Exposure to Rats and Rat-Associated *Leptospira* and *Bartonella* Species Among People Who Use Drugs in an Impoverished, Inner-City Neighborhood of Vancouver, Canada

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Abstract

Rat infestations are common, particularly in impoverished, inner-city neighborhoods. However, there has been little research into the nature and consequences of rat exposure in these neighborhoods, particularly in Canada. In this study, we sought to characterize exposure to rats and rat-associated *Leptospira interrogans* and *Bartonella tribocorum*, as well as risk factors associated with exposure, in residents ($n=202$) of the Downtown Eastside (DTES) neighborhood of Vancouver, Canada. There was no evidence of exposure to rat-associated *L. interrogans* but 6/202 (3.0%) of participants were exposed to *B. tribocorum*, which is known to be circulating among DTES rats. We also found that frequent and close rat exposure was common among DTES residents, and that this exposure was particularly associated with injection drug use and outdoor income-generating activities (*e.g.*, drug dealing). These risk factors may be good targets for interventions geared toward effectively reducing rat exposure.

Keywords: *Bartonella*, Leptospirosis, rat exposure, *Rattus norvegicus*, zoonotic disease

Introduction

NORWAY AND BLACK RATS (*Rattus norvegicus* and *Rattus rattus*) are ubiquitous in cities around the world (Feng and Himsworth 2014). Urban rat infestations are particularly problematic because rats are the source of several zoonotic pathogens associated with significant human morbidity and mortality (Himsworth et al. 2013b). Although rat-associated zoonotic diseases are most common in developing nations, these diseases may also occur in more developed countries, particularly within impoverished, inner-city communities. These communities are subject to a confluence of factors that promote rat infestations, rat-human contact, and disease transmission. These include environmental disorder (*e.g.*, abandoned and derelict buildings, accumulated refuse, overgrown vegetation, etc.), substandard housing, inadequate or degraded urban infrastructure (particularly sewerage systems), risky health behaviors, and poor health status (*e.g.*, injection drug use and HIV/

AIDS), as well as insufficient resources to address rat-related issues (Himsworth et al. 2013b).

Despite these vulnerabilities, there is a paucity of research characterizing rat exposure and associated health threats in these “high risk” communities. Nowhere is this knowledge gap more prominent than in Canada, where, before the Vancouver Rat Project (VRP), there had never been a comprehensive study on the rats or rat-associated health risks in Canada. From a public health standpoint, this knowledge gap is problematic, because without an understanding of rats, rat exposure, and rat-associated disease risks, health officials and practitioners cannot accurately assess the health threats posed by rats or to develop strategies to efficiently and effectively monitor and mitigate those threats.

The VRP is focused on Vancouver’s Downtown Eastside (DTES) neighborhood, an impoverished, inner-city community. It is of note that the City of Vancouver has no municipal programs in place to monitor, address, or prevent rat infestations. During the first phase of this study (2011–2014), DTES rats

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were found to carry a number of zoonotic and potentially zoonotic pathogens, including *Leptospira interrogans* (Himsworth et al. 2013a), *Bartonella tribocorum* (Himsworth et al. 2015), methicillin-resistant *Staphylococcus aureus* (Himsworth et al. 2014a), and *Clostridium difficile* (Himsworth et al. 2014b). In response to that finding, we set out to determine if any DTES residents had been exposed to these pathogens. We elected to focus on *L. interrogans* and *B. tribocorum*, specifically, as rats are almost certainly the only source of these two pathogens for DTES residents, thus evidence of human exposure could be directly attributed to rats. *Leptospira* spp. is transmitted to humans via rat urine and can cause fever, headache, myalgia, and, in severe cases, kidney and liver failure or fatal pulmonary hemorrhage (Himsworth et al. 2013b), *B. tribocorum* is transmitted via arthropod vectors, and has been associated with relapsing fevers, lymphadenopathy, and bacteremia (Kosoy et al. 2010, Kandelaki et al. 2016, Regier et al. 2016). The objective of this study was to determine if DTES residents had serologic evidence of exposure to either of the aforementioned pathogens and to identify risk factors associated with exposure to those pathogens and to rats in general.

Materials and Methods

Ethics

This study was approved by the University of British Columbia's Clinical Ethics Research Board (H12-02174).

Study area

This study was conducted in Vancouver's DTES (49°15'0"N/123°8'0"W), an inner-city neighborhood with high rates of poverty, substandard housing, drug addiction, HIV infection, unemployment, and homelessness (Linden et al. 2013).

