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Rat Population Assessment and Control In Eastern Suburbs of Cleveland, Ohio

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RAT POPULATION ASSESSMENT AND CONTROL IN EASTERN SUBURBS OF CLEVELAND, OHIO

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ABSTRACT

The Norway rat (*Rattus norvegicus*) is found to inhabit many urbanized areas; needs to be controlled, given that it is a carrier of diseases and a source of economic damages. As harborage areas in suburbs, the rat prefers compost piles, cesspits, sewer systems, and basements that are near water. Norway rats prefer food sources such as waste disposal sites, unclean yards with trashcans, gardens, and slaughterhouses (Traweger and Slotta-Bachmayr 2004). The typical range for this species in an urban setting is 25-150 meters (27-164 yards). The research for this thesis was done in conjunction with the Cuyahoga County Board of Health (CCBH). Data was collected from residents who reported seeing a rat to CCBH. The resident's property and surrounding properties were then assessed for rat activity, harborage, and food sources. When rat activity was noted the property was baited using rodenticides, and re-baited until no further activity was noted. The number of baiting visits until no activity was noted was recorded for each location and was the main outcome variable of the study. The number of baiting visits was correlated to Census and parcel data utilizing Pearson, Kendall's tau, and Spearman's rho. Also Chi-squared analysis was conducted on the parcel data to determine similarities and differences with locations seeking county services for rat control and general demographic characteristics of the region. Finally, using the GIS system, densities were done to possibly show high concentration of rats to be used for future study sites.

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CHAPTER I

INTRODUCTION

1.1 Norway Rat History and Biology

The Norway rat (*Rattus norvegicus*), also known as the brown rat or sewer rat, is typically associated with humans residing in areas of poor sanitation. These conditions provide a suitable environment with plenty of food and harborage (Samanta and Wijk 1998, Keiner 2005, Traweger and Bachmayr 2005). Initially the Norway rat was found in Asia and Japan, but is now found throughout the world except in Antarctica. Europe was the first continent outside of Asia to be infested with Norway rats in the 1800s. Shortly after, Norway rats began colonizing North America (Pascal et al 2005).

The Norway rat is about 18 to 26 cm in length and weighs 141 to 510 grams as an adult (average 397 g). The coat of the Norway rat is typically a brownish color on the top with a tan or white on the belly. The ears and tail are bald, with the tail being 6 to 9 cm in length (CDC 2005, DC Department of Health 2005).

The average lifespan of a wild Norway rat is approximately 2 years (Richter 1942). These rats are efficient and generalist foragers, which allows them to adapt to broad types of habitats, including garbage dumps, woodlots, basements, open fields, and sanitary sewers (Traweger and Bachmayr 2005). However, the Norway rat prefers cool damp areas in proximity to water and food. The typical home range of the Norway rat is approximately 25-150 meters. Nevertheless, these rats are known to travel greater distances for food and water (Badi et al 1992). .

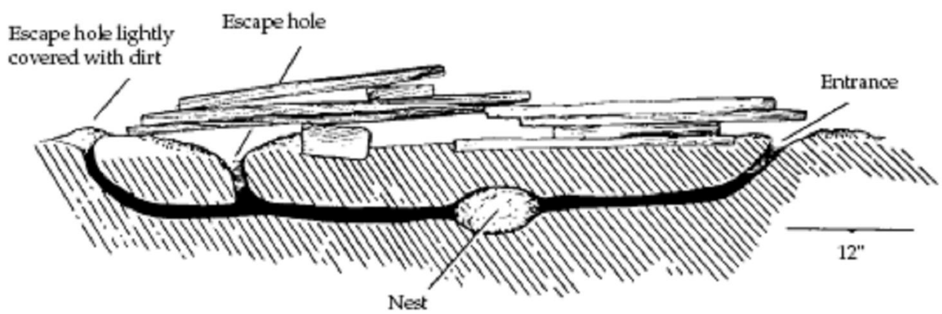

Figure 1. Diagram of Norway rat burrow. (Schwartz and Schwartz 1981)

The Norway rat is primarily nocturnal; they forage for food and water and dig burrows, in the late evening or at dusk. Burrows are very elaborate, consisting of multiple compartments for storage as well as escape tunnels (see Figure 1). Typical items that can be found in the storage compartments are food and nesting materials (twigs and leaves) (Traweger and Bachmayr 2005). The ability of the Norway rat to learn these elaborate burrows, as well as sewer systems, is evidence of their excellent learning ability (Bramley et al 2000). Within these complex burrows, multiple “families” compose a “clan.” Clans usually consist of a dominant male with other females and sometimes other males. The dominant male is typically the largest rat in the clan (CDC 2005 and Keiner 2005).

Reproduction in the Norway rat takes place all year long. The breeding behavior is communal, in that there are no distinct partners for mating and all females care for all the young. A higher reproductive rate occurs in the warmer summer months when food and water availability is most abundant (Schroder and Hulse 1979). While reproduction still occurs in colder winter months, the availability of food and water is diminished. The typical female Norway rat reaches her sexual maturity and is able to mate about 4 months after birth. After only 22- 24 days of gestation, a litter of typically about 8 neonates is born. These neonates take 14-17 days for the eyes to open and are fed milk for about 3 weeks. Shortly after the litter is born (about 18 hours), the female is able to mate again. Typically, a female Norway rat mates about 7 times per year, which can result in a female giving birth to 60 or more young a year (Madsen and Shine 1999, CDC 2005).

Norway rats are good communicators with each other. This is done by vocalization and body language, but most commonly by feel and scent. These particular rats have a very good sense of smell that enables them to be excellent foragers. This excellent sense of smell can also help to distinguish one rat from another within the same clan (Bramley et al 2000). The Norway rat has very poor eyesight and therefore one major means of communication is sensing vibrations or using whiskers to detect body position (Pascal et al 2005). Their whiskers are also used to navigate through borrows and sewer systems.

In addition to using vocalization, body language, feel, and scent for communication, they are also used as the major means for scavenging. The Norway rat eats primarily seeds but will also eat just about anything that is digestible, including birds, small mammals, amphibians, reptiles, fish, eggs, insects, mollusks, worms, marine invertebrates, leaves, roots, wood, bark, stems, nuts, fruit, nectar, flowers, sap, fungus, garbage, human waste, pet waste, and pet food (Schein1953, Taylor et al 2000). However, given the option, the Norway rat is a carnivore. These rats are in the middle of the food chain and have predators that include larger birds, mammals, and reptiles (Corrigan 2005).

1.2 Negative Effects

The Norway rat has been documented as a vector of many diseases including the Plague, Murine Typhus, Rat Bite Fever, Seoul Virus, Salmonella, and Cryptosporidium (Hinson et al 2004, Welch et al 1941, Quy et al 1999, Myers and Armitage 2004). The Plague is the most well known of these diseases because of its large outbreaks in the Middle Ages and during the World Wars I and II. The Plague is actually transmitted by a rat-borne flea carrying the bacteria, *Yersinia pestis*. The Plague is still around today, but fortunately is less prevalent, with about 5 to 15 cases per year in the United States and about 1,000 to 3,000 worldwide (CDC 2005). Like the Plague, Murine Typhus is transmitted by flea on the rats (CDC, 2009). Travelers are at a greater risk for Murine Typhus than U.S. citizen, although there have been a few cases in California, Texas, and Hawaii without travel history.

While Rat Bite Fever also still occurs but is less common than the plague. According to the CDC, Rat Bite Fever comes from two different organisms, *Spirillum minus* and *Streptobacillus moniliformis*, which are found in the rat's saliva (2007). It is transmitted when a person is scratched or bitten by an infected rat. Fortunately it can not be transmitted from human to human like the plague. Another form of transmission for

Rat Bite Fever is through food or drink that has been contaminated with rat excrement. The incidence of Rat Bite Fever is rare in the United States but accurate counts are not available because it is not required to report this disease to the CDC.

Norway rats are a reservoir for the Seoul Virus, which is a moderate form of Hantavirus. Humans become infected with this virus after inhalation of aerosolized urine and droppings. The virus can also be transmitted through rat saliva. Seoul virus is found worldwide in domestic rats and recently thought to be linked to an outbreak in Baltimore. According to the CDC, between 1993 and 2007 there have been only 465 cases of Hantavirus in the United States (2007).

Two bacteria which are carried by the Norway rat are Salmonella and Cryptosporidium. Salmonella affects the gastrointestinal tract. Cryptosporidium is a parasite that also affects the gastrointestinal tract. Typically, Salmonella or Cryptosporidium is not deadly except for immuno-compromised individuals. Both diseases are better known as a foodborne illness but rats are also a reservoir for these diseases.

Along with disease transmission, the Norway rat is known to cause large economic losses. The largest losses come from the food industry either by crop destruction or food contamination (Thomas 1999). For the Norway rats that live in a rural setting, such as woodlots or open fields, the primary food sources are field crops and harvested crops. In urban areas, these rats cause a great deal of concern for the food industry by the contamination of food product, loss of food, and negative publicity.

At first, heavy application of pesticides was thought to be the best means to control the Norway rat population (Keiner, 2005). During World War II Naples, Italy had experienced a Typhus epidemic. Even though American solders were protected with powder the city was off limits to the troops. During World War II when more troops were dying of vector-borne diseases than in battle, research was sparked to better control these vectors such as mosquitoes, lice, and rats by using pesticides (Keiner, 2005). Many new pesticides were invented during this period, including the popular DDT to control mosquitoes and alpha napthyl thiourea (ANTU) to control rats (Keiner 2005). ANTU was tested in Baltimore, MD with the first city-wide rat control campaign in 1942 led by Curt Richter, a psychobiologist at John Hopkins Hospital. From this study there were several important discoveries were made that are still used in rodent control today. During this time it was first observed the home range of the Norway rat was about 50 meters (Keiner 2005). After working with DuPont Chemical, Richter and his staff came up with a tasteless compound known as ANTU. He also stated that ANTU was to be used in extreme circumstances to bring a large rat population under control, but sanitation and rat proofing structures were the best means of control.

1.3 Integrated pest management

Integrated pest management (IPM) examines environmental conditions, behavior of the species, reproduction, and habitat to find multiple approaches to control a target pest with a goal of using less pesticides that are harmful to the environment, humans, and non--target species (Thomas 1999). IPM takes a more scientific approach to controlling a pest. President Carter in 1979, though a Presidential Memorandum, recommended that all government agencies take an IPM approach to pest control (NPS 2005). As Pratt and Brown (1976) illustrated, in Figure 2 below, proper sanitation is a more effective tool in controlling Norway rat populations than pesticides. Without proper sanitation, including removal of the Norway rats' food and water sources, applying pesticides will only diminish the population for a short time with no prolonged control.

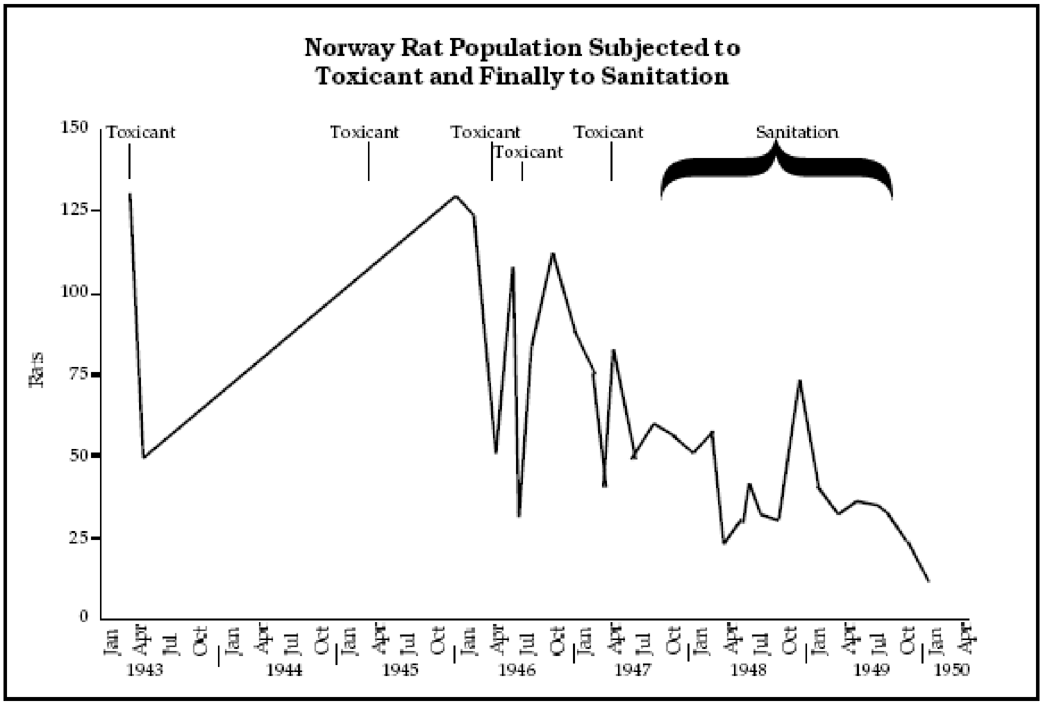

Figure 2. Graph from Pratt and Brown study demonstrating importance of sanitation and application of rodenticides.

1.4 Study Area

The study area of this thesis is made up of four different communities, Cleveland Heights, East Cleveland, South Euclid, and University Heights (See Figure 3.). Integrated pest management can be implemented anywhere, but undoubtedly fits well within the study area because of the differences within the four communities. Each community has its own unique circumstances and environmental factors. This is why implementing IPM with GIS in this type of study can be a very useful instrument (Rob 2003).

Since downtown Cleveland is west of the study area, development started closest to Cleveland and headed east. Therefore the oldest city is East Cleveland, mostly developed in the first decade of the 1900s, and ending in South Euclid and University Heights around 1950s (O'Donnell 2005, and Vild 2005).

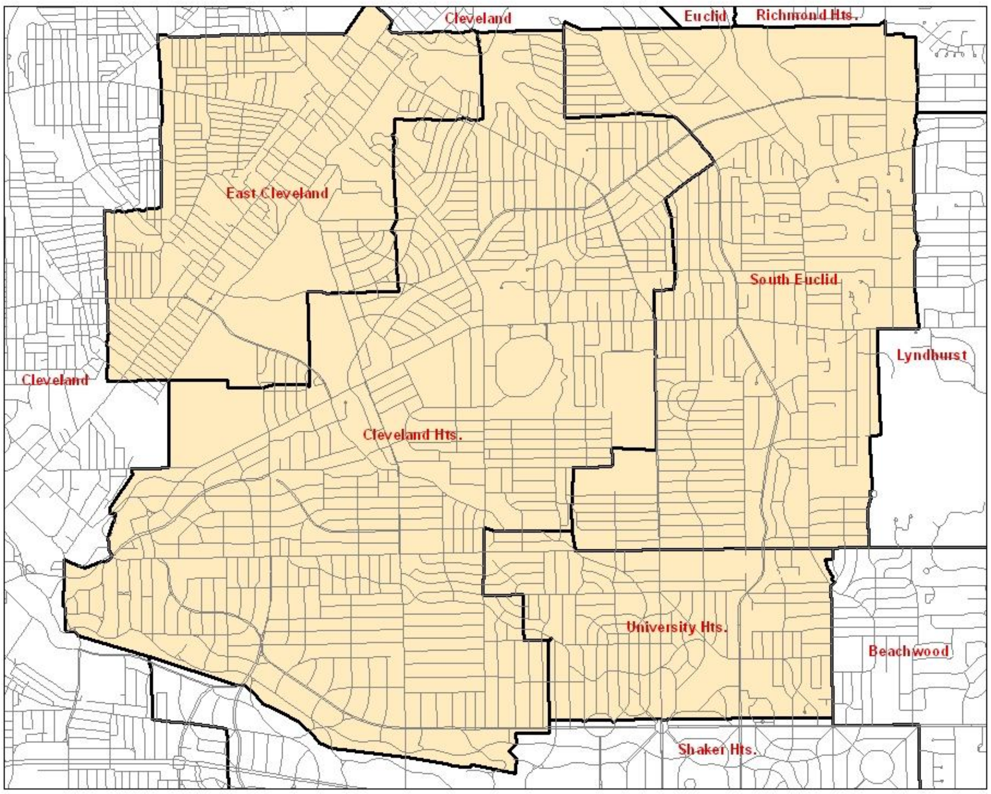

Figure 3. Map of the study area.

The city of East Cleveland is a unique situation in age, demographics, and topography. Since East Cleveland is the oldest of the four cities in the study area, it is most likely to contain more deteriorating structures and/or vacant properties. Vacant properties provide excellent harborage areas and in most cases, good food sources as well. East Cleveland has the lowest income according to the 2000 Census, which can cause less available resources to practice IPM (Census Bureau 2000). Finally, another unique characteristic is the topography in that the border between East Cleveland and

Cleveland Heights is an elevated park. This possibly serves as a barrier for the Norway rats to travel between the two cities.

The city of Cleveland Heights started to be developed about a decade later, and progressed to the east. Cleveland Heights is the largest of the four in terms of geographic size (O'Donnell, 2005). In the cities of Cleveland Heights and University Heights there is a stream that lies beneath two major roads (Vild 2005). When the cities were being developed, the streams were routed underground using culverts. The roads were then developed directly over top the culvert streams. In University Heights, there are two storm sewers under one of these roads. When the road hits Cleveland Heights, both culverts drain into only one storm sewer (Vild 2005, Webster 2005).

As the name suggests, University Heights is home to John Carroll University. Finally, South Euclid is similar to the other cities in regard to building types and, like University Heights, houses a small college, Notre Dame College. These four communities were chosen as the study area for the similarities between three of the communities and the contrast from the fourth. The cities of Cleveland Heights, South Euclid, and University Heights are all similar in the development of the cities, socioeconomics, and green space. East Cleveland differs substantially with respect to the condition of homes and socioeconomic status of the residents.

Norway rats use sewers for food, water, and shelter. The Norway rat has been documented to live in the sewer systems (Madsen and Shine 1999, Traweger and Slotta-Brachmayr 2005). There are three different types of sewers in these cities, each providing different environmental factors. The sewer types in these four cities are combined, over/under, sanitary, and storm with all cities having at least some of each (NEORSD 2005).

