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NORWAY RAT INFESTATION OF URBAN LANDSCAPING AND PREVENTATIVE DESIGN CRITERIA

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ABSTRACT: Fifty-four landscaped areas in downtown Boston were surveyed for Norway rat (*Rattus norvegicus*) activity. Each location also was characterized based on size, types of plantings, density of plantings, type of mulch, and sanitary and maintenance conditions. Factors most associated with the presence of rats were dense contiguous stands of shrubbery (e.g., needled evergreens) and refuse/litter availability on the ground. Design criteria should include effective spacing of shrubbery, limiting mass plantings of dense shrubs, selection of plant varieties that grow with openness underneath, strategically-placed and rodent-proof refuse containers, and use of crushed-stone inspection strips. Rodent control should be considered when landscapes are designed, and proper maintenance of landscaped areas should be part of urban rodent control programs.

KEY WORDS: vertebrate pest control, urban rat control, habitat management

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INTRODUCTION

Urban rodent problems exist because people provide resources that rats require to successfully colonize and sustain their populations. However, through effective planning, it should be possible to create and manage environments so that resources needed by rats are limited or not ideally provided. This would require shifting emphasis from a reactionary (poisoning/trapping) approach typically found in urban areas to a preventative rodent control strategy.

In highly urbanized areas, where asphalt and concrete environments prevail, landscaping can be a particularly attractive and prized resource for Norway rats (*Rattus norvegicus*) because soil in which to burrow is often a limiting factor. Additionally, many urban landscapes are located in and around where people congregate, thereby combining soil and plantings (harborage) with food resources (refuse, food litter). As a result, urban landscaping can become chronically infested or re-infested within a few days after poisoning.

Urban landscapes that serve as rat habitat can vary widely in size and complexity. They can include small planters with flowers near public sitting areas, "islands" of ground covers and shrubbery at entrances to commercial or government buildings, and parks with extensive plantings and shrubbery. In each situation, rats can pose public health and serious aesthetic problems. The impact of these problems is not only at the particular property that is rat infested; rats may use the landscaping on one property for burrowing while feeding on adjacent properties. They may also use landscaped areas as breeding sites, thus resulting in potential impacts to abutting properties and neighborhoods as young disperse.

As part of an integrated pest management (IPM) program in Boston (Colvin et al. 1990), downtown properties were surveyed for Norway rats. Because rats were frequently observed within landscaped areas, landscape features were further evaluated in an attempt to establish long-term population reduction through habitat alteration. The purpose of this paper is to describe those observations and design criteria that resulted.

METHODS

During 1992 to 1995, standardized urban rat surveys were conducted on more than 650 land parcels (2,700 addresses) in downtown Boston within the commercial/financial district. This area is highly urbanized and includes businesses, restaurants, hotels, apartment buildings, and residences on the upper floors of commercial buildings.

Subsequently, 54 landscaped areas (34 with rats) identified in the original survey were re-evaluated in detail, and the following features were characterized: types of shrubs, ground covers, trees; size and slope of the area; dimensions of contiguous stands of shrubbery; average height of shrubbery; spacing of shrubbery (random, linear, patch); visibility underneath shrubbery from horizontal view (ranked 1 low to 5 high); percent of ground covered by shrubbery when viewed from above; proximity of shrubbery and ground covers to walls; shrub limbs touching walls (ranked 1 low to 5 high); quality of landscape (plant) maintenance (ranked 1 low to 5 high); presence of fruit/seed from plantings; type and amount of soil cover (bark mulch, crushed stone, weeds, grass, bare soil); number, type, and height of refuse containers; easy accessibility of refuse containers based on a 45 cm distance between the container and any surface from which a rat could jump; proximity to eating locations, food vendor (e.g., restaurant, market, push cart), and refuse storage areas; and overall presence and accessibility of food within 23 and 46 m.

Each landscaped area also was assigned an index value to characterize rat activity based on the number of burrows and persistence of infestation. Activity indices ranged from 1 = none to 5 = high, and the shrub species closest to the rat burrows was noted. Light was measured 8 cm above the soil next to the burrow entrance using a hand-held camera light meter; for plots without rats, light was similarly measured where the densest shade occurred. To help assess the food value of plant materials, fruits and seeds found within various landscapes were examined for signs of rat feeding.

