Article title:

Characteristics of the Urban Sewer System and Rat Presence in Seattle

Journal name:

Urban Ecosystems

Author Information

1. Guo, Xiaocong (corresponding author)
   * The University of British Columbia, School of Population and Public Health, Vancouver, British Columbia, V6T 1Z3, Canada
   * Email: [xiaocong@student.ubc.ca](mailto:xiaocong@student.ubc.ca)
   * Address: 2206 E Mall, Vancouver, BC V6Y 1Z3, Canada
   * Phone: 1-778-321-8907
   * ORCID: 0000-0002-7608-025X
2. Lee, Michael J.
   * The University of British Columbia, School of Population and Public Health, Vancouver, British Columbia, V6T 1Z3, Canada
   * Canadian Wildlife Health Cooperative, Animal Health Centre, Abbotsford, British Columbia, V3G 2M3, Canada
   * ORCID: 0000-0001-7223-3258
3. Byers, Kaylee A.
   * The University of British Columbia Faculty of Graduate Studies, Interdisciplinary Studies, Vancouver, British Columbia, V6T 1Z3, Canada
   * Canadian Wildlife Health Cooperative, Animal Health Centre, Abbotsford, British Columbia, V3G 2M3, Canada
   * ORCID: 0000-0003-4008-4416
4. Helms, Leah
   * Public Health – Seattle & King County, Community, Toxics, Science and Policy Section, Solid Waste, Rodent, and Zoonotic Disease Programs, Seattle, Washington, 98104, USA
5. Weinberger, Kate R.
   * The University of British Columbia, School of Population and Public Health, Vancouver, British Columbia, V6T 1Z3, Canada
   * ORCID: 0000-0001-6001-0081
6. Himsworth, Chelsea G.
   * British Columbia Ministry of Agriculture, Animal Health Centre, Abbotsford, British Columbia, V3G 2M3, Canada
   * Canadian Wildlife Health Cooperative, Animal Health Centre, Abbotsford, British Columbia, V3G 2M3, Canada
   * The University of British Columbia, School of Population and Public Health, Vancouver, British Columbia, V6T 1Z3, Canada
   * ORCID: 0000-0002-8081-9555