The city of East Cleveland is dominated by the combined sewer system design, shown in Figure 4. The combined sewer design provides the Norway rat with easy access between food and water sources. The city of Cleveland Heights primarily has the separate sanitary and storm sewer design, but in the older sections also has many over/under designs. The over/under sewer design restricts access to the rat's food and water sources. The over/under sewers are setup as two vertically aligned sewers with the storm sewer on top and sanitary sewer on the bottom. In every manhole a metal plate separates each sewer. In deteriorating over/under sewers, gaps between this metal plate and the sewers allow access to food and water. The cities of University Heights and South Euclid predominately use the separate sanitary and storm design, shown in Figure 5. The separate sanitary and storm sewer design completely separates the food and water source for the Norway rat. The year in which the sewer system was constructed determine which sewer type was used.

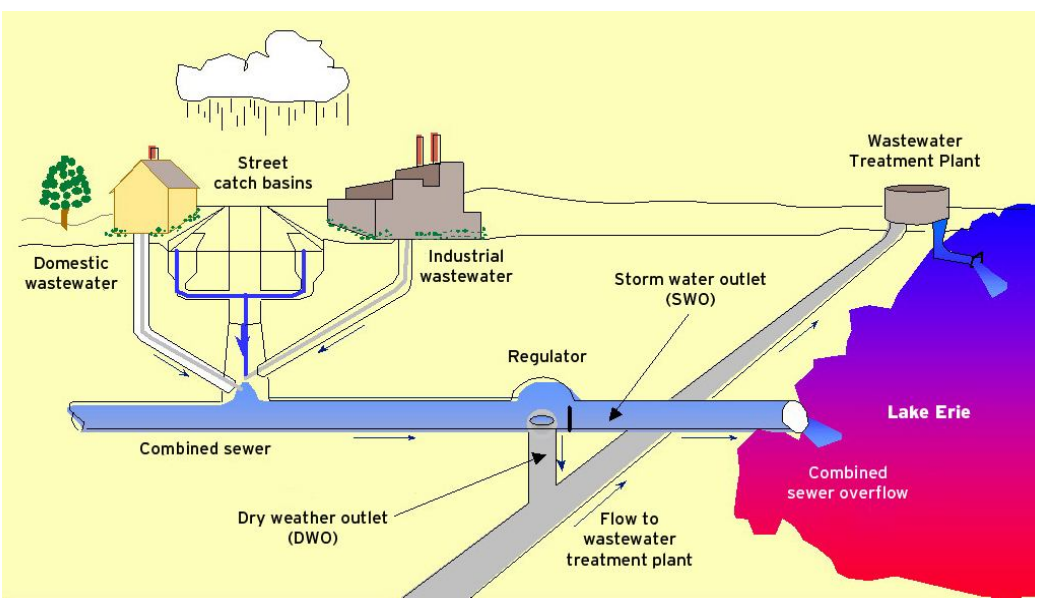

Figure 4. Diagram of combined sewers and overflow. (NEORSD)

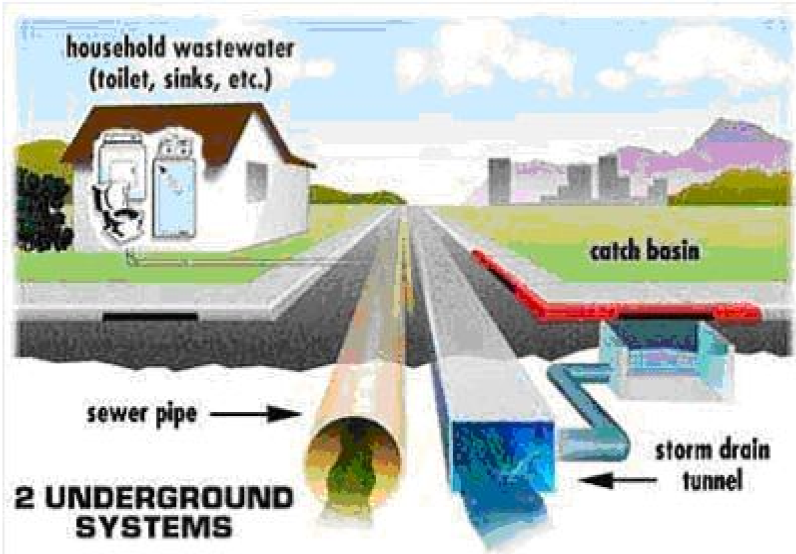

Figure 5. Diagram of separate storm and sanitary sewers.

1.5 Hypothesis

The factors that were chosen for investigation in this study were the age of the structure, socioeconomics of the citizens, and sewer systems. These factors were correlated to the number of baiting visits, which is the number of times the site was baited. Over time buildings deteriorate, creating opportunities for the Norway rat to gain access into the structure for food or harborage. The socioeconomic status of the citizens that comprise the community have many implications for how that area is maintained. For example, citizens with lower income are probably less likely to have the money to fix any building/structural problems. Also citizens with lower education levels might not make the connections between proper sanitation and rodent control. Finally the number of owner vs. renters can have a similar effect in that an owner is more likely to take better care of property, causing fewer access points as well as fewer food sources for rats.

The number of baiting visits required to eliminate the rat activity was used as an indicator for resources necessary to remedy a rat-control issue at a location and is the main outcome variable of this study.

The four hypotheses examined in this thesis are:

- Number of baiting visits is correlated with census group data variables median year built, percent above poverty, percent high school graduate, percent vacant, percent renter occupied, percent owner occupied, and median income;
- Number of baiting visits is correlated with parcel-level variables actual year built, distance to closest restaurant, distance to closest apartment, size of closest sewer;
- Number of baiting visits is correlated with ordinal parcel-level variables of construction quality, condition of house, and sewer order;
- Descriptive characteristics of the individual properties (such as occupancy type condition of home, garage type, style of home construction quality, and sewer type) differ in percentage the percentages for the region.

All data collection was done in collaboration with the Cuyahoga County Board of Health.

CHAPTER II

METHODS AND MATERIALS

2.1 Data Collection

The data collected and used in this study are from visits to sites in the study area in 2003 to 2005 that were initiated in response to residents' reports of rats or rat activity. A Cuyahoga County Board of Health (CCBH) employee would take each caller's contact and location information, as well as a description of what the person observed. This information was then logged into the computer. During the first site visit, an exterior inspection of the property was conducted for any evidence of rat activity. If such evidence was observed, then the homeowner was requested to sign a permission form allowing the placement of baits on the property. If the homeowner was not present, the permission form and a report of findings were left with a door hang-tag. After receiving the permission, the property was baited by placing the bait in burrows, sewers, and/or bait stations. A survey of nearby properties was also conducted, and the same process was followed if the survey revealed evidence of rat activity on the adjoining properties. Each bait placement was given a unique, numerical identification code, which was recorded in the computerized database.

The placement of baits in response to a given call, regardless of the number of individual baits placed during that visit, is counted as one baiting in the data set. After a week to ten days, the property was revisited. Any sign of rat activity was recorded, and bait packs were inspected for evidence of displacement or consumption of bait as seen in Figure 6. If the baits were consumed, re-baiting was done at this time. A re-baiting event, regardless of the number and location of baits was again recorded as one baiting. Properties were re-inspected repeatedly until evidence of rat activity was no longer observed, at which time baits were removed from the property. The number of baiting visits therefore reflects the number of visits to the site, not the specific number of baits place. Once the inspector determined rat activity had ceased, the complaint would be considered closed.

Figure 6. Open bag of bait indicating activity.

Sewer baiting follows the same basic methods. When the information was called in, it was logged into the computer. Once out in the field, the sewers were baited if the resident stated that a rat was observed coming up through a drain or toilet. Also, the sewers were baited if rat activity such as droppings was observed in the sewer. After it was determined that the sewer needed to be baited, the manhole would be lifted using the pickaxe and mallet and bait was placed in the sewer. The sewers were then checked every seven to ten days.

Figure 7. Four Weather Blox baits on bolt attached to wire.

Figure 8. Baited Sewer

The method of baiting sewers changed during the study period. In 2003 and 2004, the Weather Blox were tossed into the sewer without being able to retrieve them to monitor activity. However, because monitoring the bait was important to determine the rat activity in the sewers. The use of a method to retrieve the bait was implemented in 2005.

A wire was cut to the depth of the sewer. This wire was then looped at both ends using metal clamps, one loop for a bolt and the other for a screw. Four Weather Blox baits were placed on the bolt and secured by a washer and a nut. The end with the bait was then lowered into the sewer and placed out of water, as shown in Figure 7. The other end was then screwed into the top of the manhole or out beside the lid.

Rat activity was noted when the edges of the Blox had gnaw marks. It was not possible to note rat activity when the Blox were completely gone. This could occur when the baits were used in a storm sewer and there was a significant rain or when the bait was pulled into the water by the rats. The sewers were baited until no activity was noticed. At this time, the bait was taken and the wire was tied to the edge of the manhole so that if necessary it could be used in future years.

2.2 Field Materials

The rodenticides (baits) that were used in this study were Talon-G products, which have the active ingredient Brodifacoum. The two Talon-G products were Bait Pack Mini-Pellets and Weather Blox. The Talon-G Bait Pack Mini-Pellets were used to bait burrows and other harborage areas. The Weather Blox were used for bait stations and in sewer baiting. The Bait stations, seen in Figure 9 and 10, were small plastic boxes with two openings large enough for a rat to go in and out. They were used when the owner of the property either requested it or if there were a threat or risk of other larger animals consuming the bait. Brodifacoum is an anti-coagulant. When a Norway rat consumes a lethal dose, it will die in approximately 4-5 days. Meal bait is added to the Brodifacoum so that the Norway rat cannot use its sense of smell to determine that it is toxic.

Figure 9. Bait Station.

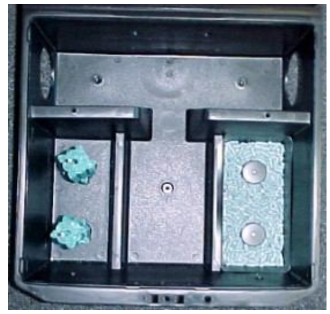

Figure 10. Inside of a Bait Station.

2.3 GIS and Data Visualization

Geographic Information Systems (GIS) allows researchers to visualize many environmental factors all at once. In doing so, researchers get a better understanding of what could be contributing to, or causing a problem (Okunuki, 2001). GIS uses multiple layers to display data on a single map. Each of these layers contains different types of information typically with an attribute table that links information fields to spatial location. The spatial analysis tool, which is a part of ArcGIS, is capable of statistical analysis, including correlations (Boots, 2000). Using GIS along with IPM, instead of overusing pesticides, is a possible way to control Norway rat populations much more effectively than before (Russell and Clout 2004). All GIS data in this study was supplied by: The US Census Bureau, the Ohio Department of Health Zoonotic Disease Program, Ohio Geographically Referenced Information Program (OGRIP), Ohio Statewide Imagery Program (OSIP), and the Cuyahoga County Board of Health Epidemiology and Surveillance Service Area. These layers were projected using the coordinates system of State Plane Ohio North (feet).

This thesis is focused on using Geographic Information Systems (GIS) to identify factors that can be used to enhance integrated pest management (IPM) to decrease the

Norway rat population in urban environments. GIS can locate high densities of rat populations within the cities. The areas that are identified as having high densities of rats are then used as target areas to focus implementation of IPM.

In this study, ArcGIS was used to assign census block group data to each rat sighting (US Census Bureau). This was done by a function in ArcGIS called spatial join. Each dot on the map that represented a rat sighting was joined with the census data for the block group in which the dot was located. The result of the spatial join was then exported to Microsoft Excel for further analysis.

For the sewer type analysis, River Tools was used with a Digital Elevation Model (DEM) to create a scale of the probability that a sewer will contain water. River Tools creates a new variable called sewer order. Sewer order is a numerical variable where 1 represents the highest elevation, a location in which the water originates from. Once this sewer joins another first order sewer the resulting sewer becomes a second-order sewer. This process is continued for the entire sewer system and is entirely analogous to the well-known Strahler system of surface stream orders (Ritter et al, 1995). Once this application was complete, the new sewer layer was then analyzed in ArcGIS. Again a spatial join was done, joining the new sewer order variable to the nearest dot representing a rat sighting. The layers that were used in ArcGIS were streets, city boundaries, rat complaints each year, census data, parcels, and sewers.

2.4 Data Analysis

With each record of a rat sighting, the number of baiting visits that were required to eliminate the rats was recorded. This indicator was chosen as the dependant variable for the statistical analyses.

The census, parcel, and sewer data, most of which are continuous variables, were analyzed using SPSS software. Simple frequencies were done to find the minimum, maximum, mean, median, and standard deviation of the quantitative variables in the datasets. Pearson, Spearman rho and Kendall's tau correlations were computed using SPSS to determine any correlations.

Finally, the categorical data was analyzed using the chi-squared test. This test expresses the difference between expected frequencies and observed frequencies. The percentage of each categorical variable for the entire study area was computed using ArcGIS. Many of the categories were combined based on similarity and to ensure sufficient frequencies to run the analysis.

CHAPTER III

RESULTS

3.1 Dependent Variable

Table I below shows the number of baiting visits that were made to all properties that observed Norway rat activity, as well as the mean, maximum, minimum, and percentiles.

Table I. Summary of Number of Baiting Visits

Number of Homes	Mean	Standard Deviation	Minimum	Median	Maximum
651	1.95	1.907	0	2	14

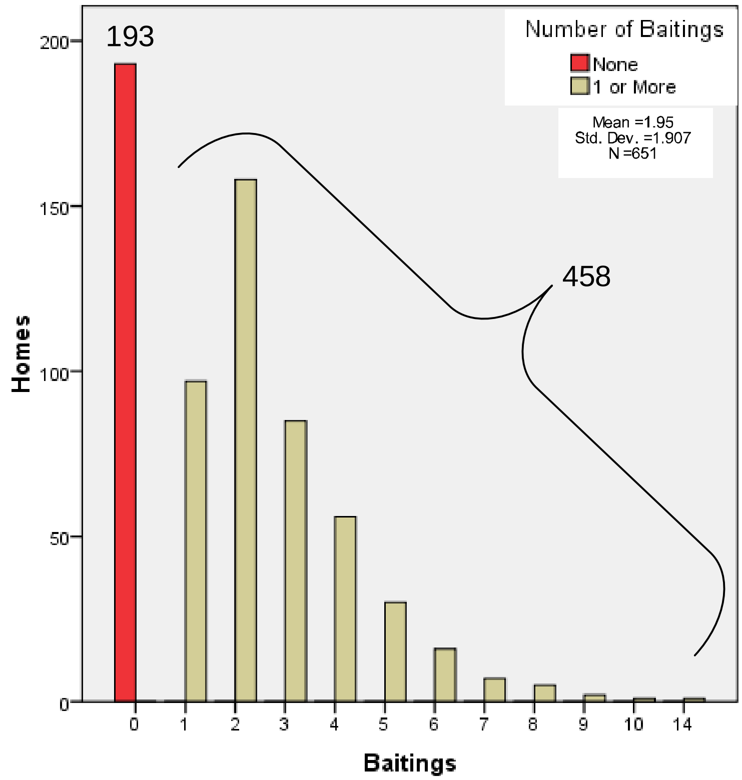

Figure 11. Histogram of the number of baiting visits to each property with reported Norway rat activity.

The number of visits was broken down into two categories. One category contained only the initial visit to respond to the call. In this category no bait was placed on the property because no Norway rat activity was observed by the inspector. The next category was for 2 or more visits, suggesting that rat activity was observed, baits were placed and re-baiting was required. Table II gives the frequencies for each classification.

Table II. Distribution of calls with rat activity

	Frequency	Percent
No Activity	193	29.6
Rat Activity	458	70.4
Total	651	100.0

For those calls where rat activity was noted (N=458), the mean number of baiting visits was 2.77 with a standard deviation of ± 1.7 number of baiting visits.

3.2 Continuous Variables

The continuous variables used in the correlations were the actual number of baiting visits, the actual year the house was built, estimated year the house was built based on condition, distance to nearest restaurant, distance to nearest apartment building, percent of population living above poverty, percent with high school education, percent of population whom rented and owned, and median income. Graphical displays of the distributions of these variables, as well as a scatterplots showing the relationship with the number of baiting visits appear in Appendix A.

Table III. Descriptive statistics for continuous variables .

	Mean	SD	Min	Max	Corr.	Correlation with all observations (p-value)	Correlation with 1 or more baitings (p-value)
Number of Baiting Visits	1.95	1.9	0	14			
Actual Year Built	1930	16.4	1853	1981	.064	.127	.825
Median Year Built	1943.9	6.0	1939	1971	.010	.791	.810
Restaurant Distance (ft)	2042	1462	19	7072	.076	.052	.694
Apartment Distance (ft)	1665	1303	0	6042	-.004	.917	.188
Percent above Poverty	84.9	14.2	51.4	100	.123	.002	.728
Percent High School Graduate	85.2	13.4	52.4	100	.133	.001	.544
Percent Vacant	8.1	8.2	0.5	34.2	-.114	.003	.826
Percent Renter Occupied	30.3	20.4	1.1	91.7	-.107	.006	.253
Percent Owner Occupied	61.6	25.7	4.1	96.9	.122	.002	.324
Median Income	47,749	26,469	10,879	130,550	.152	.000	.450
Sewer Size	16.5	13.3	8	156	.044	.332	.313

Pearson correlations were calculated on the above continuous variables with number of baiting visits, many of the correlations were significant at the 0.05 level (2-tailed). Although the correlations for most of the variables were significant, they were so weak (with the highest correlation coefficient was .190) that it is questionable whether any of them are meaningful.