Study subjects

Participants were recruited from two simultaneous, ongoing prospective cohort studies: (1) the Vancouver Injection Drug Users (VIDUS) study (Strathdee et al. 1997) and (2) the AIDS Care Cohort to Evaluate Access to Survival Services (ACCESS) study (Milloy et al. 2016). Participants in ACCESS are HIV positive and have used illicit drugs other than cannabis in the month before enrollment. Individuals in VIDUS are HIV negative (although they are tested regularly for seroconversion) and injected drugs in the month before enrollment. We selected these cohorts because HIV positivity and injection drug use have been identified as risk factors for zoonotic infections, including *Bartonella* spp. infections, in urban centers (Comer et al. 2001, Leibler et al. 2016).

All participants are ≥ 18 years of age. At the time of cohort entry (baseline) and semiannually thereafter, participants volunteer a blood sample and complete interviewer-administered questionnaires. The questionnaires capture current information (i.e., referent to the previous 6 months) on sociodemographic characteristics (e.g., age, gender, income, housing), drug-use patterns (e.g., duration and frequency of drug use, public injecting), and other behaviors (e.g., employment in sex work or drug dealing).

Sampling methodology

Only those participants who self-identified as being residents of the DTES for the previous 6 consecutive months on a

screening questionnaire (generated for the purpose of this study) were included. This was done to ensure that the data obtained from both DTES rats (Himsworth et al. 2013a, 2015) and people corresponded to approximately the same time period. Participants for whom a serum sample and/or complete questionnaire data were not available were excluded from the study sample.

It was determined that at least 143 individuals would need to be screened for antibody against *L. interrogans* and *B. tribocorum* to detect exposure at $\geq 2\%$ prevalence, assuming (1) 100% sensitivity and specificity for all diagnostic tests, (2) a population size of 1853 (the total size of the ACCESS and VIDUS cohorts at the time of the study), and (3) and alpha level of 0.05 (Survey Toolbox, ACIAR, Canberra, Australia). This detection threshold was selected given that the prevalence of exposure to zoonotic pathogens in marginalized, North American urban populations can be low (Leibler et al. 2016). Eligible participants were recruited at the time of their regularly scheduled follow-up with the ACCESS/VIDUS studies, starting at the time this study was initiated and ending when a sufficient number of individuals were recruited.

Sample and data collection

All participants provided blood samples for the purpose of this study and answered a 12-item questionnaire regarding the frequency and nature of their exposure to rats (Appendix A1). In particular the questionnaire asked whether subjects had seen rats, had been within 10 feet of rats, and had been in direct contact with rats in the preceding 6 months.

Data were also obtained from the individual's most recent ACCESS/VIDUS questionnaire (collected at the time of recruitment for this study) and from their baseline ACCESS/VIDUS questionnaire.

Serum testing

Serum was separated from blood samples shortly after collection and stored at -20°C before being shipped to the National Microbiology Laboratory (NML), Winnipeg, Manitoba.

At the NML, all sera were screened using the 96-well format of the microagglutination test (MAT) as previously described (Levett 2001). The MAT used *Leptospira* spp. serovar Icterohemorrhagiae (RGA), among others. It should be noted that there is significant cross reaction, particularly among members of the same serogroup, therefore, the MAT generally contains only one representative per serogroup. Both rat-associated serovars, Icterohemorrhagiae and Copenhageni, are within the Icterohemorrhagiae serogroup.

B. tribocorum previously isolated from DTES rats (Himsworth et al. 2015) and used to make slides for an indirect immunofluorescence assay. Twenty microliters of positive control (most anti-*B. tribocorum*), negative control (human serum from a commercial *Bartonella henselae*/*Bartonella quintana* IgG kit; Focus Diagnostics), and participant sera (screened at a dilution of 1:64) were applied to appropriate wells of the slides, and then incubated for 30 min in moist chamber at 37°C . Slides were washed for 10 min in phosphate-buffered saline (PBS) with gentle rocking, then briefly rinsed with distilled water and air dried before applying $20\ \mu\text{L}$ of IgG conjugate (Focus Diagnostics). Slides were incubated for 30 min in moist chamber and 37°C before being washed for 10 min in PBS with gentle rocking, rinsed with distilled water, and air dried. A coverslip was applied and slides were read at $400\times$ on

fluorescence microscope. For this assay, cross-reactivity between *B. tribocorum* and other species (*B. henselae* and *B. quintana*) was low.

