (D) density of FSE prior to the lockdown

from FSE dissipated or disappeared (Fig. 2C). This loss of hotspots is most easily observed in areas of Brooklyn close to the Gowanus canal and north of Prospect Park (Fig. 2C). These areas include industrial areas, a polluted canal and many waste-recycling centers, which may serve as a sink for populations that have left FSEs.

Following the widespread media reports, we might have expected to find more rat-related calls overall. Yet, the opposite occurred. The overall 29.5% decrease in the number of 311 calls can be partly explained because people were more likely to be

inside social distancing than outside observing rats (Bobby Corrigan, Department of Health and Mental Hygiene, NYC, pers. comm.). Additionally, due to the abrupt reduction in available food, many rat populations had temporarily subsided due to stress, competition and muricide. Finally, many people decided to temporarily leave the city (see counter-urbanization; Peterson et al. 2020). Given each of these factors and the lack of calls made in less-densely populated areas, it might be surprising that rat calls only decreased by < 30%. Indeed, the reduction in hotspots away from restaurants implies that report rates



**Figure 3:** Survey responses from pest control companies in North America ( $n = 53$ ). (A) Relative volume of overall rat-related calls/jobs before and after the lockdown period. (B) Number of all rat-related calls/jobs from new clients. (C) Proportion of new rat-related calls as compared with old clients—a measure to determine new locations of rats

were decreasing in some areas, while areas near FSE would have actually increased. The fact that individual rats do not generally move more than 100 m or so during their life (Byers et al. 2019b) also suggests that large-scale movements of rats were unlikely to have occurred. We further note that rat reports from Tokyo, Japan indicated that rats did not move significant distances during the lockdown period (Kiyokawa et al. 2021).

Our surveys to pest management companies are mostly consistent with the 311 data. They reported the shift in clientele was different from previous years. More than one-third of pest management companies reported 50–100% of their post-lockdown jobs were from new clients, while six companies reported that 100% of their client-base had changed from old to new clients. A change in client-base indicates rats may be moving to new residences. However, this does not imply rats are moving long distances, as business for most companies has seen a local increase in the same general areas under their purview. Within the pest management industry, such local changes in rat populations following catastrophes are expected and quite common (Peterson et al. 2020; Shiels et al. 2020).

If social distancing has indeed changed populations of rodents, then stressed rat populations may initially subside due to loss of food and subsequent increased competition. However, rats breed rapidly, and should theoretically quickly re-establish population equilibrium (Emlen et al. 1948). For example, such a rapid rebound in population size has been seen in urban rats after being targeted with lethal control (Richardson et al. 2019). This effect is well known and usually referred to as ‘the boomerang effect’ (Smith 1963). The boomerang effect appears to already be occurring in Sydney, Australia (Bedoya-Pérez et al. 2021). There is a potential that after the re-opening of restaurants (expected in summer 2021), the rat populations could

increase if they re-establish their old colonies. We hope that, by this time, new methods will be developed and refined to better quantify these changes. For instance, Bedoya-Pérez et al. (2021) have already shown electronic trapping devices can be deployed to collect ongoing data while controlling rats. Our study suggests new efforts utilizing a range of predictors and geospatial correlates be examined across time and space to help determine where to strategically target such monitoring devices.

## Study limitations

There are few means to study increases in rat populations or changes in their behavior, particularly following natural disasters when research efforts are hampered. Thus, our study is limited to citizen-reported rat sightings to public authorities and voluntary reporting by pest management companies. We also note that the sample size of the surveys ( $n = 50$ ) was small, given that they ensued from national level authorities. It is unclear whether those who responded to the survey would be more likely to report findings that supported, or refuted, the common media narrative. While our early findings appear to confirm what most rodent ecologists would predict (e.g. natural disasters that affect human behavior would affect commensal rodent populations), they are suggestive only. Indirect measures of rat movements and behaviors cannot be considered as anything other than reasonable confirmation that something is occurring, and that more direct measures should be implemented to provide more rigorous and thorough data. We can only hope that the limitations of these data encourage more robust and regular monitoring practices by cities around the world.

Supplementary data are available at JUECOL online.

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*Conflict of interest statement.* All authors declare no conflicts of interest in this study.

## Ethics approval

We used publicly available open-source data (e.g. calls to 311) and industry-based surveys that were developed and submitted directly to industry. There were no instances of protected health information being collected.

## Consent to participate

Consent to participate is not required for public, or anonymous, data-sets.

## Availability of data and material

These data will be made freely available in a public repository such as Dryad.

## Code availability

Code will be made freely available in a public repository such as Dryad.

## Authors' contributions

RMC, M.H.P. and R.S. proposed the ideas behind the paper; industry surveys were created by M.H.P., R.S. and Y.K. with the help from industry (M.A.D.); spatial analyses were conducted by J.L.R. and assisted by F.E.P. and M.H.P.; 311 data were conducted by F.E.P. The manuscript was written by M.H.P., R.S. and Y.K. All authors participated in commenting on, and editing, several drafts and approve the submitted version.

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