3.3 Categorical and Ordinal Variables

Table IV. Occupancy Type

		Frequency	Percent	Region
Valid	Unknown	85	13.1	0
	1 Family	456	70	88.2
	2 Family	106	16.3	11.5
	3 Family	4	0.6	0.4
	Total	651	100	100

Table V. Style of Home

		Frequency	Percent	Region
Valid	Missing	83	12.7	0
	Bungalow	85	13.1	20.2
	Colonial	475	73	74.5
	Condo	1	0.2	0.2
	Ranch	7	1.1	3.9
	Total	651	100	98.8

Table VI. Garage Type

		Frequency	Percent	Region
Valid	Missing	83	12.7	0
	Attached	117	18	20.9
	Basement	1	0.2	1
	Detached	403	61.9	72.4
	None	47	7.2	5.9
	Total	651	100	100

Table VII. Construction Quality

		Frequency	Percent	Region
Valid	Missing	83	12.7	
	A	18	2.8	2
	A+	8	1.2	1.5
	AA	18	2.8	0.9
	B	140	21.5	28.5
	B+	78	12	14.6
	C	71	10.9	13.8
	C+	234	35.9	38.4
	D+	1	0.2	0.1
	Total	651	100	99.8

Table VIII. Condition of House

		Frequency	Percent	Region
Valid	Missing	83	12.7	0
	Average	302	46.4	60.9
	Excellent	1	0.2	0.05
	Fair	150	23	16
	Good	90	13.8	19.3
	Poor	16	2.5	1.9
	Very Good	7	1.1	1.6
	Very Poor	1	0.2	0.2
	Total	651	100	99.95

Table IX. Sewer Order (Ordinal)

		Frequency	Valid Percent
Valid	5	372	57.1
	6	139	21.4
	7	99	15.2
	8	37	5.7
	9	4	.6
	Total	651	100.0

Tables IV. thru IX. demonstrate the frequency of occurrence for the categorical and ordinal variables analyzed. Kendall's tau and Spearman's rho were used for the correlation analysis for construction quality, condition of house, and sewer order with number of baiting visits.

Table X. Categorical and Ordinal Correlation

Variable	Kendall's tau value (p-value)	Spearman value (p-value)
Construction Quality	.590	.587
Condition of House	.654	.669
Sewer Order	.265	.262

3.4 Chi-Squared Analysis

We also examined whether characteristics of the homes that called for services differ with respect to household conditions than the general region. We used the Chi-Squared Test of Homogeity to answer these questions. All of the variables were significant at the 0.01 level except for the Garage type which was just barely not significant at the 0.05 level, shown in Table XI.

Table XI. Chi-squared analysis of categorical data

	Observed Frequency	Observed Percent	Expected Frequency	Expected Region	Chi Squared	P-value
Occupancy Type						
1 Family	456	80.57	499.21	88.20	3.74	
2 and 3 Family	110	19.43	67.35	11.80	27.00	
Total	566	100.00		100.00	30.74	2.95E-08
Condition of Home						
Excellent, Very Good, Good	98	17.28	119.07	21.00	3.73	
Average	302	53.26	345.30	60.90	5.43	
Fair, Poor, Very Poor	167	29.45	102.63	18.10	40.38	
Total	567	100.00		100.00	49.54	0.00000
Garage Type						
Attached	118	20.77	124.39	21.90	0.33	
Detached	403	70.95	410.66	72.30	0.14	
None	47	8.27	33.51	5.80	5.43	
Total	568	100.00		100.00	5.90	0.052
Style of Home						
Bungalow	85	14.99	114.74	20.60	7.71	
Colonial	475	83.77	423.16	74.80	6.35	
Ranch	7	1.23	22.15	4.60	10.36	
Total	567	100.00		100.00	24.42	4.97E-06
Construction Quality						
AA, A+, A	44	7.75	24.99	4.40	14.46	
B+, B	218	38.38	244.81	43.20	2.94	
C+, C, D+	306	53.87	297.06	52.40	0.27	
Total	568	100.00		100.00	17.66	0.0001
Sewer Type						
Combined	98	15.96	36.92	7.70	101.05	
Over/Under	128	20.85	53.39	10.30	104.25	
Sanitary	218	35.50	236.86	43.70	1.50	
Storm	170	27.69	211.86	38.30	8.27	
Total	614	100.00		100.00	220.82	9.90E-46

3.5 GIS

An additional visual analysis was conducted on the data using GIS. In Appendix B Figures 32-37 represent different types of maps that were created to analyze this data. In figures, the blue dots are 2003 complaints received, red dots are 2004, and black dots are 2005. The GIS data used to create the following maps was supplied by; The US

Census Bureau, the Ohio Department of Health Zoonotic Disease Program, and the Cuyahoga County Board of Health Epidemiology and Surveillance Service Area.

ArcGIS software was used to do the research for analysis of controlling Norway rat populations. One of the many benefits to using GIS is a lot of information can be displayed using one map. Besides the baseline data, additional layers can be added such as sewer types or parcel conditions to give the person out in the field a better idea of additional environmental factors that could be attributing to the problem. Data that has been collected over the years could be added, so that the inspector could know of issues associated with that area in the past.

What appear to be different color streets are actually the different types of sewers; color-coded to design. The red lines indicate the four city boundaries with East Cleveland to the northwest corner, Cleveland Heights taking up the center and southwest, South Euclid is in the northeast corner, and finally University Heights in the southeast. The different colored shaded areas are the density of complaints with the darker the color the higher the density.

CHAPTER IV

DISCUSSION

This thesis examined 16 factors that were commonly believed significant the most impact on Norway rat populations. When considering the Norway rats' basic needs -- food and shelter -- there is more than one underlying factor that contributes to where rat burrows are located. As Bramley et. al (2000) states, the Norway rat can smell predator odors and possibly even differentiate between carnivores and herbivores in an effort to avoid them. Also, if there is no suitable shelter or access to shelter for the Norway rat, then proper soils for burrows may be the limiting factor (Traweger and Slotta-Bachmayr, 2004). Regardless of the factors, a Norway rat will still limit its home to 25-150 meters from the primary food source. It is also important to note that any reduction in the Norway rat population can lead to positive results such as less disease transmission and a decrease in economic losses.

4.1 Correlations

The analysis of the data collected in this study provided insight into facets of Norway rat control in an urban setting. Although many of the correlations were significant, none demonstrated a strong correlation. In fact some of the variables were trending in the opposite direction then would be expected. For example, the higher the percentage of people in a census block group that were above the poverty level and had a high school education, the more baiting visits were needed (positive correlation). However, it would be expected that people with a high school education and not in poverty would have a better understanding of how to prevent rats and the money to fix any structural flaws allowing access for harborage. Therefore, a negative correlation between the number of baiting visits and high school education would be expected.

A power analysis shows that for sample sizes over 400 (which is the case for the number of residences with 1 or more baiting), the power that a Pearson correlation with magnitude of .15 is deemed significant is 86%. With sample sizes over 500 (the case with all the residences), the power is 92%. This tells us that the sample sizes in this study can make correlations of almost meaningless magnitude statistically significant.

One explanation is that those properties that were reporting rat activity that did not actually have rat activity were properties with the lower education level. This caused the lower education level and lower number of baiting visits to have a pseudo-significance effect. This pseudo-significance can be seen in Figures 19 and 21, where the scatterplots show several cases in the lower left hand corner of the graph. The corner represents lower percentage of people with a high school education that required zero baiting visits because there was no rat activity. In an attempt to account for this pseudo-significance the data were analyzed again removing the cases with zero baiting visits, indicating no rat activity. When the data are analyzed removing the cases where there were no baiting visits, none of the variables were significant. This is indicated in the last column of Table III.

4.2 Chi-Squared

The Chi-squared analysis of the categorical data showed a significant difference in the number of observed rat complaints and total percentage of the category in the study area. The total percentage in the study area represents the expected frequency for each category. For example 46.4% of the complaints were from homes that were rated as average for the condition of the home. Of all the homes in the study area, 60.9% are rated as average. As a result there was a significant difference in the distribution of the rat complaints between all of the groups of conditions of the home. The chi-squared analysis in this thesis has some data limitations. The data used in this study was only from reported rat sightings to CCBH. The results of the chi-squared analysis are in Table XI.

4.3 Density

Figure 35, which represents the 2003 density of complaints, shows five separate areas of density. Of the three years in this study (2003, 2004, and 2005) 2003 has the least concentration of complaints. This was determined by the output file that ArcGIS creates the raster file. In 2004, Figure 36, there are fewer densities clusters, only 3, and have a slightly higher concentration than in 2003. The densities appear to be around the over/under and combined types of sewers. In 2005, Figure 37, there are only two density clusters that have the highest concentration. In this year, however, different types of sewers appear to have a higher density: the sanitary and storm. This could be due to some sewer construction that occurred in 2005. One can speculate that at this time the rats were moving out of their normal area. Residents in the areas to which the rats moved were not accustomed to seeing rats and called the County Board of Health more frequently than residents who were used to seeing rats (Webster 2005). East Cleveland had the highest density, again around the combined sewers.

Comparing all three years indicates that the Norway rat population appears to be shifting. Because East Cleveland is sectioned off by the large hill known as Forest Hill Park, it appears that the populations keep moving between the northeast and southwest corners of the city. For the other three communities it appears as if there is a counter clockwise shift. More years of data would need to be collected and mapped to determine if there is a trend. Traweger and Slotta-Bachmayr suggest that by taking into account three environmental factors -- food, shelter, and barriers -- location of Norway rat populations can be predictable. Although Traweger and Slotta-Bachmayr model is a way to study Norway rat populations it is the intention of the Cuyahoga County Board of Health to reduce Norway rat populations. Two of the three factors, food and shelter, can be reduced by educating the public. Through public education, food and shelter factors could be diminished, making this model unnecessary for the study area.

4.4 Education

The control of Norway rat populations includes many factors, but with a better understanding of the problem by the citizens and collaborative efforts with the cities and citizens, Norway rat populations can be kept under control. Education programs are still being implemented to raise the level of awareness of rodents and best practices to control the rodent population. Educating the general public has unique circumstances, in that everyone is starting at a different level. Many residents do not know the first thing about rats -- including that there are several species of rats. While other citizens are very knowledgeable on the subject, they are unclear as to what can be done about it.

In an effort to resolve this issue the Cuyahoga County Board of Health has educational pamphlets that are distributed to residents upon inspection and are also placed in city hall and community newsletters. Within these pamphlets are information about reducing food sources, reducing harborage areas, and the difference between mice and rats. To date, none of the findings of this study have been included in the pamphlets.

Most residents know some of the typical food sources for rats, such as trash. However many do not realize that their birdfeeder, their dog waste, or food in gardens or compost piles can contribute to or cause the problem. The same can be said for harborage areas: many people know that rats live in the sewers but do not know that they also live in compost piles, woodpiles, burrows in the ground, under lawnmowers, and under porches.

Finally, if a resident can distinguish the difference between mice and rats, it would save time and money on rodent control. Regardless of knowledge, many residents do not know of the county service that is offered to reduce rats. Again this can be partially accomplished though the use of community newsletters. Finally, speaking with city officials to inform them of the efforts of CCBH to address the situation will result in more accurate data and often assistance with the rodent control program.

4.5 Policy

City governments can also help to control Norway rat populations by implementing some new policies. One new policy that could be implemented to reduce food and harborage areas would be to restrict the rodent control service to those properties that are well maintained. When an inspector from the Cuyahoga County Board of Health notes rat activity on a property that also provides the rats with an excellent food and harborage source, under such a policy no rodenticides would be applied until the resident resolves the issues. This policy by CCBH would be coupled with education and assistance to the residents.

This new policy change would allow the inspectors a greater probability of success in reducing or eliminating the rat populations in that area. Again, according to a study by Pratt and Brown (1976), regardless of the number of times rodenticides are applied the rat population will persist until the food and harborage conditions are eliminated. Furthermore, the Chi-Squared results of this study demonstrates that the condition of the home, the garage type, and the number of family significantly effect where the Norway rats are found. The condition of the home and garage type can provide the harborage and food source for the Norway rat with easy access into the structures. The higher the number of families living in one structure the greater the amount of trash allowing for the food source for the rats.

CHAPTER V

CONCLUSION & SUMMARY

The hypotheses that were tested in this thesis provide a foundation for improving the control of rat populations in the study area. The outcomes of the hypotheses for this thesis were:

Hypothesis 1:

- Number of baiting visits is correlated with census group data variables median year built, percent above poverty, percent high school graduate, percent vacant, percent renter occupied, percent owner occupied, and median income;

Although the variables were significant, it was at such a weak level that no meaningful relationship can be understood.

Hypothesis 2:

- Number of baiting visits is correlated with parcel-level variables actual year built, distance to closest restaurant, distance to closest apartment, size of closest sewer

Again, the variables that were significant were at such a weak level that no meaningful relationship can be understood.

Hypothesis 3:

- Number of baiting visits is correlated with ordinal parcel-level variables of construction quality, condition of house, and sewer order;

The ordinal variables showed no significant correlation to the number of baiting visits.

Hypothesis 4:

- Descriptive characteristics of the individual properties (such as occupancy type condition of home, garage type, style of home

The condition of the home as listed in the County Auditor's database was analyzed using the Chi-squared test with a p-value of .000, indicating that rats exhibit a strong preference for homes in poor condition. The Chi-squared analysis of sewer type also showed that rats are strongly related to certain types of sewers.

Even with many of the socioeconomic factors of the community being analyzed, none of the factors have a strong correlation to the number of baiting visits it took until the rat issue at a particular address was controlled. One conclusion from this study is that Norway rats do have a preference regarding sewer type. The combined sewer types allow the rat easy access between the clean water source and sanitary sewer for a food source. Therefore, the Board of Health and City personnel could bait these types of sewers more often to help control the rat population.

Norway rats always have and always will live in close proximity to humans. It is not feasible to eradicate the entire population; our goal should rather be to keep it under control to limit the many negative problems it causes, mostly disease transmission and impact on property values. With proper sanitation practices by the residents and an integrated pest control practice by the local health officials the Norway rat can be controlled by a safe and effective means.

CHAPTER VI

FUTURE STUDIES

The mission statement of the Cuyahoga County Board of Health reads, "to prevent disease and injury, promote positive health outcomes and provide critical health services to improve the health status of the community". Additional research is being done to use less rodenticides to better control rat populations in order to prevent the spread of possible diseases. A new study that is already under way based on the outcome from this thesis is to examine two areas of high density to determine if there are any similar significant environmental factors attributing to these two areas. One area being studied is located in East Cleveland and the other is the border of Cleveland Heights and University Heights where culvert streams are present. The reason for the selection of these two particular areas is the different factors in the two areas such as sanitation, education, and types of sewers. The current objective of the project is to locate specific factors that could be affecting to rat populations, correct those factors, and to do sewer baiting to see if a decline in rat population (or at least complaints) is observed.

To be able to monitor a decrease in the number of complaints in this region, most of the work has to be done early before rat populations begin to rise. To date, four streets in the city of East Cleveland have been surveyed for sanitation, vacant homes, and sewer manholes for baiting. This information is being loaded into the GIS system to monitor the two areas to find any decrease in signs of rat habitation. The next step is to do the sewer baiting the same way as described in the materials and methods section, so that the rat activity can be recorded. Over time, the same type of surveys will be done to monitor the sanitation of the areas and addressed if needed. Finally the new complaints will be logged into the system in the same method and density maps will be produced to see if this new study had any effect on the rat populations in these areas.

Another area of focus for future research is a more detailed analysis of sub-populations of the data. Those complaints where no rat activity was noted could be studied to determine the need for the call. Would it be that more education is needed in the area to differentiate between rats and mice? Another reason observed in the field for a complaint with no rat activity is due to a neighbor dispute. Most times this included maintenance of the neighbor's property. Either there was a lot of trash or clutter in the yard or the yard had not been mowed in a long time. Also another reason to look into the complaints with no rat activity is to determine why rats are not present. Looking into the factors of why the rats are not there and then applying that knowledge could reduce rat populations.

Major events that disturb rat populations in the study area can affect the visibility causing an increase in the number of complaints to CCBH. Such events can include sewer projects, high rainfall, or temperature. Rats have been documented to have a higher rate of activity in warmer climates (Madsen, T. and Shine, R. 1999). Therefore a seasonal analysis may also prove insightful. A high amount of rainfall could flood the sewers, which as this thesis has shown are an important factor in rat habitat. Along with the rainfall, a major sewer project can disrupt the rat populations in the study area. Any of these issues could cause a rise in the number of complaints to CCBH, and possibly explain the change in high density areas.

In order to address these additional questions, more data need to be collected. There are two items required to collect this additional data; more computers and additional personnel. The software to collect the data is already in use on one computer used by one person. Therefore more computers are needed on which to install this software. Most of the rat activity that comes into CCBH is during the summer months. Thus summer interns would be needed to collect this additional information in the field. With these two additional resources in place, more data can be collected and analyzed to contribute to the reduction or elimination of the Norway rats.

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APPENDICES

APPENDIX A

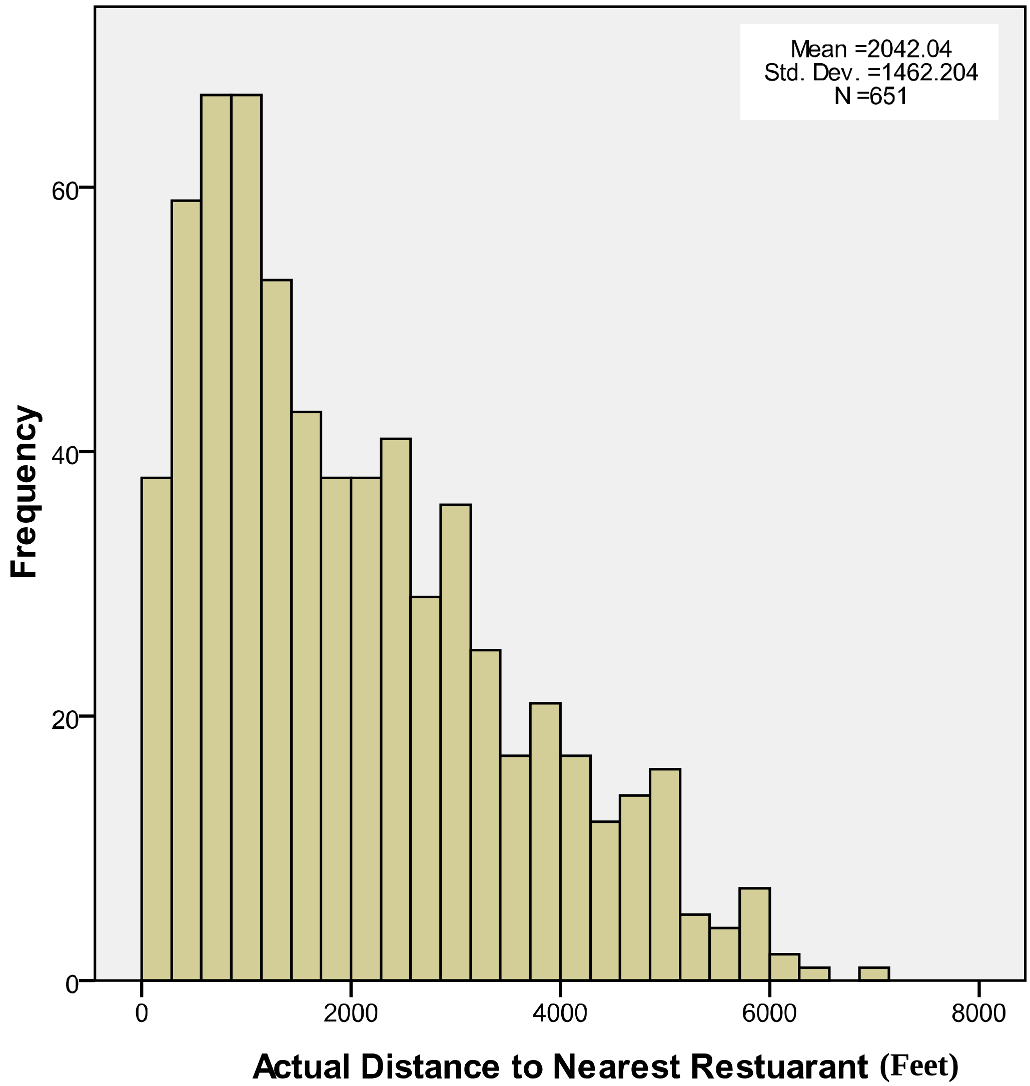

Figure 12. Histogram of number of rat sighting and distance to nearest restaurant.