Leptospira testing

Twenty *L. interrogans*-positive kidney samples from rats previously trapped within 11 different city blocks in the DTES (Himsworth et al. 2013a) were analyzed using Multispacer Sequence Typing (Zilber et al. 2014) to characterize the prevailing serovars and ensure that appropriate antigens were included in subsequent human serologic testing.

Statistical analysis

Logistic regression was used to identify risk factors associated with exposure to rats and/or rat-associated zoonoses. Outcome variables included seeing rats (daily vs. less than daily), close contact with rats (*i.e.*, within 10') (greater than monthly vs. never), direct contact with rats (*e.g.*, a rat scurrying over an extremity while people are resting in the street, accidental touching while people are scavenging in garbage bins, or rat bites) (greater than monthly vs. never), seropositivity for *L. interrogans* Icterohemorrhagiae serogroup, and seropositivity for *B. tribocorum*. Explanatory variables included for consideration included the following (note variables were dichotomous, *i.e.*, yes vs. no, unless otherwise stated): gender (male vs. female), age (<40, 40–50, >50), education ($\geq$ high school vs. < high school), any government income (welfare, employment insurance, or Canadian Pension Plan payments), any employment income (regular or temporary job), any outdoor alternative income-generating activity (street begging, collecting bottles/cans, squeegeeing windows, or selling drugs), amount of nongovernmental income (<\$100, \$100–\$500, >\$500), homelessness (ever and within the previous 6 months), alcohol use, any injection drug use, heroin use, noninjection drug use, and outdoor public injection drug use (in a park, street/alley, or parkade). Data regarding the amount of government income received were not available.

Simple logistic regression was used for bivariate comparisons among each explanatory and outcome variable. Simple logistic regression was used to examine relationships between the outcome variables and each of the explanatory variables. Stepwise manual selection Akaike's Information Criterion was used to identify final multivariate logistic regression models. Individuals with missing values from any variables included for consideration were excluded. All statistics were calculated using R (R Foundation for Statistical Computing, Vienna, Austria).

Results

Participant characteristics

A total of 202 participants were included in the final study sample (Supplementary Table S1; Supplementary Data are available online at www.liebertpub.com/vbz). The median age was 49.2 years (interquartile range [IQR]=41.4–53.9), and 141/202 (70%) were male. Approximately half (112/202, 55%) of the participants were HIV positive, 139/202 (69%) had used injection drugs in the preceding 6 months, and 17/202 (8%) had been homeless in the past 6 months.

Nearly all (192/202, 95%) of the cohort reported receiving government assistance of some form. Many supplemented this income, and increased nongovernmental income was

primarily associated with increased engagement in outdoor alternative income generating activity (*e.g.*, selling drugs, panhandling, recycling) (Supplementary Table S2). Injection drug use and heroin use increased with increased nongovernmental income, as did the proportion of participants engaging in public injecting. Homelessness was not consistently related to income. Regarding gender, fewer women injected drugs outdoors and participated in outdoor work. However, more women engaged in sex work, and it could not be determined whether this work was performed indoors or outdoors.

Exposure to rats

Exposure to rats was nearly ubiquitous among participants, with 194/201 (94%) having seen a rat at least once in the preceding 6 months, and 120/201 (60%) reporting seeing rats daily (Supplementary Table S3). Rats were generally seen in groups, with 98/193 (51%) of respondents seeing groups of ≥ 5 rats at any one time, and 94/193 (49%) seeing an average of 2–5 rats per sighting. Rats were most commonly seen in streets or alleys (179/201, 89%).

With regard to close contact (*i.e.*, being within 10') of a rat, 47/201 (23%) had such contact daily, while 63/201 (31%) and 52/201 (26%) had such contact weekly or monthly, respectively. Direct physical contact occurred in over a quarter of respondents (55/200, 28%), with 8/200 (4%) reporting daily direct contact, and 18/200 (9%) and 29/200 (15%) reporting weekly and monthly direct contact, respectively. Two of 201 (>1%) participants reported having been bitten by a rat during the past 6 months.

L. interrogans and *B. tribocorum* serology

All rats were carrying serovar Copenhageni; however, antibodies against this serovar were not detected in human sera (although two serum samples were positive for serovar Pomona and one for serovar Hardjo). Six serum samples were positive for *B. tribocorum* (Supplementary Table S1).

Statistical analysis

Regression modeling was not performed for exposure to *L. interrogans* and *B. tribocorum* due to low rate of positivity.