# Supplementary

Table 1 Summary of the variables included in the analyses evaluating rat presence in relation to sewer characteristics. Previous studies that investigate urban rat ecology in relation to a given characteristic are provided.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variable Name | Definition | Categories | Unit | Summary Variable | Source Variable | Bivariable Analysis | Multivariable Analysis | Point / Line Feature | Prior Studies |
| Result | Rat presence or absence at the manhole | Y  N | - | No | - | Yes | Yes | Point | - |
| EQNUM | Manhole ID | - | - | No | - | No | No | Point | - |
| Baiting Area | Area code | CS MQ NE NW SS SW | - | No | - | Yes | Yes | Point | - |
| Service Date | The date on which manholes were inspected | Date | - | No | - | No | No | Point | - |
| Service Season | The seasons (defined by 4 quarters during the year) in which manholes were inspected | Q1: Jan-Mar  Q2: Apr-June  Q3: July-Sep  Q4: Oct-Dec | - | Yes | Service Date | Yes | Yes | Point | Traweger et al., 2006 |
| Temperature | The historical temperature recorded for the month when the manholes were inspected | Numerical | - | No | - | Yes | No | Point | Traweger et al., 2006 |
| Precipitation | The historical precipitation recorded for the month when the manholes were inspected | Numerical | Inch | No | - | Yes | No | Point | Channon, 2006 |
| Complaint | Citizen complaints about rat sightings in Seattle (e.g., rats found in the toilets) | Categorical | - | No | - | Yes | No | Point | Pascual et al., 2020 |
| Manhole  Feature Type | Feature types of manhole | Drop MH Flush Tank Maintenance Hole Overflow MH Plug Tee | - | No | - | Yes | No | Point | - |
| Manhole Owner Name | Ownership of manhole | Categorical | - | No | - | No | No | Point | - |
| Surface Elevation | The surface elevation for manhole above sea level | Numerical | Feet | No | - | Yes | No | Point | Channon et al., 2006 |
| Pipe Elevation | The invert elevation for the lowest pipe, where invert elevation is a measurement upwards from sea level to the bottom of the pipe | Numerical | Feet | No | - | No | No | Point | - |
| Pipe Elevation (Dichotomized) | Dichotomized variable of Pipe Elevation | <=720  >720 | - | Categorized | Pipe Elevation | Yes | No | Point | - |
| X Coordinates | X coordinates for Washington States, using “NAD\_1983\_HARN\_StatePlane\_Washington\_North\_FIPS\_4601\_Feet” as the projected coordinate system | Numerical | - | No | - | Yes | Yes | Point | - |
| Y Coordinates | Y coordinates for Washington States, using “NAD\_1983\_HARN\_StatePlane\_Washington\_North\_FIPS\_4601\_Feet” as the projected coordinate system | Numerical | - | No | - | Yes | Yes | Point | - |
| Sewer Line  Feature Type | Feature type of sewer lines, where a stub is a small chunk of the sewer line that branch off from mainline and connect to property lines | Mainline Stub | - | No | - | No | No | Line | - |
| Sewer Line Feature Type Code | Feature type of sewer lines, described in code | M  S | - | No | - | No | No | Line | - |
| Stub | Among all the sewer lines connected to the manhole, whether there is at least one sewer line that is a stub pipe | Y  N | - | Yes | Mainline Feature Type | Yes | No | Line | - |
| Mainline | Among all the sewer lines connected to the manhole, whether there is at least one sewer line that is a mainline pipe | Y  N | - | Yes | Mainline Feature Type | Yes | No | Line | - |
| Owner | Ownership of the sewer lines | Company name(s) | - | No | - | No | No | Line | - |
| Probable Flow | The best estimation of what is flowing in the pipe | Combined Sanitary | - | No | - | No | No | Line | Brooks, 1962 |
| Sanitary (Probable Flow) | Whether all the sewer lines connected to the manhole are sanitary pipes.  Sanitary sewers are the sewage system that convey sewage only and is not designed to convey storm runoff. | Y  N | - | Yes | Probable Flow | Yes | No | Line | Brooks, 1962 |
| Combined (Probable Flow) | Whether all the sewer lines connected to the manhole are combined pipes.  Combined sewers are sewerage system that convey surface runoff water, polluted water, unpolluted water, sewage, industrial waste, effluent from storm plumbing outlets, and subsurface drainage. | Y  N | - | Yes | Probable Flow | Yes | No | Line | Brooks, 1962 |
| Permit Use | The designed pipe use for what the sewer line is supposed to convey | Combined Sanitary | - | No | - | No | No | Line | Brooks, 1962 |
| Sanitary (Permitted Use) | Whether all the sewer lines connected to the manhole are sanitary pipes | Y  N | - | Yes | Permit Use | Yes | No | Line | Brooks, 1962 |
| Combined (Permitted Use) | Whether all the sewer lines connected to the manhole are combined pipes | Y  N | - | Yes | Permit Use | Yes | No | Line | Brooks, 1962 |
| Material Code | Description of the physical substance used in the construction of the sewer lines, listed in codes | CON VC RCP AC DIP BRK OTH | - | No | - | No | No | Line | Colvin et al., 1998 |
| Material | Description of the physical substance used in the construction of the sewer lines, listed in full names | Concrete  Vitrified Clay  Reinforced Concrete Pipe  Asbestos Cement  Ductile Iron Pipe  Brick  Other | - | No | - | No | No | Line | Colvin et al., 1998 |
| Brick | Whether all the sewer lines connected to the manhole are made with brick | Y  N | - | Yes | Material | Yes | No | Line | Colvin et al., 1998 |
| Asbestos Cement | Whether all the sewer lines connected to the manhole are made with asbestos cement | Y  N | - | Yes | Material | Yes | No | Line | Colvin et al., 1998 |
| Vitrified Clay | Whether all the sewer lines connected to the manhole are made with vitrified clay | Y  N | - | Yes | Material | Yes | No | Line | Colvin et al., 1998 |