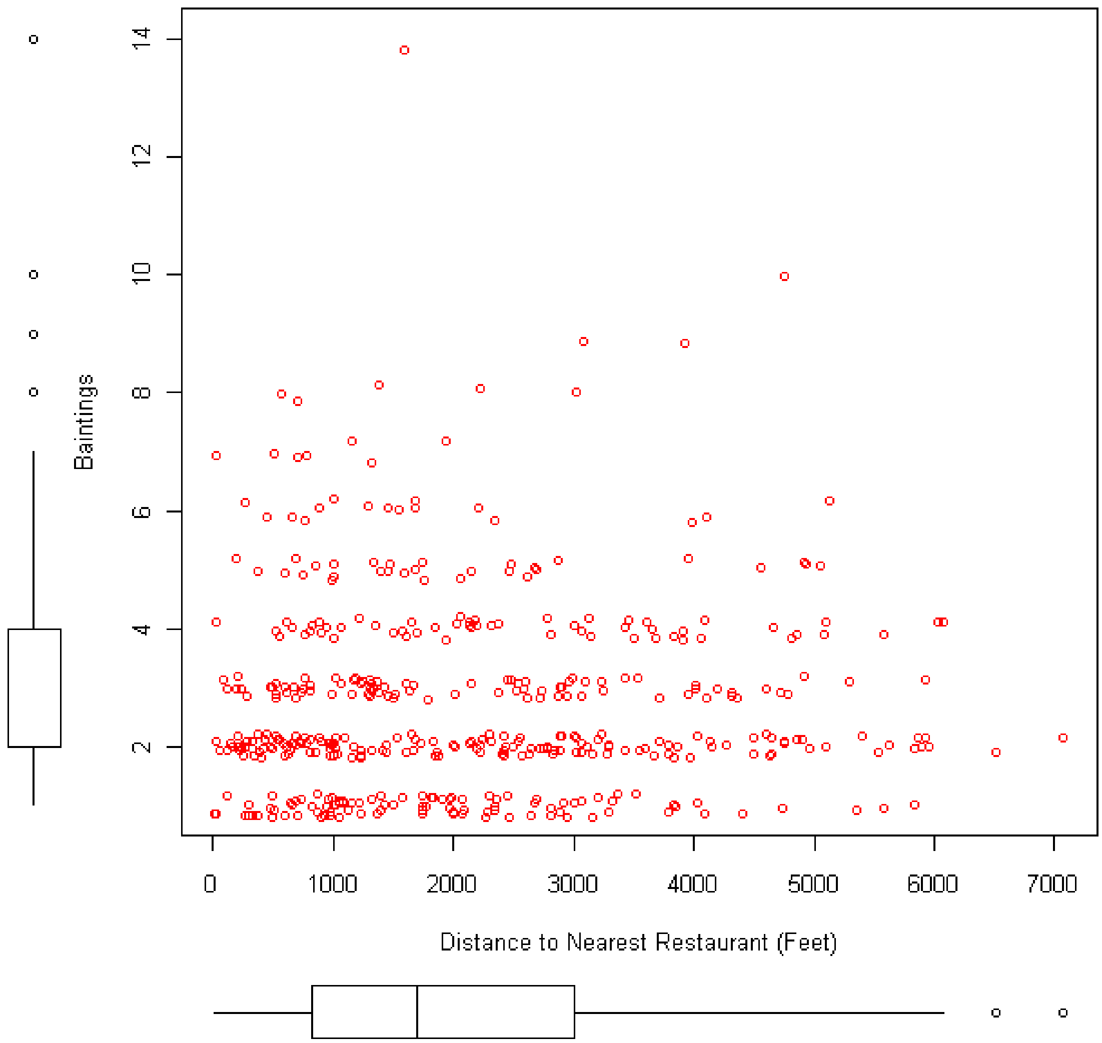

Figure 13. Scatterplot of number of rat sighting and distance to nearest restaurant.

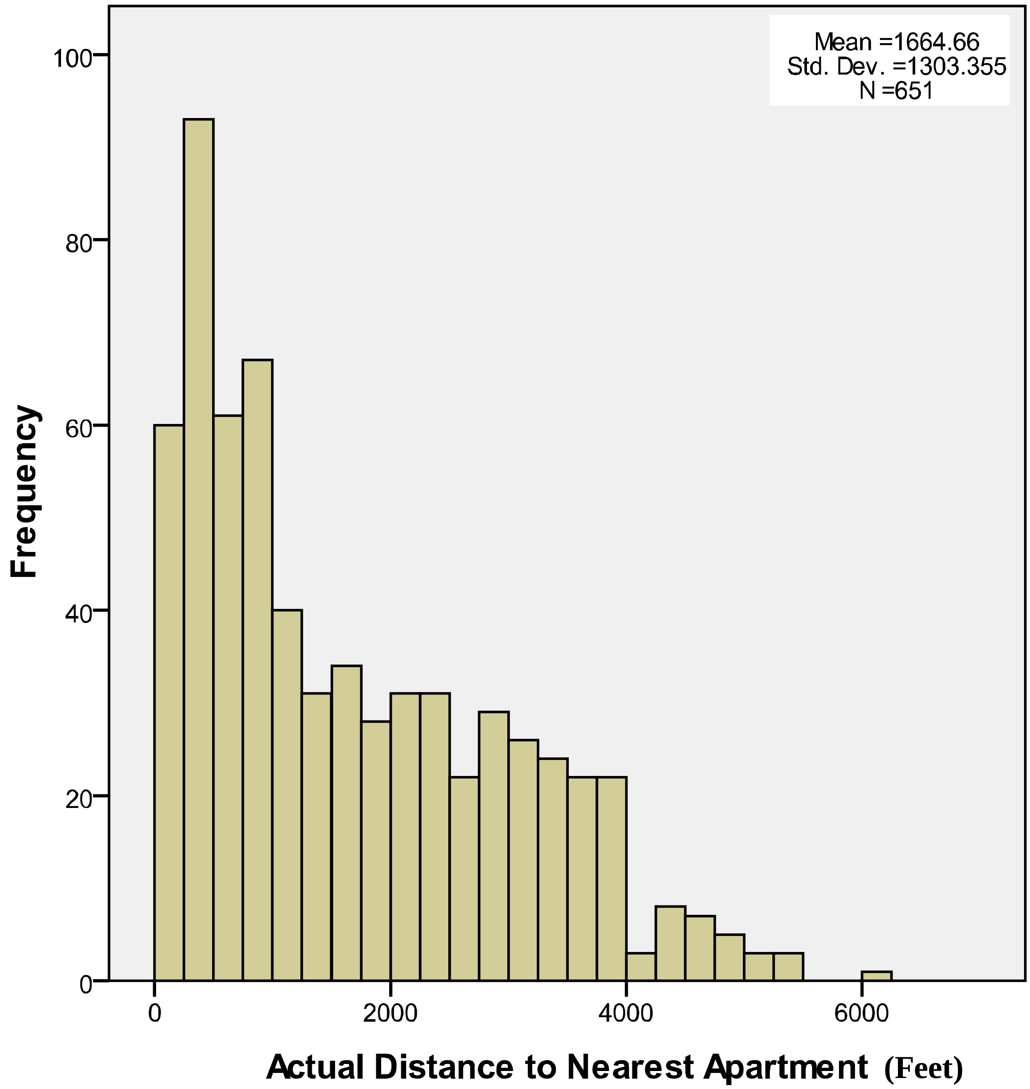

Figure 14. Histogram of number of rat sighting and distance to nearest apartment.

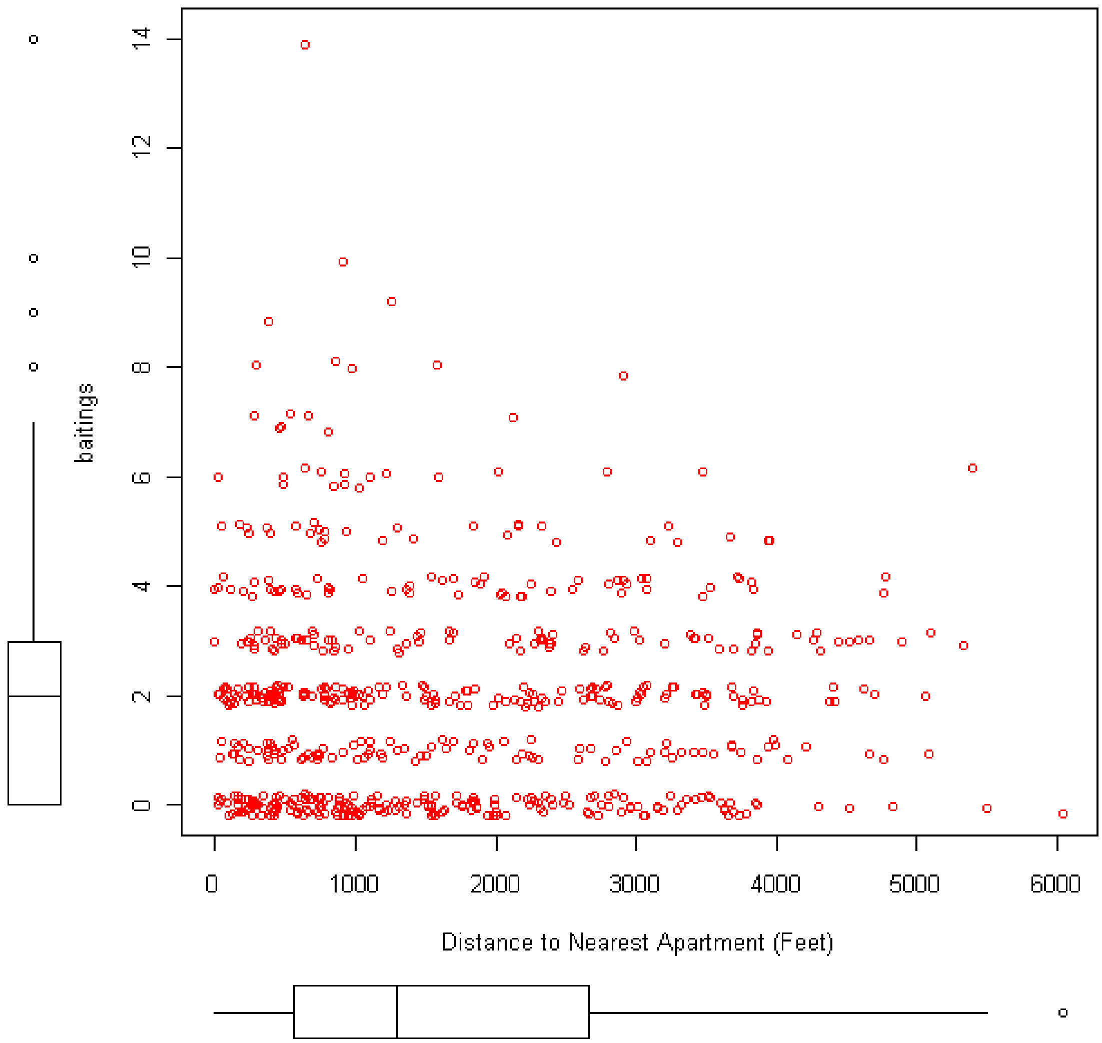

Figure 15. Scatterplot of number of rat sighting and distance to nearest apartment.

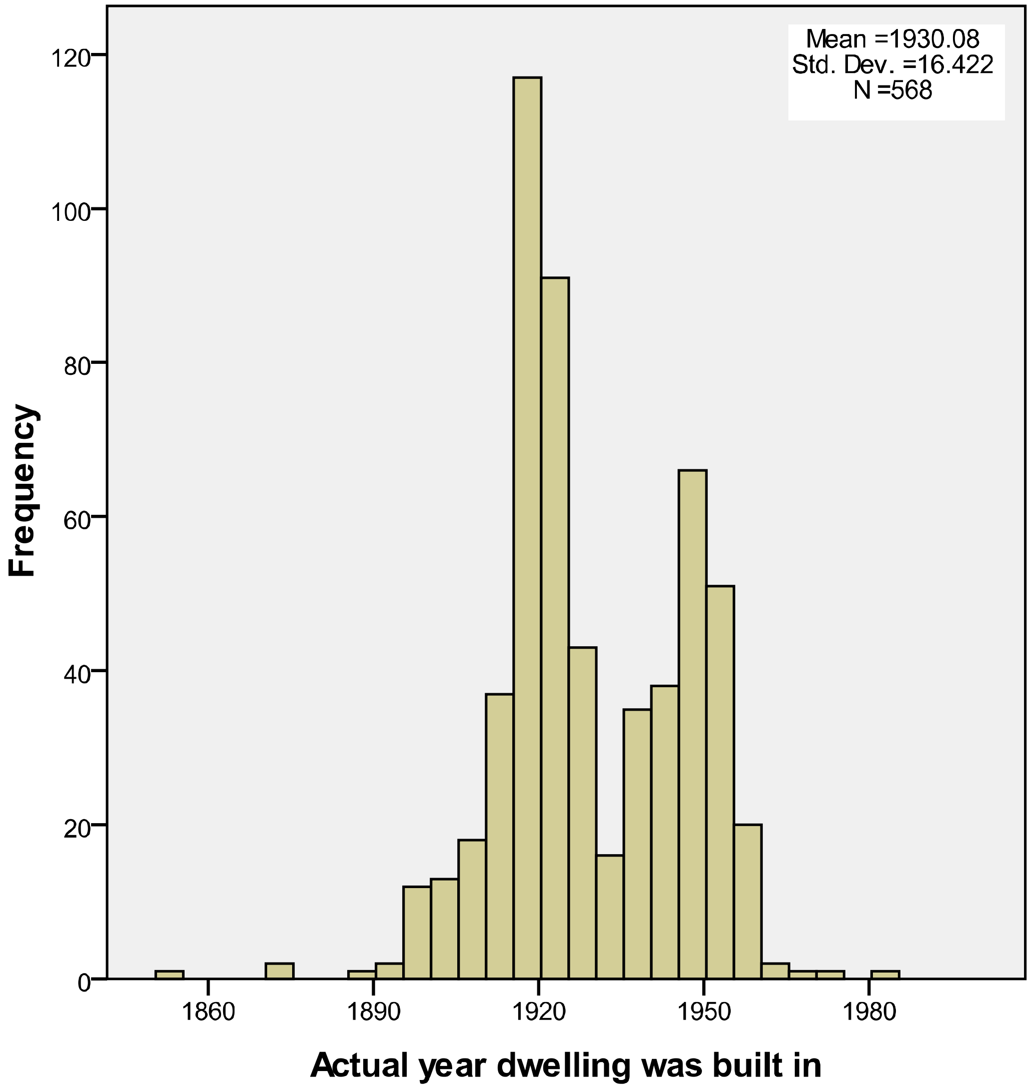

Figure 16. Histogram of number of rat sighting and year house was built.

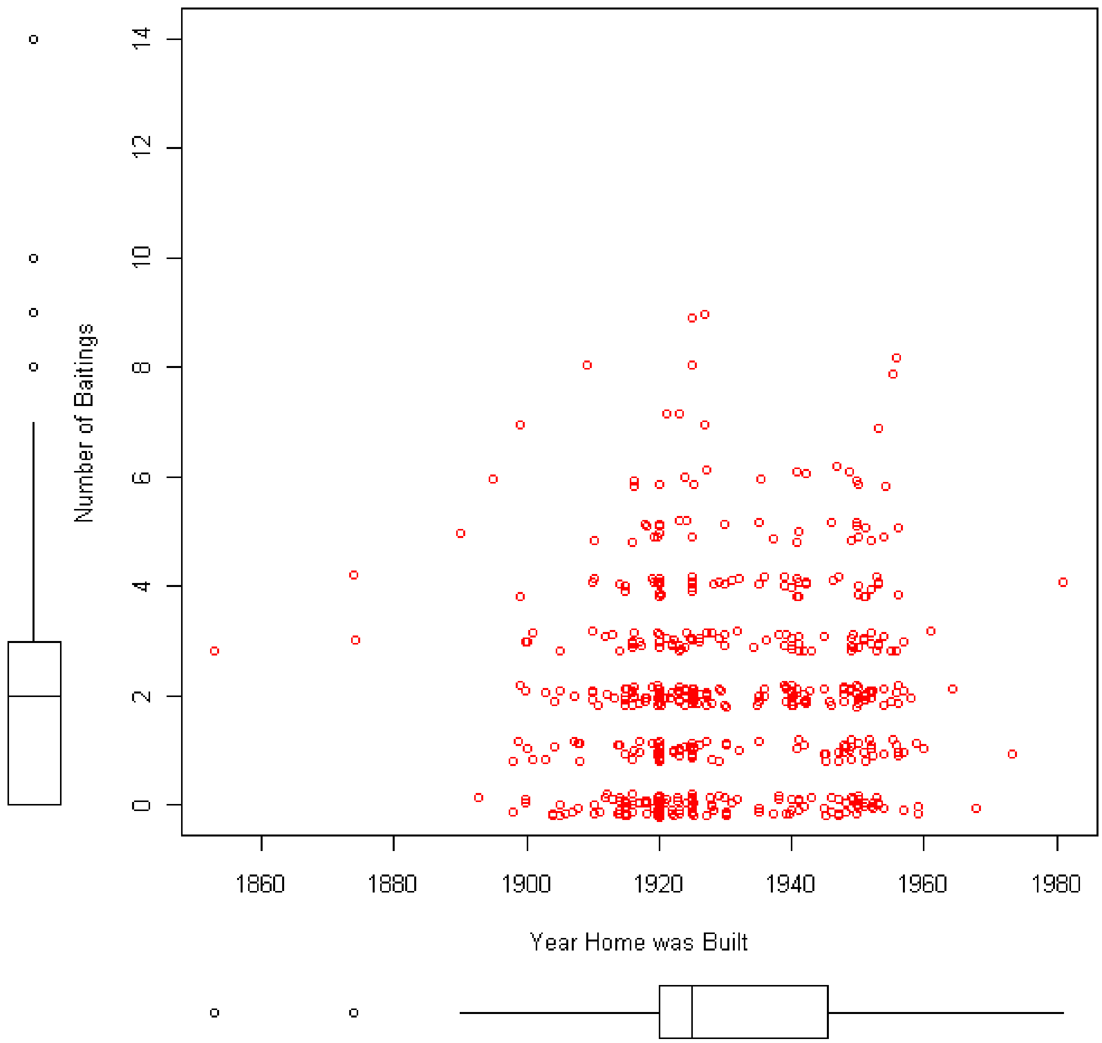

Figure 17. Scatterplot of number of rat sighting and year house was built.