In the final model, the odds of seeing rats daily or more versus less than daily (Table 1) were lower for men (OR=0.340, $p=0.005$) and greater for those with incomes >\$500 versus <\$100 (OR=3.474, $p=0.025$), those who used injection drugs in the past 6 months (OR=2.329, $p=0.019$), and those who injected drugs outdoors in the past 6 months (OR=2.389, $p=0.119$). The odds of close contact with rats monthly or more versus never (Table 1) were higher in those receiving employment income (OR=3.207, $p=0.078$), those receiving alternative income-generating activity from outdoor sources (OR=2.756, $p=0.028$), and those injecting drugs publicly outdoors in the past 6 months (OR=5.021, $p=0.125$). The odds of having direct contact with rats monthly or more versus never (Table 1) were higher in those who had ever been homeless (OR=5.66, $p=0.0941$), those with nongovernmental incomes \$100–\$499 (OR=2.71, $p=0.014$) and >\$500 (OR=6.33, $p<0.001$) versus nongovernmental incomes <\$100, those who had used noninjection drugs in the past 6 months (OR=3.58, $p=0.108$), and lower in those consuming alcohol in the past 6 months (OR=0.52, $p=0.071$).

TABLE 1. BIVARIATE AND MULTIVARIATE ANALYSIS OF CHARACTERISTICS OF DOWNTOWN EASTSIDE COHORT MEMBERS ASSOCIATED WITH RAT INTERACTIONS WITHIN PRECEDING 6 MONTHS (N=191)

<i>Characteristic</i>	<i>Seeing daily vs. less than daily</i>		<i>Close contact monthly or more vs. never</i>		<i>Direct contact monthly or more vs. never</i>	
	<i>Bivariate OR (95% CI)</i>	<i>Adjusted OR (95% CI)</i>	<i>Bivariate OR (95% CI)</i>	<i>Adjusted OR (95% CI)</i>	<i>Bivariate OR (95% CI)</i>	<i>Adjusted OR (95% CI)</i>
Gender (male vs. female)	0.38 (0.18–0.76)	0.34 (0.16–0.71)	1.06 (0.43–2.43)		1.05 (0.52–2.16)	
Age						
Under 40	Reference	Reference	Reference	Reference	Reference	Reference
40–50	0.82 (0.34–1.91)		1.15 (0.36–3.48)		0.84 (0.36–1.96)	
Over 50	0.52 (0.22–1.15)		0.83 (0.27–2.24)		0.49 (0.21–1.14)	
Income/SES						
Employment income	0.56 (0.26–1.23)		2.02 (0.65–8.85)		0.83 (0.33–1.92)	
High school educated	0.82 (1.10–2.50)		1.37 (0.62–3.10)		0.84 (0.44–1.59)	
Public outdoor income	1.76 (0.96–3.26)		2.64 (1.15–6.67)		2.11 (1.11–4.08)	
Homeless, ever	1.35 (0.45–3.94)		2.86 (0.83–8.79)		6.28 (1.2–115.22)	
Homeless, last 6 months	1.51 (0.52–4.97)		1.41 (0.37–9.29)		2.05 (0.69–5.81)	5.66 (1.09–116.44)
Nongovernmental income (\$0–\$100)	Reference	Reference	Reference	Reference	Reference	Reference
Nongovernmental income (\$100–\$500)	1.60 (0.82–3.19)	1.44 (0.70–2.98)	3.57 (1.27–12.75)		3.05 (1.42–6.67)	2.71 (1.23–6.07)
Nongovernmental income (Over \$500)	4.71 (1.79–14.83)	3.47 (1.24–11.39)			6.78 (2.8017.07)	6.33 (2.54–16.42)
Substance use, last 6 months						
Alcohol use	0.70 (0.39–1.29)		0.67 (0.29–1.47)		0.57 (0.30–1.08)	0.52 (0.26–1.05)
IV drug use	3.12 (1.64–6.05)	2.33 (1.15–4.77)	1.65 (0.72–3.69)		2.02 (0.97–4.47)	
Outdoor public IV drug use	3.40 (1.32–10.56)	2.39 (0.85–7.87)	5.94 (1.18–108.10)	5.02 (0.96–92.60)	3.23 (1.40–7.55)	
Non-IV drug use	1.41 (0.53–3.67)		1.42 (0.38–4.27)		3.84 (1.05–24.77)	3.58 (0.91–23.87)

SES, socioeconomic status.