| Concrete | Whether all the sewer lines connected to the manhole are made with concrete | Y  N | - | Yes | Material | Yes | No | Line | Colvin et al., 1998 |
| Reinforced Concrete or Ductile Iron | Whether all the sewer lines connected to the manhole are made with reinforced concrete or ductile iron | Y  N | - | Yes | Material | Yes | Yes | Line | Channon et al.,  2006 |
| Pipe Shape | The pipe shape of the sewer line | Circular  Oval | - | No | - | No | No | Line | - |
| Overflow Flag | Flag for overflow: identifies sewer line in which flow occurs as a result of an overflow at an upstream structure (i.e., usually during storm events) | Y  N | - | No | - | No | No | Line | Colvin et al., 1998 |
| Pump Flag | Flag for pump: identifies whether the pipe is under mechanically induced flow | Y  N | - | No | - | No | No | Line | - |
| Cunette Flag | Flag for cunette: identifies whether the pipe has a cunette (i.e., a channel of small cross section dug in the bottom of a much larger channel or conduit to concentrate the flow at low-water stages), which influences maintenance approach (flushing) | Y  N | - | No | - | No | No | Line | - |
| Casing Flag | Flag for casing: indicates whether the pipe has an enclosure or not | Y  N | - | No | - | No | No | Line | - |
| Perforated Pipe Flag | Flag for perforated pipe: indicates whether the pipe has perforations or not | Y  N | - | No | - | No | No | Line | - |
| Lining  Flag | Whether the sewer line has a full reline (i.e., repair of the pipes) | Y N | - | No | - | No | No | Line | - |
| Lining Flag All | Whether all the sewer lines connected to the manhole are flagged for lining | Y  N | - | Yes | Lining Flag | Yes | No | Line | - |
| Length | The length of the sewer pipe segment that is located between the upstream and downstream manholes | Numerical | Feet | No | - | No | No | Line | - |
| Minimum Length | The value of the minimum sewer length among all the sewer lines connected to the manhole (i.e., length of the shortest pipe) | Numerical | Feet | Yes | Length | Yes | No | Line | - |
| Width | The nominal length of a straight line that passes through the center of a sewer line from opposing horizontal points at the widest point of the interior surface | Numerical | Inch | No | - | No | No | Line | Heiberg et al., 2012 |
| Height | The nominal length of a straight line that passes through the center of a sewer line from opposing vertical points at the widest point of the interior surface | Numerical | Inch | No | - | No | No | Line | Heiberg et al., 2012 |
| Sewer Diameter | Average of width and height of a sewer line | Numerical | Inch | Yes | Width  Height | No | No | Line | Heiberg et al., 2012 |
| Sewer Diameter in Feet | Sewer diameter with unit conversion from inch to feet | Numerical | Feet | Yes | Width  Height | No | No | Line | Heiberg et al., 2012 |
| Maximum Diameter | The value of the maximum sewer diameter among all the sewer lines connected to the manhole (i.e., diameter of the widest pipe) | Numerical | Inch | Yes | Width  Height | No | No | Line | Heiberg et al., 2012 |
| Maximum Diameter (Dichotomized) | Dichotomized variable of Maximum Diameter | <=8  >8 | - | Categorized | Width  Height | Yes | Yes | Line | Heiberg et al., 2012 |
| Slope | The derived grade percent based on upstream and downstream elevations and the length of a sewer line | Numerical | - | No | - | No | No | Line | - |
| Minimum Slope | The value of the minimum sewer slope among all the sewer lines connected to the manhole (i.e., slope of the flattest pipe) | Numerical | - | Yes | Slope | Yes | Yes | Line | - |
| Upstream Depth | The distance between the surface ground level elevation and the upstream invert of sewer line. where invert elevation is a measurement upwards from sea level to the bottom of the pipe | Numerical | Feet | No | - | No | No | Line | - |
| Downstream Depth | The difference between surface ground level elevation and the downstream invert of sewer line, where invert elevation is a measurement upwards from sea level to the bottom of the pipe | Numerical | Feet | No | - | No | No | Line | - |
| Average Depth | Average of Upstream Depth and Downstream Depth, which is equivalent to the distance between surface ground level elevation and the bottom of the pipe | Numerical | Feet | Yes | Upstream Depth  Downstream Depth | No | No | Line | - |
| Sewer Depth | The distance between surface ground level elevation and top surface of the pipe | Numerical | Feet | Yes | Upstream Depth  Downstream Depth  Width  Height | No | No | Line | - |
| Minimum Depth | The value of the minimum sewer depth among all the sewer lines connected to the manhole (i.e., depth of the shallowest pipe) | Numerical | Feet | Yes | Upstream Depth  Downstream Depth  Width  Height | Yes | Yes | Line | - |
| Installation Year | The year of sewer installation | Numerical | Year | No | - | No | No | Line | Channon et al., 2006 |
| Maximum Installation Year | The value of the most recent installation year among all the sewer lines connected to the manhole (i.e., installation year of the newest pipe) | Numerical | Year | Yes | Installation Year | Yes | No | Line | Channon et al., 2006 |
| Zoning | Zoning category of the area the manhole falls into | Single family  Multi-family  Commercial / Mixed use | - | No | - | Yes | No | Point | Colvin et al., 1998 |
| Simulated Manhole Flooding | The manhole with capacity constrained that are simulated to flood | Y  N | - | No | - | Yes | No | Point | Heiberg et al., 2012 |
| Impervious Surface | Whether the manhole is located in an area designated impervious | Y  N | - | No | - | Yes | No | Point | - |