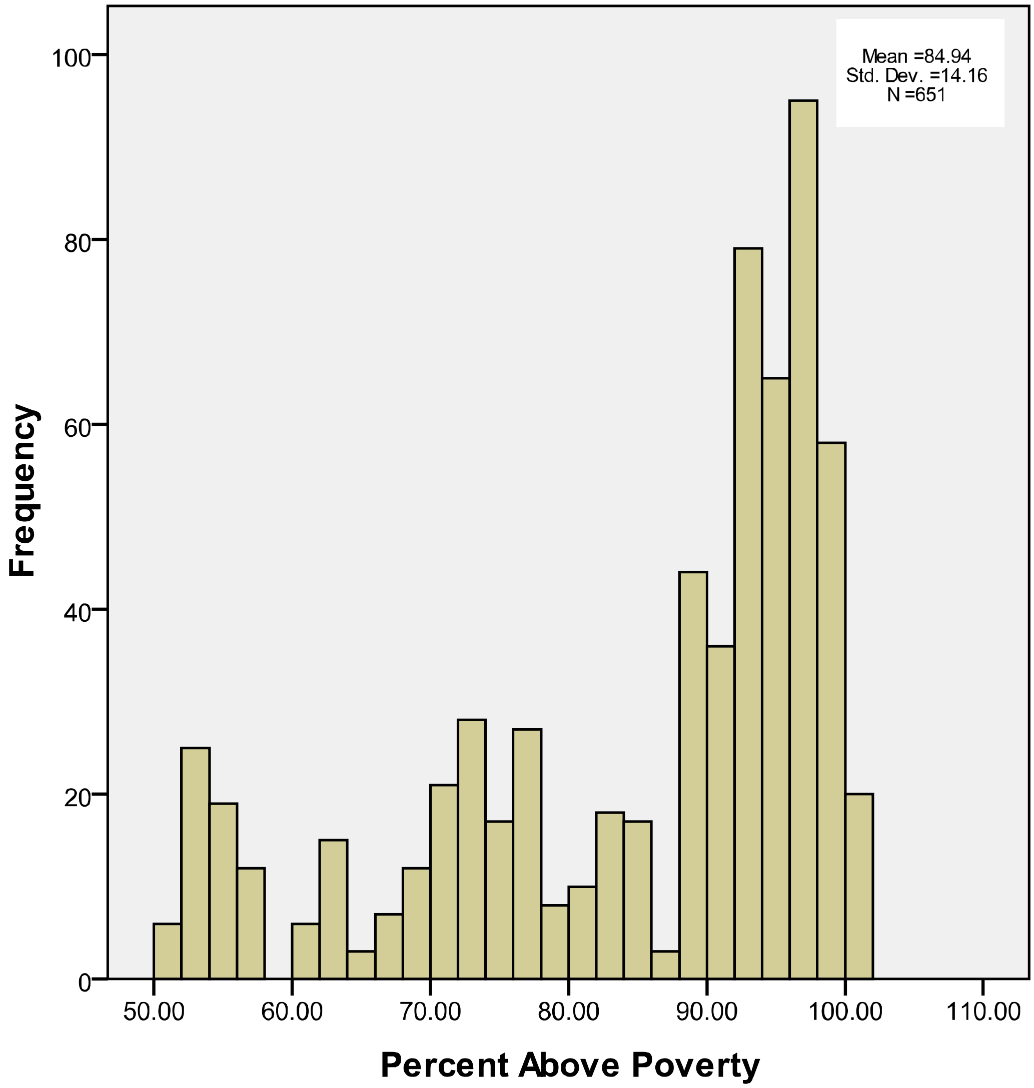

Figure 18. Histogram of number of baiting visits and percent of people in census block group living above poverty.

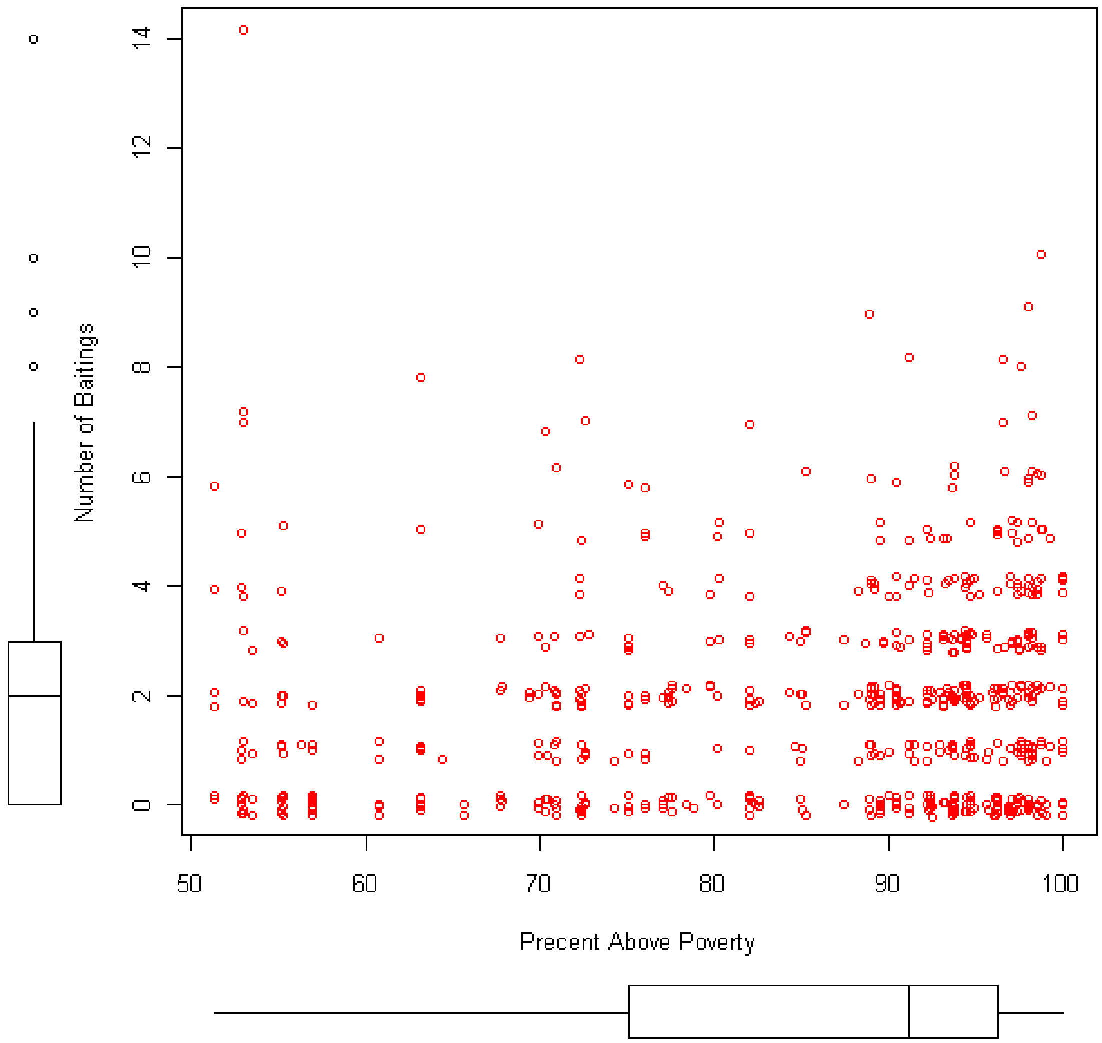

Figure 19. Scatterplot of the number of baiting visits and percent of people in census block group living above poverty.

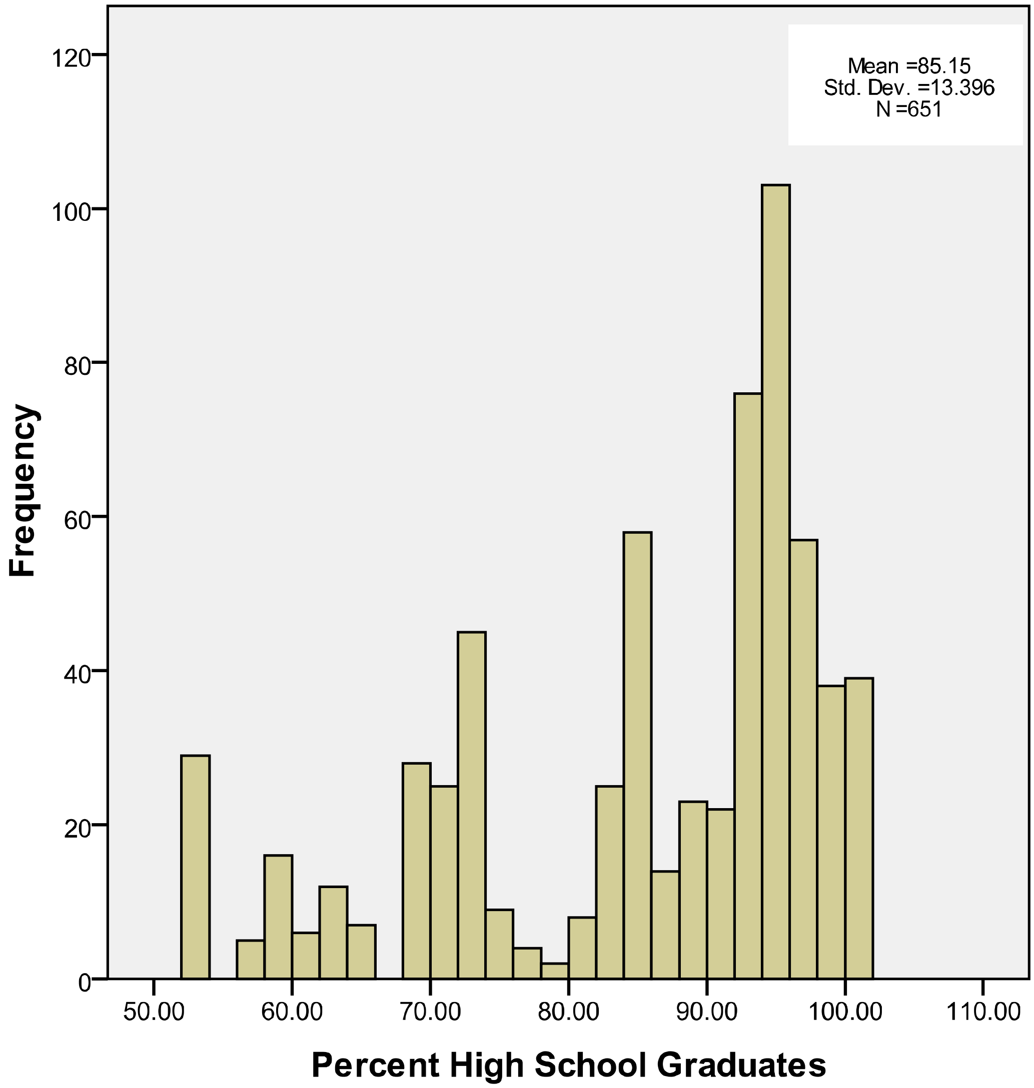

Figure 20. Histogram of number of rat sightings and percent of people in census block group with high school diploma.

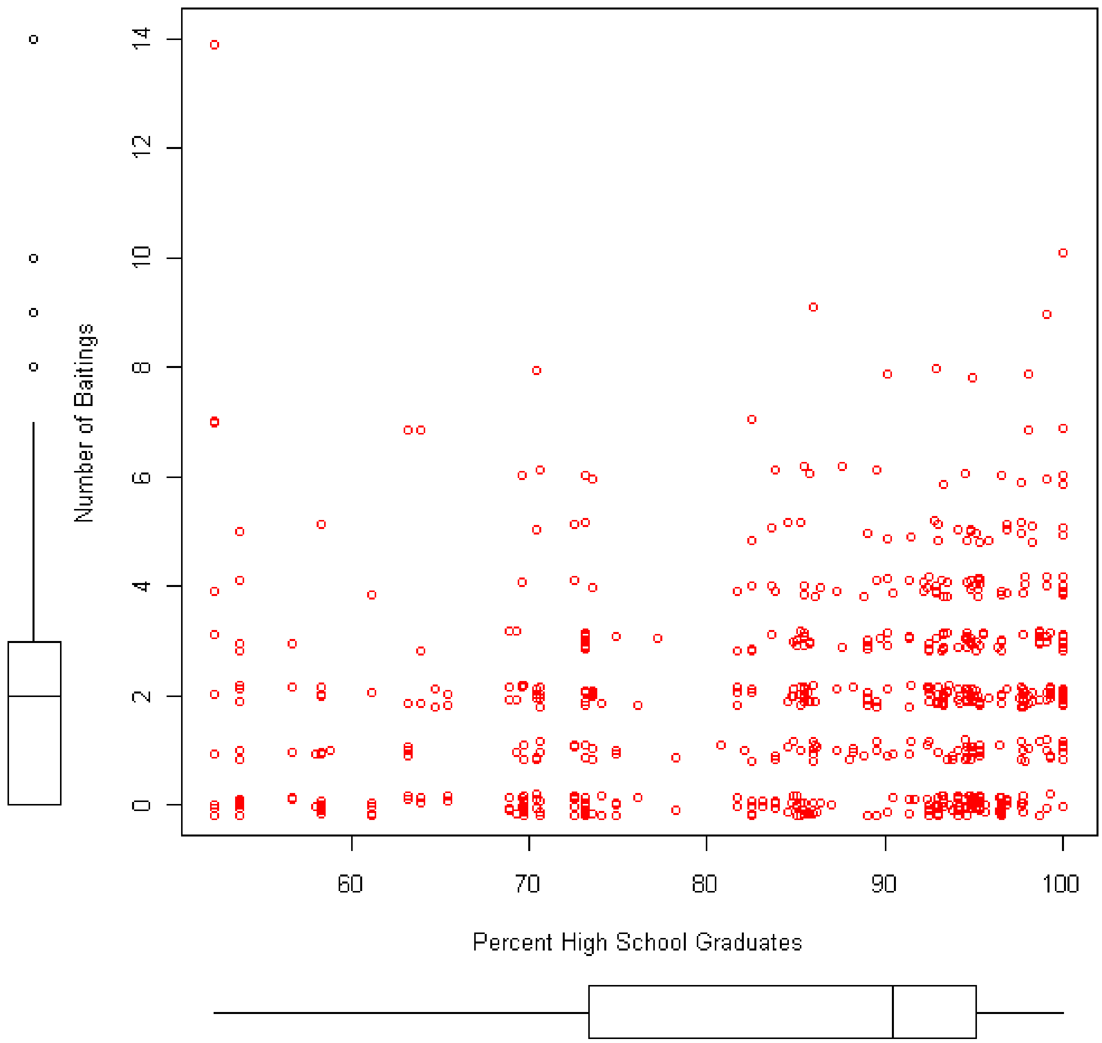

Figure 21. Scatterplot of number of rat sightings and percent of people in census block group with high school diploma.

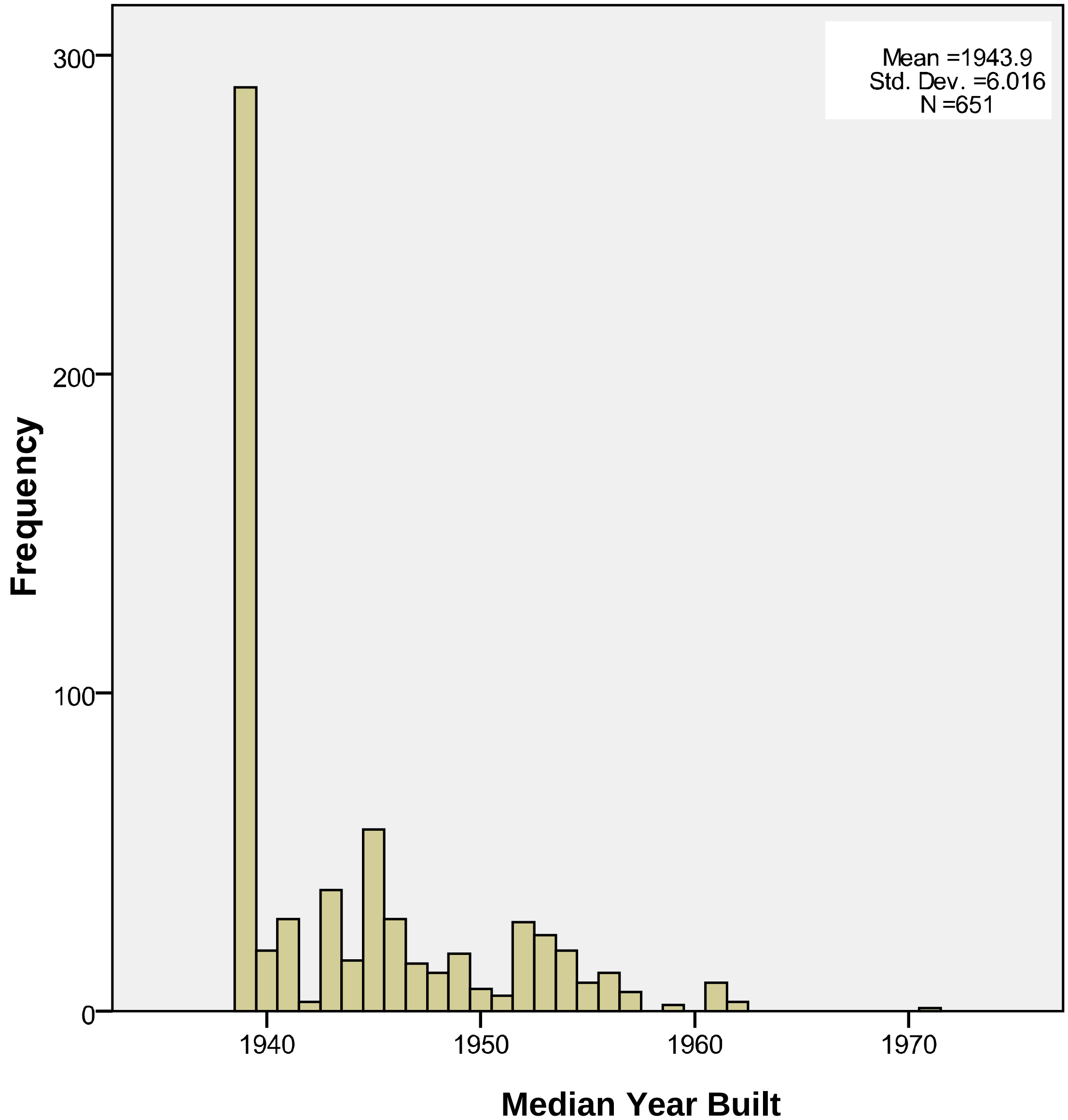

Figure 22. Histogram of number of rat sightings and median year homes were built in census block group.