Discussion

In this study, we found that exposure to rats was common in Vancouver's DTES. Previous studies in American and European cities have shown that sighting of and contact with rats is most common in impoverished inner-city neighborhoods (Davis 1953, Childs et al. 1998, Langton et al. 2001, Battersby et al. 2002, Walsh 2014). It is thought that these neighborhoods support large rat populations because of accumulated refuse, overgrown vegetation, poor building upkeep, and so on, which provide ample food and harborage for rats (Battersby et al. 2002, de Masi et al. 2009). These neighborhood-level risk factors are certainly present in the DTES.

However, factors that put individual residents of these neighborhoods at risk of contact with rats are not well known. We found that injection drug use and injection drug use outdoors were significant factors for rat exposure. These activities likely led to more time outdoors, where rats were most commonly seen. Alcohol use, in contrast, was a protective factor, which may be because, as a legal substance, alcohol can be purchased and consumed indoors in liquor store, bars, or pubs. Earlier studies of exposure to rat-borne *Bartonella* species has shown a similar pattern, with greater exposure associated with injection drug use and less exposure associated with alcohol consumption (Comer et al. 1996).

We were surprised to identify higher nongovernmental income as a risk factor for rat exposure, given the association between poverty and both rat infestations and rat-borne zoonoses (Reis et al. 2008). However, in this cohort, such income-generating activity (*i.e.*, selling drugs, sex work, or panhandling) is generally undertaken outdoors, which could lead to higher rat exposure. Higher income was also associated with injection drug use and outdoor injection, which also increases the risk of contact with outdoor rats. These findings are consistent with past research with the DTES population where higher income was explained by participation in street-based income-generating activities and associated with higher intensity drug use (Long et al. 2014).

Our analysis also showed that female gender was a risk factor for seeing rats. This was unexpected, as rat-borne zoonoses are consistently more common in men (Jansen et al. 2005, Katz et al. 2011). In our cohort, women were more frequently engaged in sex work, and although we did not include sex work in our classification of outdoor income generating activity, sex workers frequently solicit clients and work outdoors (Lazarus et al. 2011, Deering et al. 2014), possibly bringing the workers into contact with rats.

Evidence of exposure to rat-borne zoonoses was lower compared to rat exposure, with 6 of our 202 study participants having been exposed to *B. tribocorum*, and none having been exposed to rat-associated strains of *L. interrogans*. Risk factors for exposure to *Leptospira* spp. include poverty, poor housing, low education, and exposure to rodents, many of which are present in the DTES (Leibler et al. 2016). In addition, DTES rat studies during the same time period were shown to be carriers of the zoonotic pathogens under study (Himsworth et al. 2013a, 2015) and Vancouver has a mild and wet climate that could support *Leptospira* spp. transmission. That being said, although the DTES neighborhood is one of the poorest in North America, it receives hundreds of millions of dollars in aid annually, providing inhabitants with medical care and access to clean water, sanitation, housing support, and so on (Culbert and McMartin

2015). Although the extent to which study participants accessed these resources is not known, they could decrease the risk of rat-to-human *Leptospira* spp. transmission within the community. Indeed, recent homelessness was uncommon and not a significant factor in driving rat exposures and exposure to standing water may also be limited due to Vancouver's well-developed drainage/sewer system. Finally, an important factor may be heterogeneous distribution of *L. interrogans* among DTES rats (ranging from 0% to 66.7% among different city blocks (Himsworth et al. 2013a). This raises the possibility that lack of *L. interrogans* exposure among DTES residents is a virtue of the fact that, although heavily exposed to rats, they are not being exposed to *L. interrogans*-infected rats, specifically.

There was, however, evidence of exposure to *B. tribocorum*. Risk factors for *Bartonella* exposure are less well studied than those of *L. interrogans*, but there is clear overlap between the two, including poverty, injection drug use, and exposure to rodents (Leibler et al. 2016). Interestingly, a recent review of zoonotic infections among urban homeless and marginalized people in North American and Europe found higher levels of exposure to *Bartonella* spp. (1–20%) compared to other zoonotic pathogens (Leibler et al. 2016). This may relate to the mode of transmission, with exposure to arthropod vectors and vector-borne pathogens (such as *Bartonella* spp.) being more common than exposure to standing water or sewers. It is also noteworthy that other major North American municipalities have reported high levels of *B. tribocorum* in urban rats (Gundi et al. 2012) and that exposure to related zoonotic *Bartonella* species was associated with behaviors we found associated with exposure to rats, being more likely in those injecting drugs and less likely in those drinking alcohol (Comer et al. 1996, 2001).