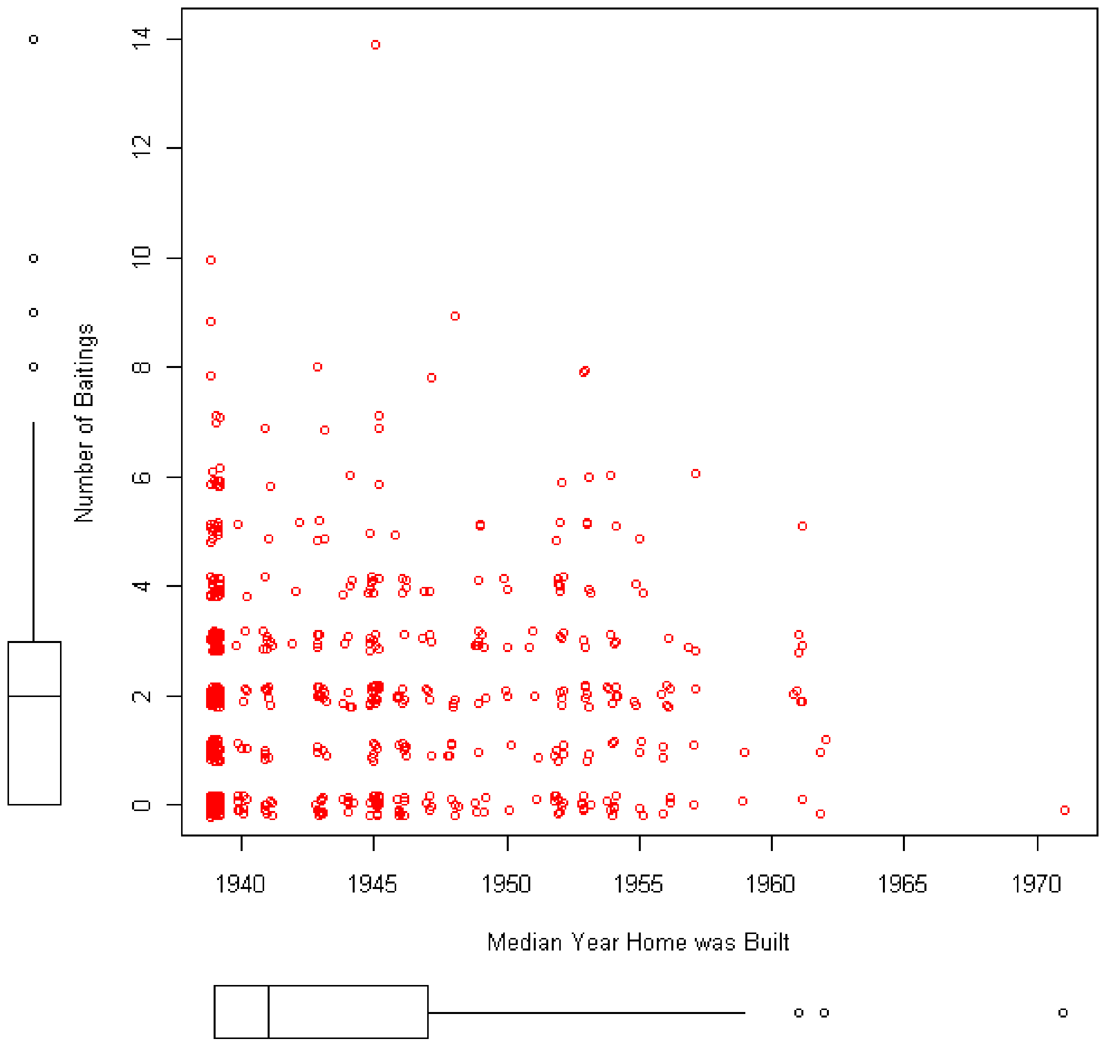

Figure 23. Scatterplot of number of rat sightings and median year homes were built in census block group.

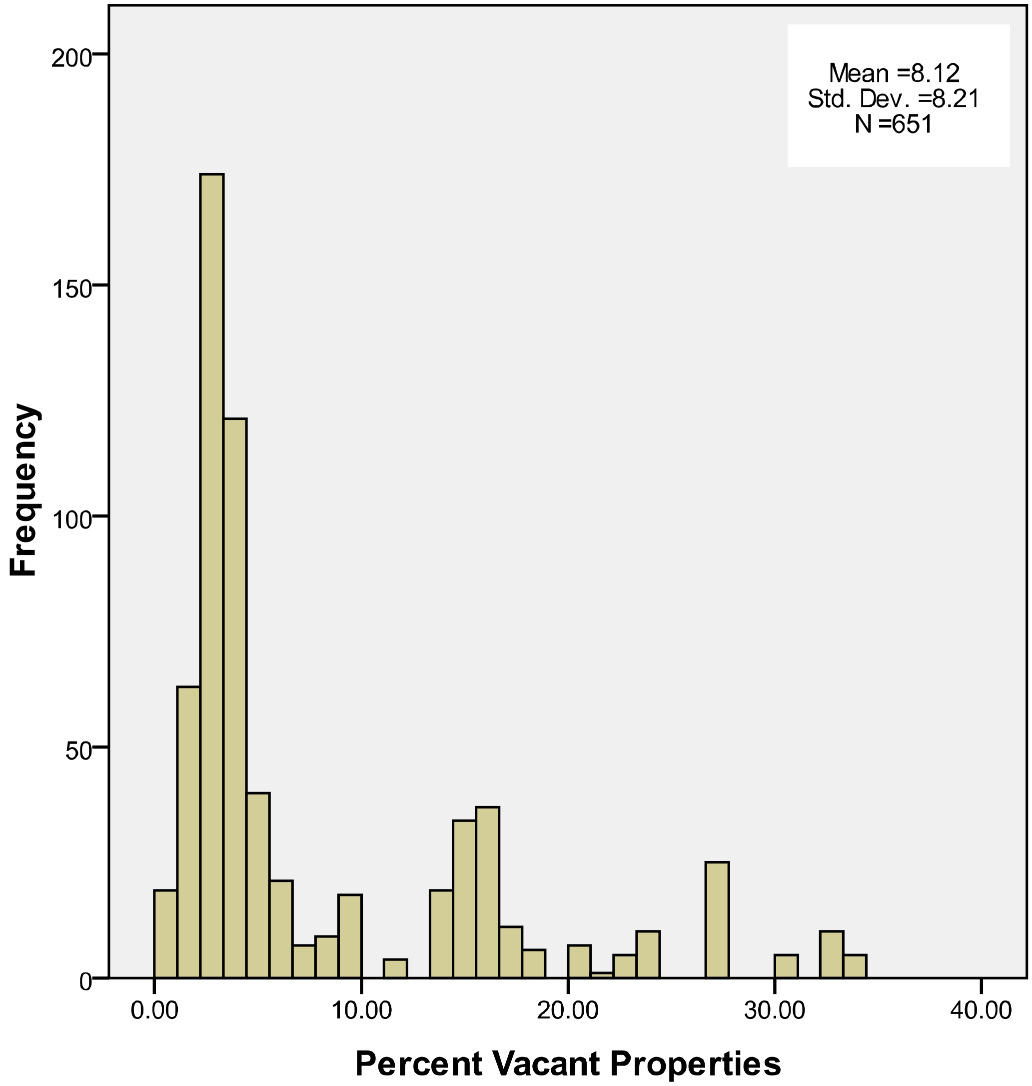

Figure 24. Histogram of number of rat sightings and percent of vacant properties in census block group.

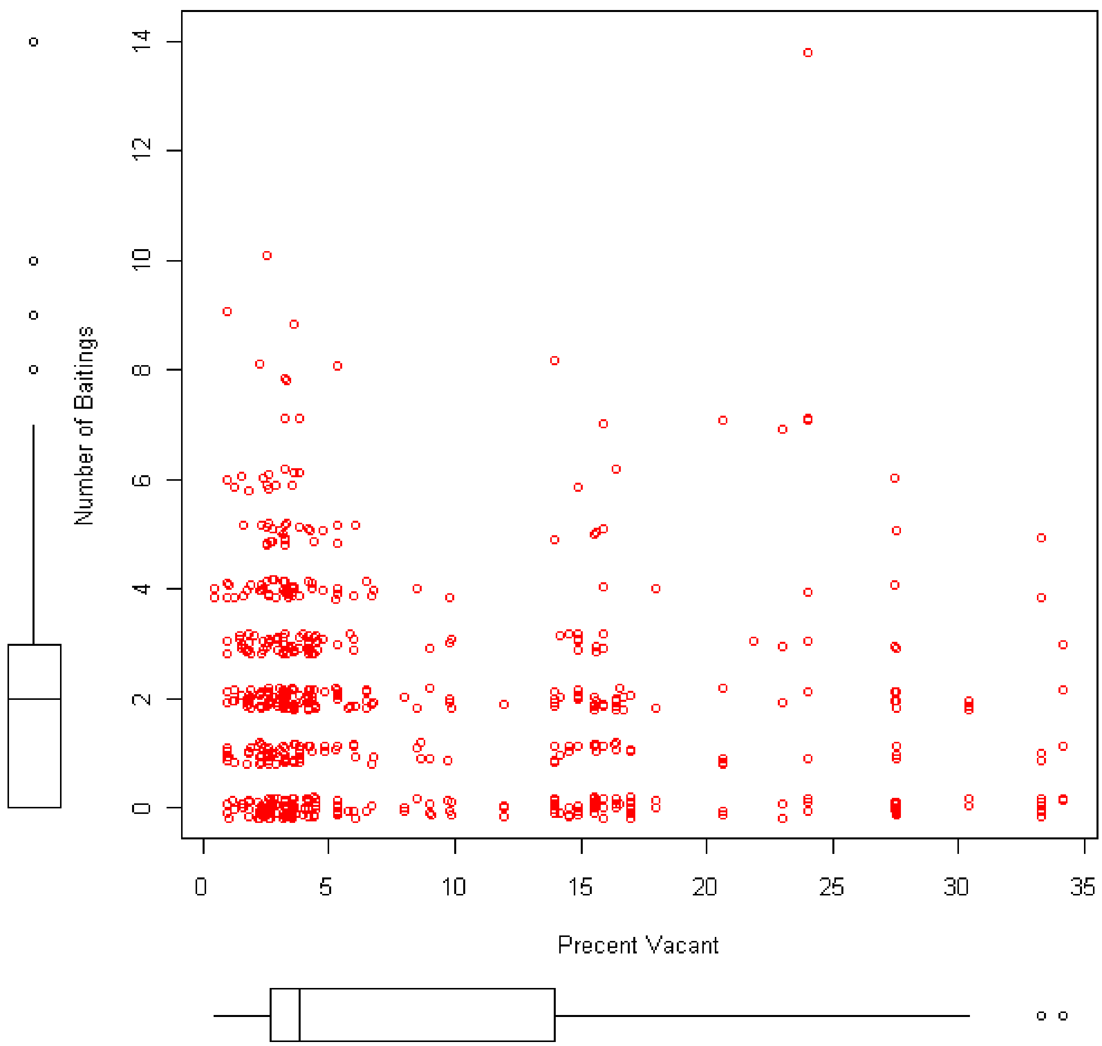

Figure 25. Scatterplot of number of rat sightings and percent of vacant properties in census block group.

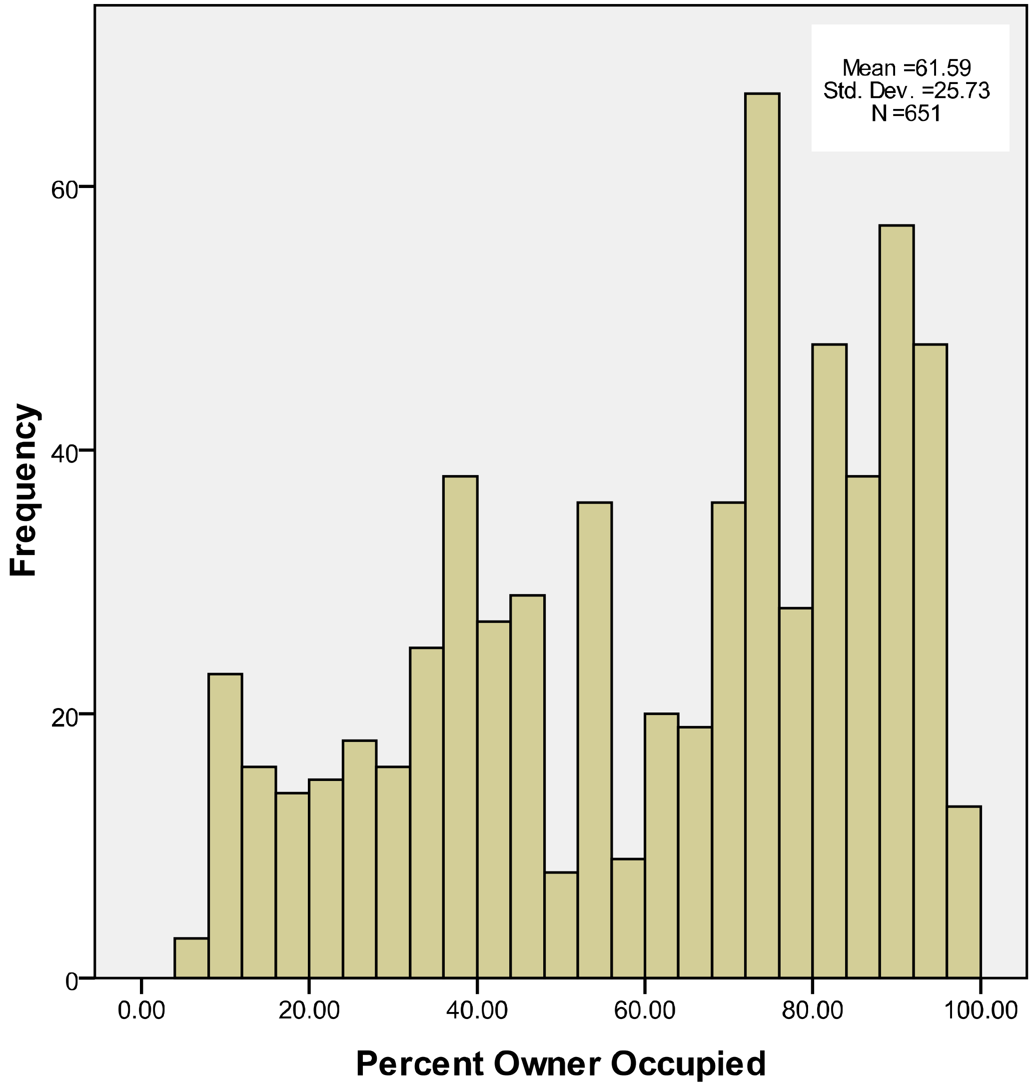

Figure 26. Histogram of number of rat sightings and percent of owner occupied properties in census block group.

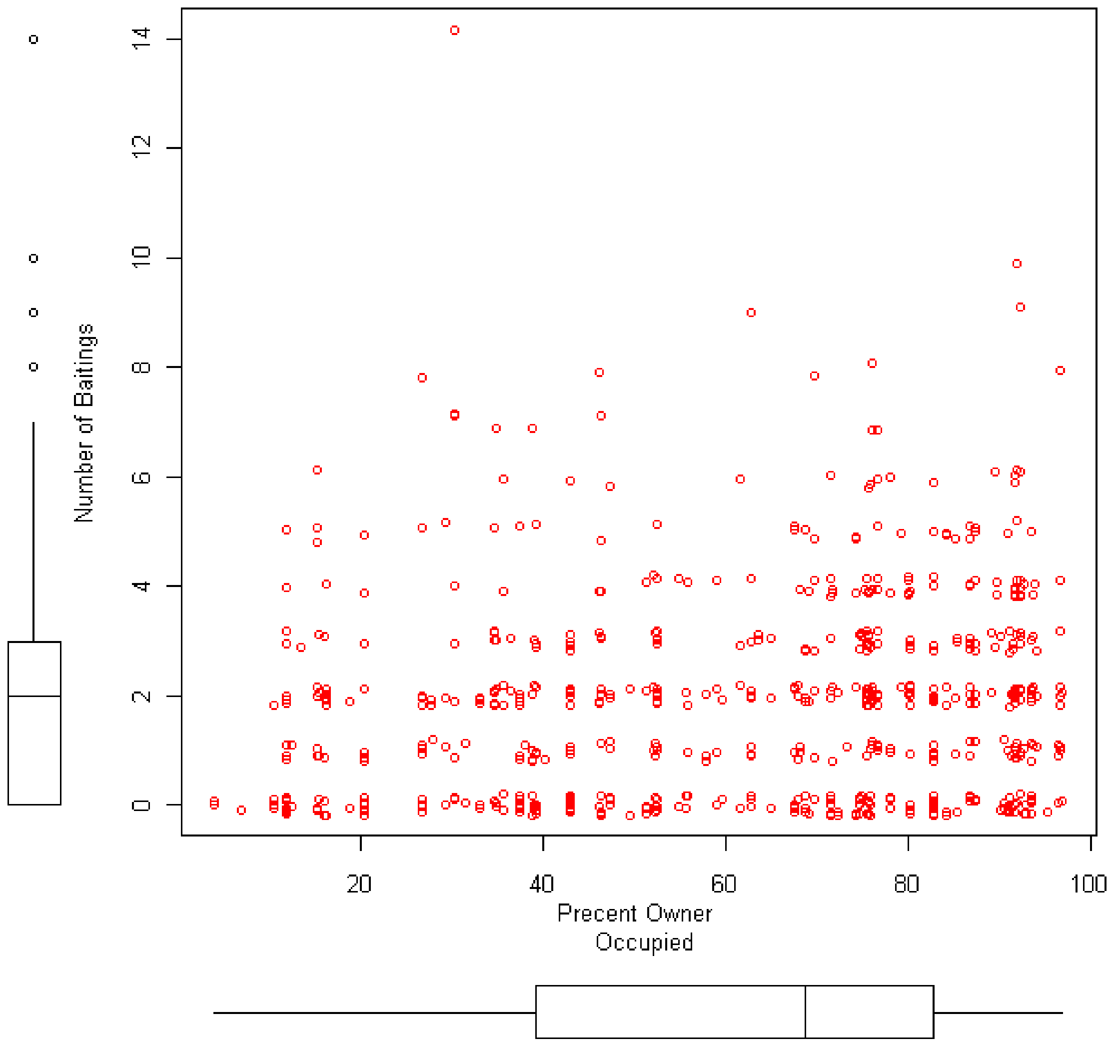

Figure 27. Scatterplot of number of rat sightings and percent of owner occupied properties in census block group.

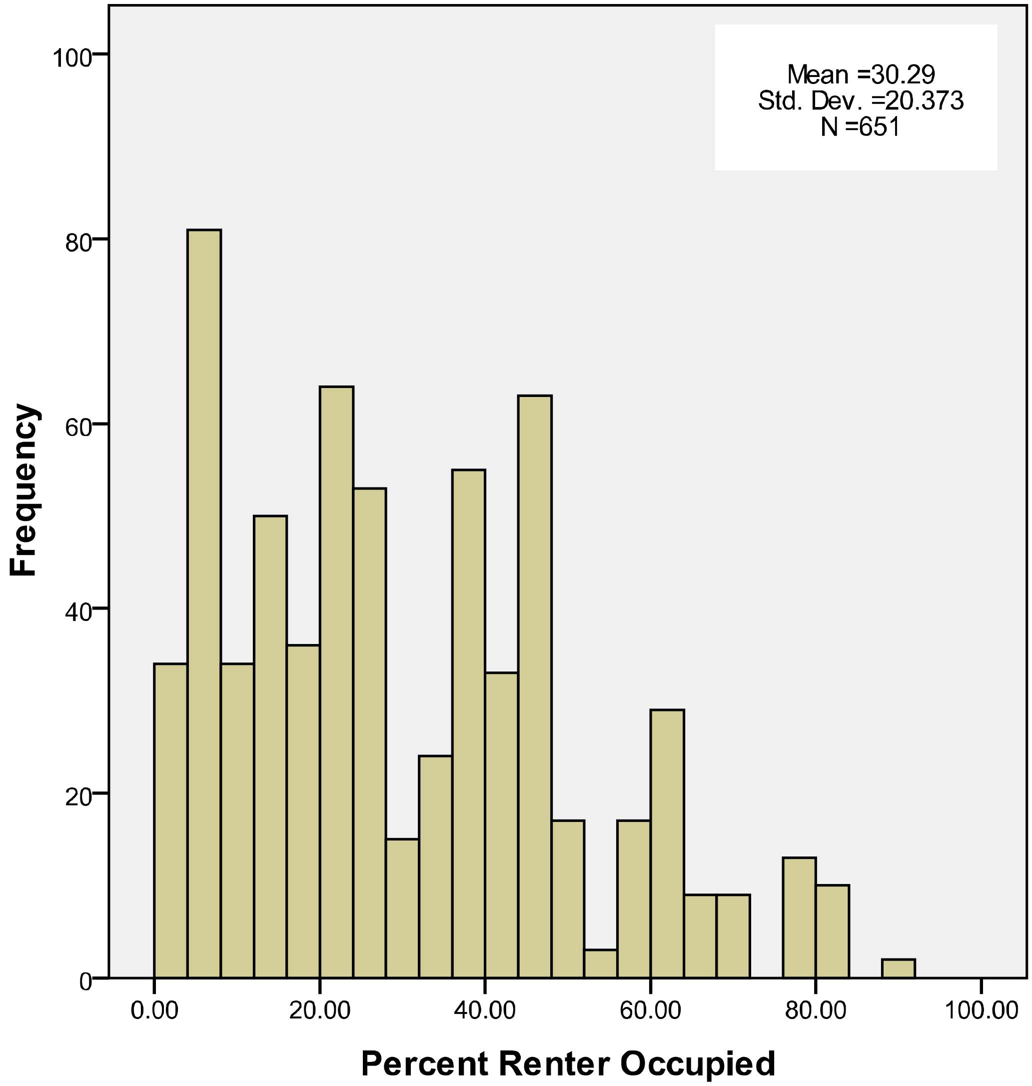

Figure 28. Histogram of number of rat sightings and percent of renter occupied properties in census block group.

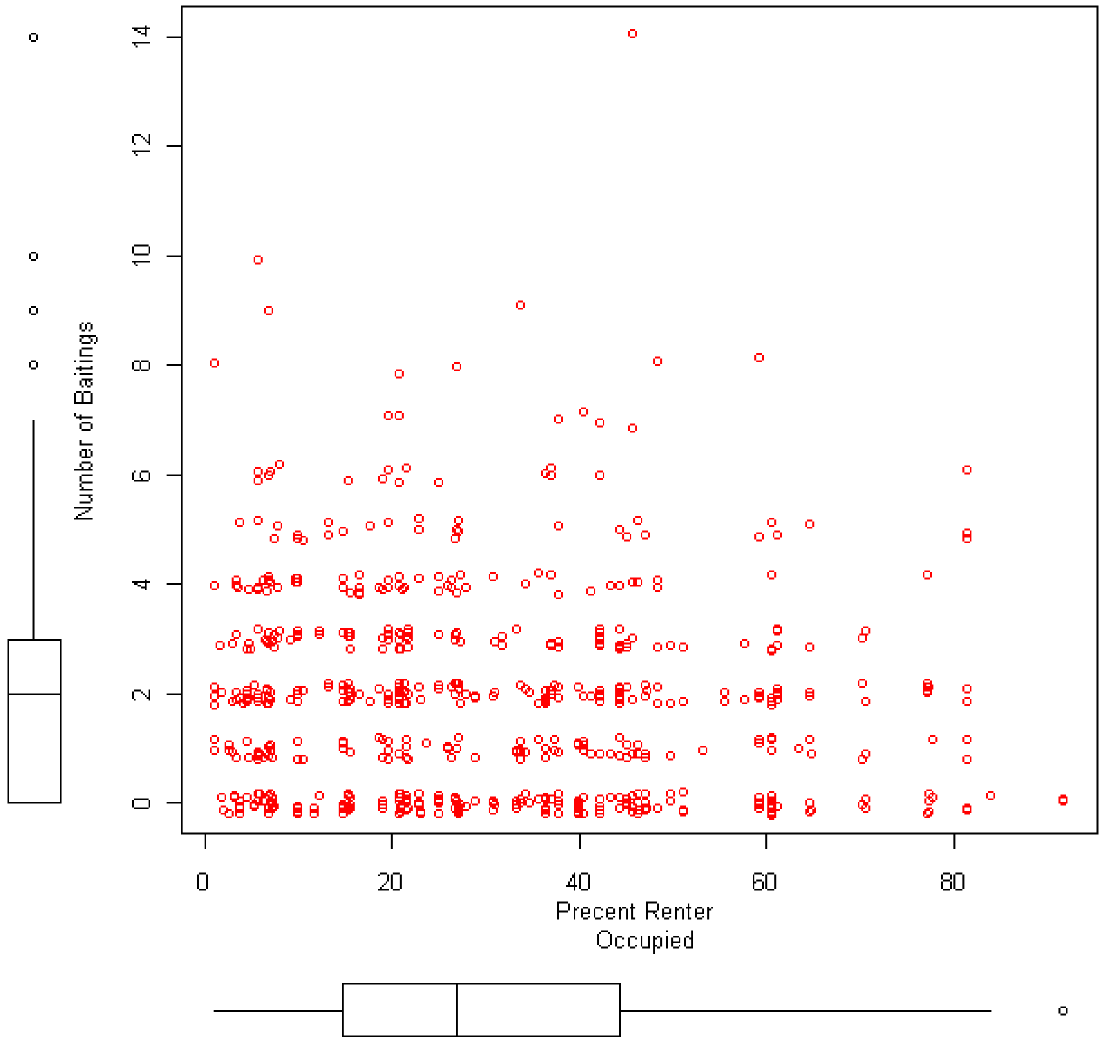

Figure 29. Scatterplot of number of rat sightings and percent of renter occupied properties in census block group.

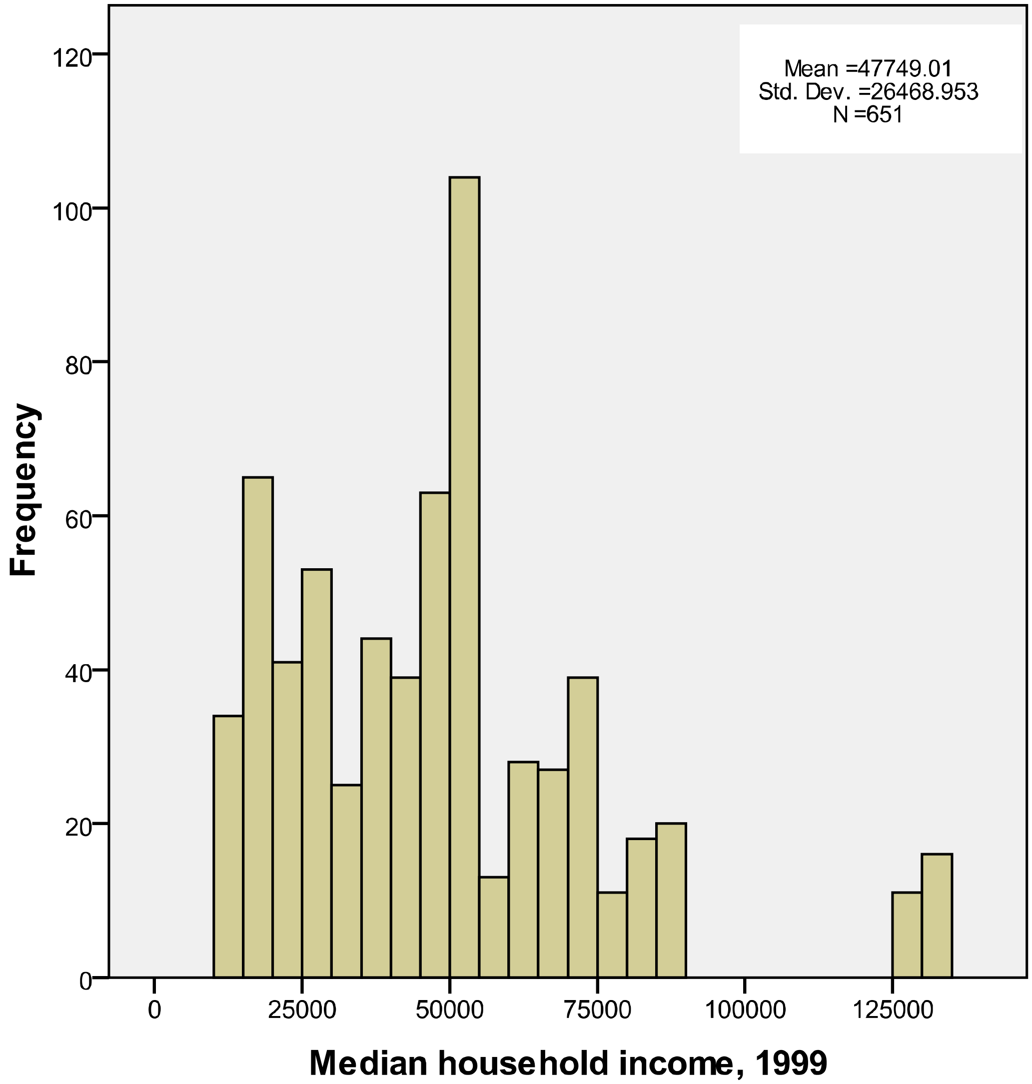

Figure 30. Histogram of number of rat sightings median household income in census block group.

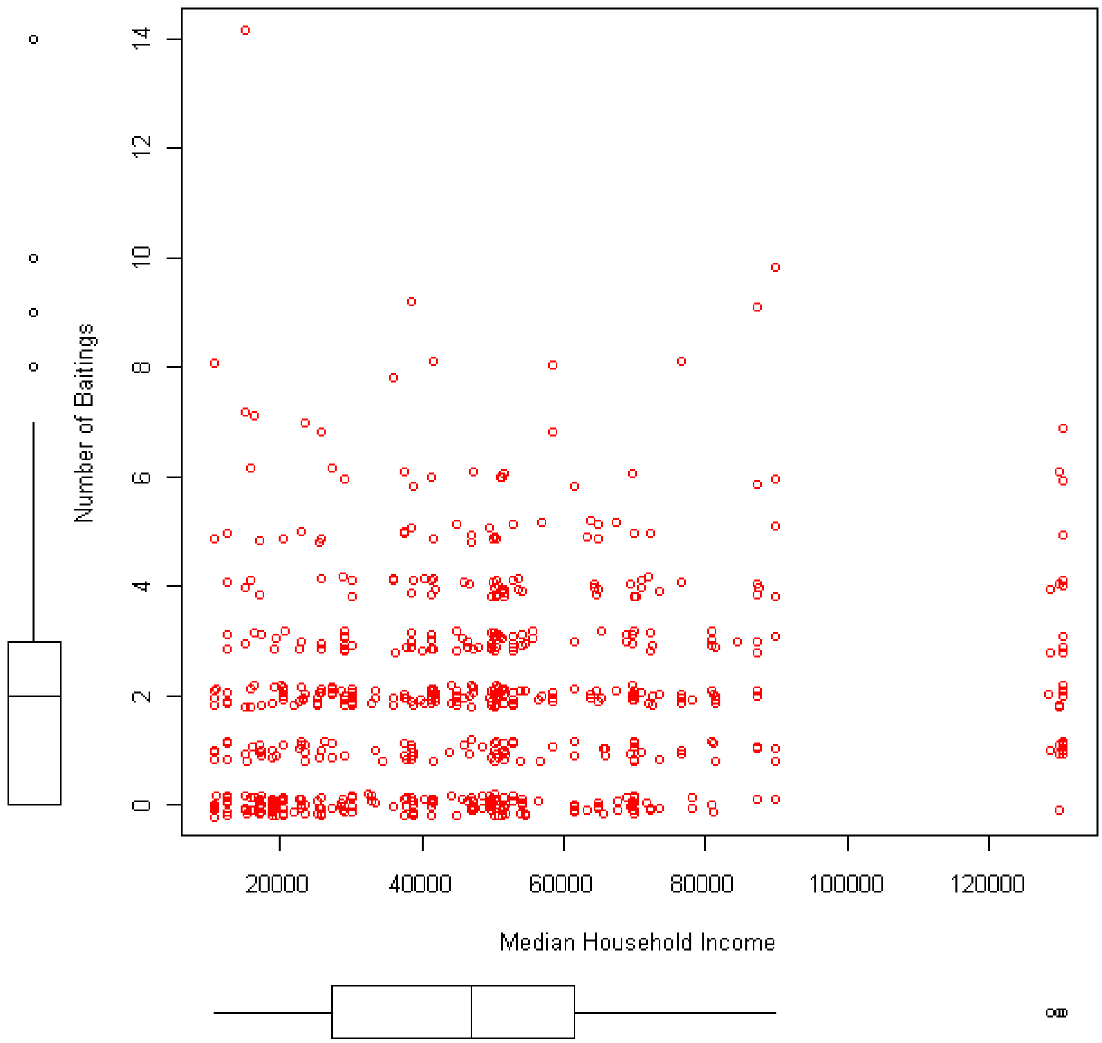

Figure 31. Scatterplot of number of rat sightings median household income in census block group.