This study had several limitations primarily related to methods used to collect data regarding rat exposure and participant characteristics/behaviors. The use of self-reported data could have led to inaccuracies in the measurement of many of the included variables. For example, it is possible that gender-based differences in recalling or reporting rat exposure created a spurious association between female gender and seeing rats. However, given that data for explanatory and outcome variables were collected at different times, and in different contexts, for the majority of associations, systematic recall bias is unlikely. A second limitation is the use of data from the VIDUS and ACCESS studies, which were not specifically designed to measure risk factors for rat exposure. They meant that certain risk factors and/or confounders may not have been captured or measured precisely. For example, we could not specifically capture data regarding the amount of time spent in streets and alleyways (the most common places rats were sighted), a factor that likely contributed to many of the observed associations (*e.g.*, the association between rat exposure and alternative-income generating activity). Future studies should therefore seek to better dissect and explain the relationships found here.

Conclusions

Overall, our results show that the factors that put neighborhoods at risk at high levels of rat infestation, such as low median income, are not the same as those that put an individual at risk of rat contact. This means that strategies aimed at addressing risk factors for neighborhood rat infestation may not be effective in reducing rat exposure in individuals. In addition, many of the individual-level factors identified here may be more amendable

to intervention compared with neighborhood-level factors, such as reducing poverty or overall rat populations. For example, we found that specific behaviors that increase time spent outdoors are important risk factors for rat exposure. This suggests that strategies like targeting rat infestations in areas frequented by people and providing indoor venues for behaviors such as injection drug use (e.g., supervised injection sites) may decrease rat exposure by decreasing outdoor injecting (Wood et al. 2004). In addition, our results highlight the fact that exposure and associated health impacts are highly contextual and cannot be directly translated from one jurisdiction to another. In a highly developed country with a comparatively robust social security system, relative poverty or low education may not be a substantial risk for rat-associated zoonoses. Specific behaviors, such as selling drugs, sex work, or injecting drugs outdoors may be more important factors, regardless of socioeconomic status.

Finally, it is worth noting that most research regarding rat exposure has focused on the potential physical consequences of that exposure (i.e., disease transmission). The effect of rats on psychosocial health and quality of life has been largely neglected and the subject of few studies (German and Latkin 2016). Given the frequent and close contact reported by these study participants, we suggest that this ought to be a priority for future study.

Author Disclosure Statement

No competing financial interests exist.

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Appendix

Vancouver Rat Project Main Questionnaire

Participant number: _____

1. Over the past six months, did you **ever** see a rat?

☐ Yes

☐ No

If the participant answered “yes” to question 1, proceed to the following questions, if s/he answered “no”, end the rat questionnaire.

2. Over the past six months, **how often** did you see rats?

☐ Often (daily)

☐ Occasionally (weekly)

☐ Rarely (monthly or less)

☐ Never

3. Over the past six months, **where** did you see rats (check all that apply)?

☐ At home (apartment/single-room occupancy hotel room/other accommodation)

☐ On the street

☐ While binning (i.e., going through garbage bins)

☐ At work

☐ Other _____

☐ Other _____

If the participant responded “At work”, ask what kind of work they were doing:

4. Over the past six months, **where** did you see rats **most often** (check only one)?

☐ At home (apartment/single-room occupancy hotel room/other accommodation)

☐ On the street

☐ While binning

☐ At work

☐ Other _____

☐ Other _____

5. Over the past six months, what was the **average number** of rats you saw at **any one time**?

☐ Single rat

☐ Groups of 2–5 rats

☐ Groups of >5 rats

6. Over the past six months, what was the **greatest number** of rats you saw at **any one time**?

☐ Single rat

☐ Groups of 2–5 rats

☐ Groups of >5 rats

7. Over the past six months, **how often** did you have **close contact** with rats (i.e., the rat was within about 10 feet of you, even if it was physically separated from you by a wall, bin, etc.)?

☐ Often (daily)

☐ Occasionally (weekly)

☐ Rarely (monthly or less)

☐ Never

8. Over the past six months, **how often** did you have **direct contact** with rats (i.e., close enough that the rat touched you)?

☐ Often (daily)

☐ Occasionally (weekly)

☐ Rarely (monthly or less)

☐ Never

9. Please describe the circumstances surrounding your **last close contact** with a rat:

10. Over the past six months, were you **ever bitten** by a rat?

☐ Yes

☐ No

If the participant answered “yes” to question 10, proceed to the following questions; if s/he answered “no”, end rat questionnaire.

11. Please describe the **circumstance** you were in when you got **bitten**:

12. Over the past six months, approximately **how many times** have you been **bitten** by a rat? _____