APPENDIX B

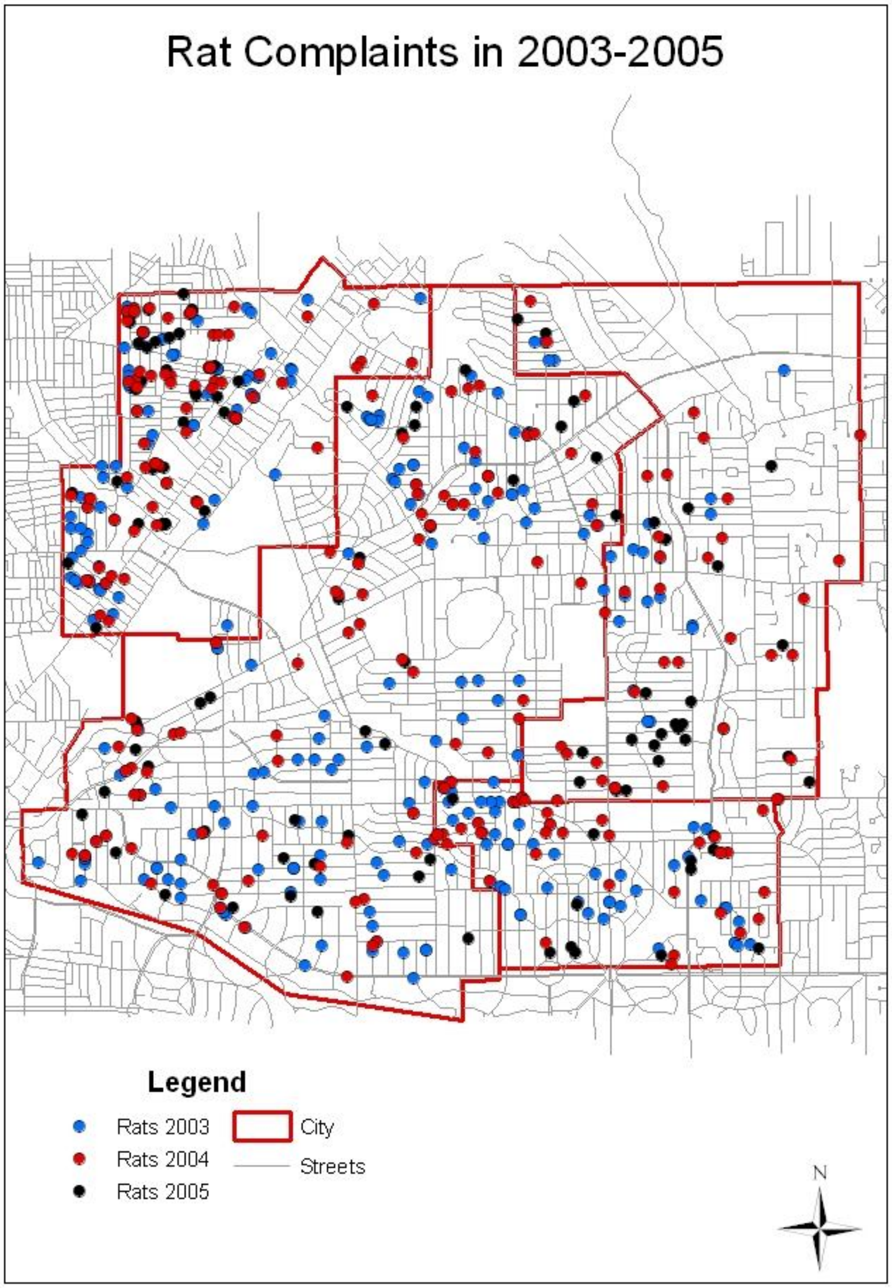

Figure 32. 2003 (blue), 2004 (red), and 2005 (black) legitimate rat complaints

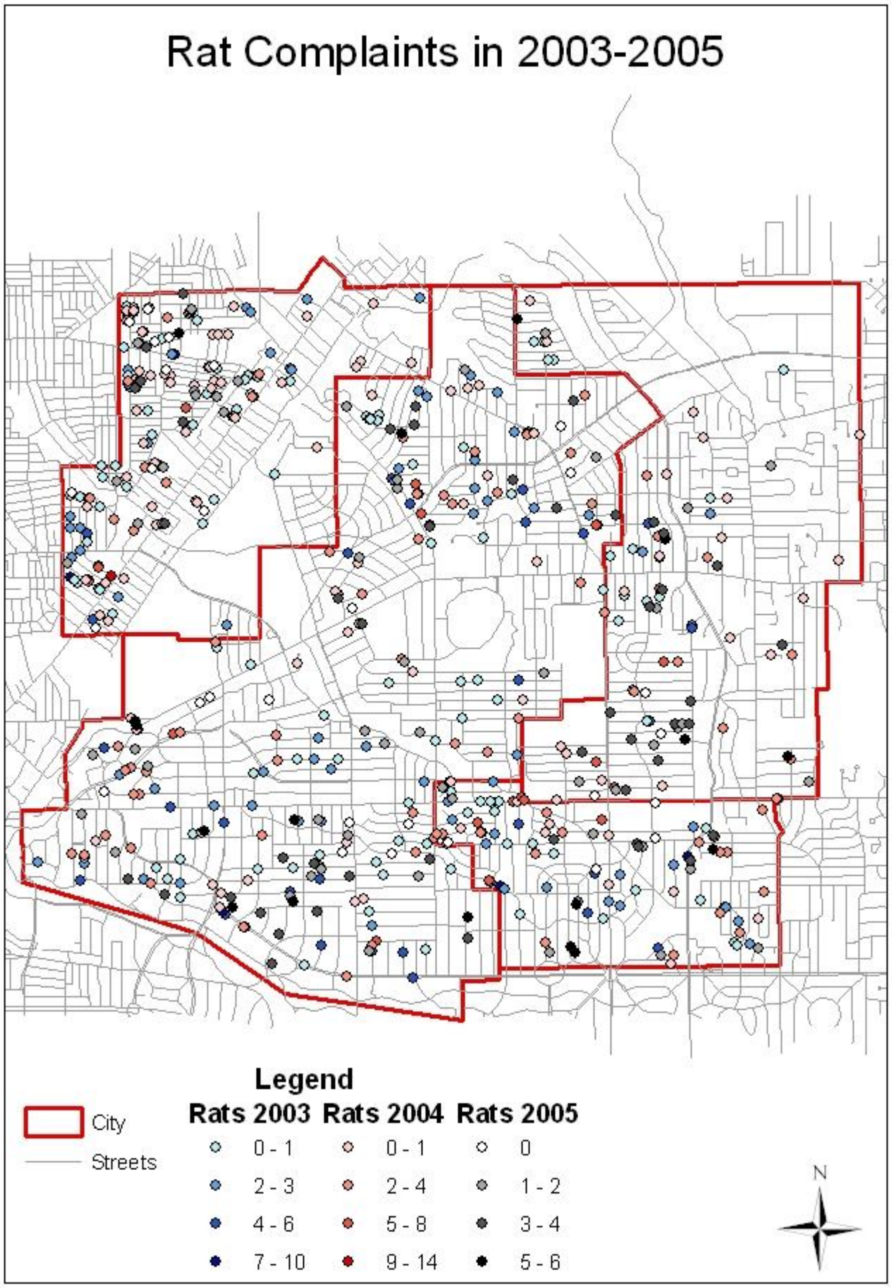

Figure 33. Number of Baiting Visits by Year.

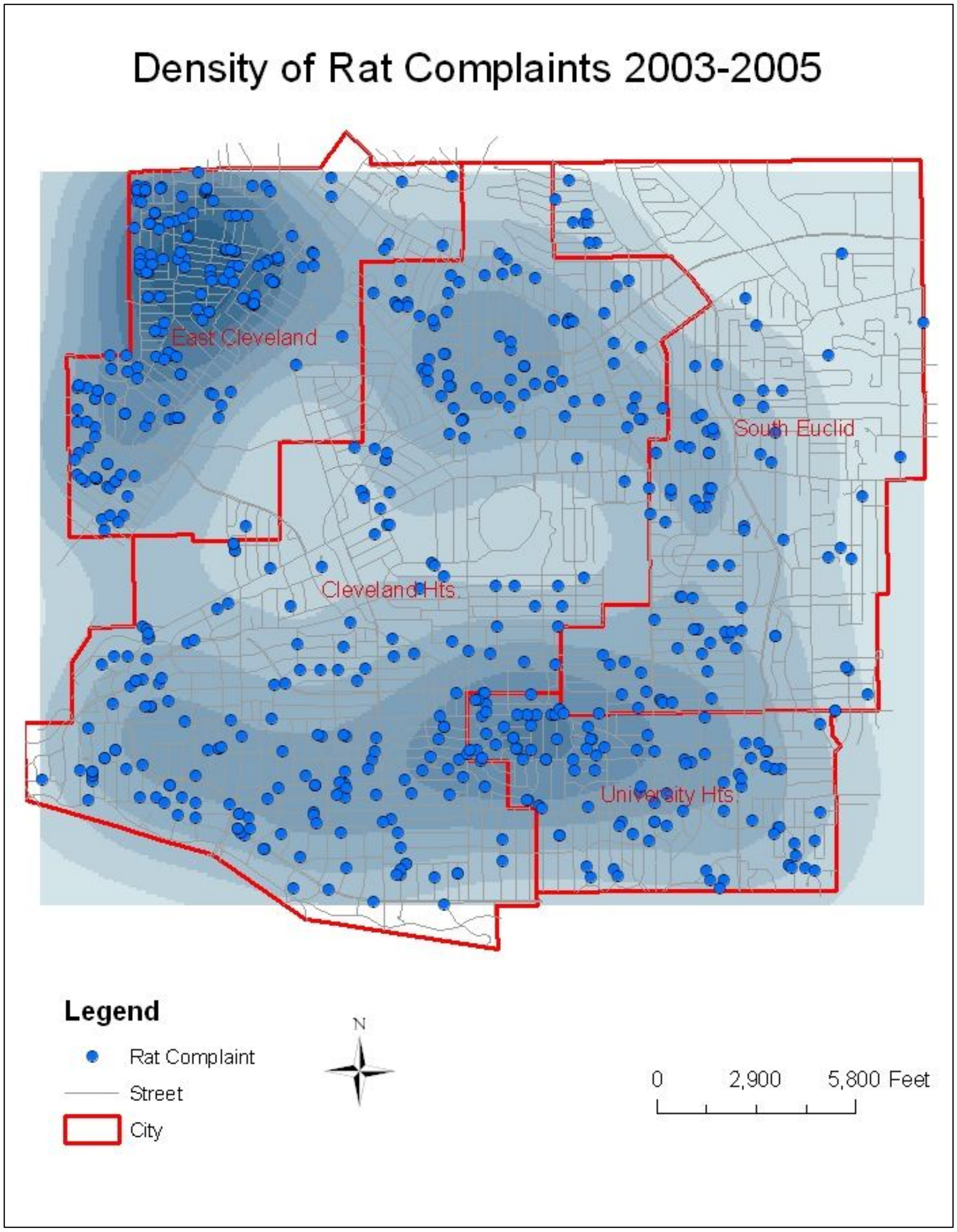

Figure 34. Density of Rat complaints for 2003-2005.

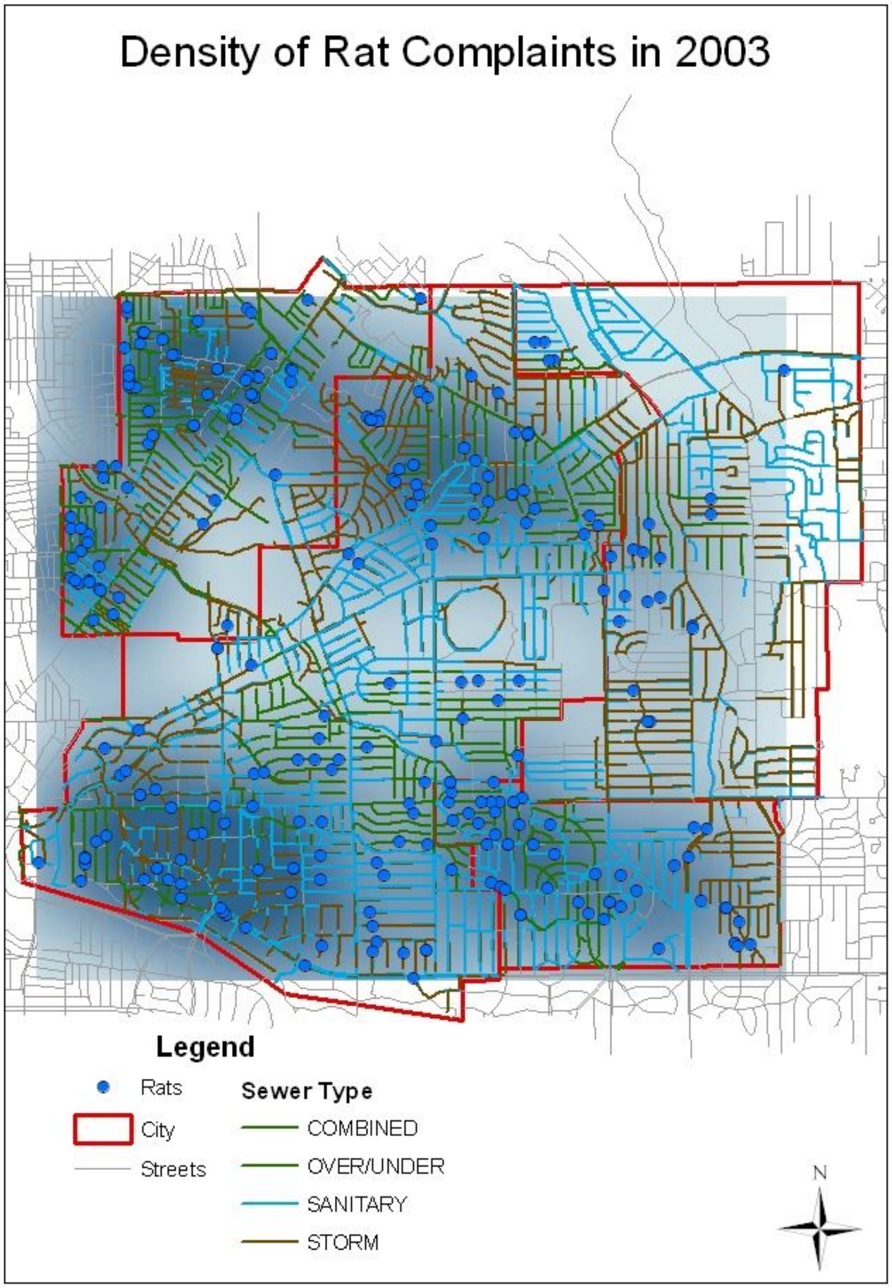

Figure 35. Density of rat complaints in 2003 with types of sewers. The green lines are either the combined or over/under design, blue lines are the storm sewers, and brown lines are sanitary sewers.

Figure 36. Density of rat complaints in 2004 with types of sewers.

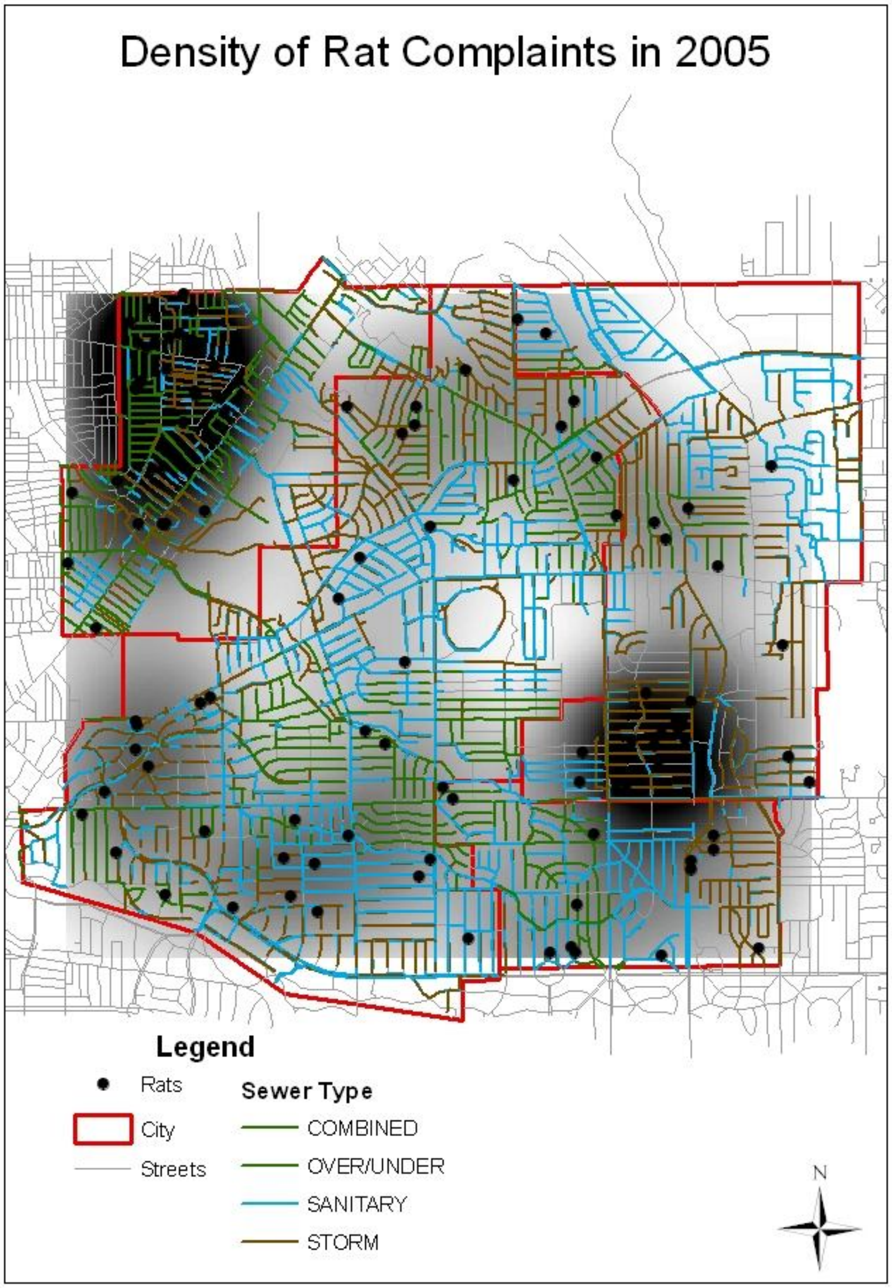

Figure 37. Density of rat complaints in 2005 with types of sewers.

Table XII. Field Definitions for Residential Building

OCCUPANCY	**1**	1 Family	**3**	3 Family
	2	2 Family	**4**	4 Family
STYLE	**RAN**	Ranch	**ELE**	Elevator
	BUN	Bungalow	**GAR**	Garden
	COL	Colonial	**TWN**	Townhouse
	SPL	Split-Level	**4P**	Four-Plex
	BIL	Bi-Level	**DUP**	Duplex
	CON	Contemporary	**3FM**	Three Family
	WU	Walk-up	**OTH**	Other
QUALITY	CONSTRUCTION QUALITY			
	AA	Excellent +	**C-**	Average
	A+	Excellent	**D+**	Poor +
	A-	Very Good	**D-**	Poor
	B+	Good +	**E+**	Very Poor +
	B-	Good +	**E-**	Very Poor
	C+	Average +		
CONDITION	**EX**	Excellent	**F**	Fair
	VG	Very Good	**PR**	Poor
	G	Good	**VP**	Very Poor
	AVG	Average		
BASEMENT TYPE	**BMT**	Basement	**CWL**	Crawl
	SLB	Slab	**WLK**	Walk-out
YEAR BUILT	Actual year dwelling was built in			
GARAGE TYPE	**DET**	Detached	**BMT**	Basement
	ATT	Attached	**N**	None
	BLT	Built-In		