In addition to field surveys, pen trials were used to help evaluate the depth of crushed stone necessary to limit rat burrowing. These trials were conducted outside in a 1.5 x 1 x 0.6 m plastic (oval) arena using 19 mm (3/4 inch) stone placed at a depth of 30 cm. Fifteen rats (5 male, 10 female), locally trapped and with water and food provided *ad libitum*, were individually placed in the arena; their excavation performance was documented after 48 hours.

RESULTS

Among the 1,141 shrubs found within the 54 plots examined, rat burrows were associated with needled evergreens such as yew (*Taxus* spp.) more often than broad-leaf evergreen and deciduous plants (Chi-square 13.18, $P<0.001$); the low relative abundance of juniper (a needled evergreen) among plots, in contrast to its high association with rat burrows, suggests preference by rats for that type of plant structure (Table 1). In contrast, there was no association between rats and the presence of ground cover plantings such as English ivy (*Hedera helix*), wintercreeper (*Euonymus fortunei*), and pachysandra (*Pachysandra terminalis*) (Chi-square = 0.16, $P>0.05$).

The proportion of the plot covered by shrub canopy was the landscape characteristic most associated with the presence of rats (Table 2). Other important variables included low visibility into shrubbery from side view, high number of shrubs per plot, limbs touching the ground, large contiguous shrub stands, and lack of plant maintenance; shrubbery touching walls appeared important in the field and showed a trend towards statistical significance when tested. The size of the landscaped plot (soil area) was not significantly associated with the presence of rats (Table 3), and there was no significant difference between light intensity by burrow entrances and the shadiest location within landscapes that were not rat infested (Table 2). The primary landscape feature for cueing rat infestation appeared to be the density and contiguous area of shrubbery within the plot.

The amount of litter and the overall presence of food among all refuse sources (bird food, dumpsters, plastic bags on sidewalks for collection, refuse containers, food from homeless people) were strongly associated with the presence of rats (Table 3). Landscapes with dense stands of shrubs readily trapped litter, likely contributing to their infestation.

Among the landscapes, 33% had accessible stored refuse within 23 m, and 44% had accessible stored refuse within 46 m (n = 48); however, there was not a significant difference in this regard between rat and no-rat plots (Table 2). Additionally, within 46 m, there were no significant differences in the number, height, or accessibility of refuse containers between plots with and without rats. Thus, stored refuse did not appear to be a

Table 1. Shrubbery and associated rat activity within landscaped plots in downtown Boston.

Shrub (*genus*)	Relative abundance (n = 1,141)	Plots where found (n = 54)	Plots with rats (n = 34)
Yew (*Taxus*)	58%	50%	56%
Juniper (*Juniper*)	8%	20%	55%
Rhododendron (*Rhododendron*)	5%	19%	0%
Euonymus (*Euonymus*)	4%	11%	0%
Boxwood (*Buxus*)	5%	6%	0%
Azalea (*Rhododendron*)	1%	6%	0%
Rose (*Rosa*)	11%	4%	(1 of 2)
Holly (*Ilex*)	<1%	2%	(1 of 1)
Other*	8%	19%	0%

*Includes mugo pine (*Pinus*), cotoneaster (*Cotoneaster*), arborvitae (*Thuja*), barberry (*Berberis*), and unidentified deciduous shrubs.

Table 2. Comparison of mean values for shrubbery, sanitary conditions, and other landscape elements between landscaped plots with and without Norway rats in downtown Boston.

Variable	Mean (n) Rat	Mean (n) No-rat	Test Statistic	P
Plot coverage by shrubs - percent	48.4 (23)	16.3 (49)	4.901[a]	<0.001
Number of shrubs	26.2 (23)	10.1 (49)	3.241[a]	<0.01
Shrub visibility from side - 1 low, 5 high	1.7 (23)	2.8 (45)	3.124[a]	<0.01
Limbs touching ground - 1 low, 5 high	3.0 (23)	2.1 (45)	2.499[a]	<0.05
Area of contiguous shrub stand (m^2)	81 (18)	40 (13)	2.122[a]	<0.05
Perimeter length (m), contiguous shrub stand	28.6 (18)	15.2 (13)	2.042[a]	<0.05
Shrubbery touching walls - 1 low, 5 high	2.6 (23)	1.6 (45)	1.553[a]	>0.05
Shrub height (cm)	63.2 (23)	74.7 (45)	0.456[a]	>0.05
Shrubbery distance to walls (m)	2.4 (21)	1.5 (39)	0.063[a]	>0.05
Distance to nearest benching (m)	3.8 (26)	6.1 (19)	0.151[a]	>0.05
Height of shortest refuse container within 46 m (cm)	75 (16)	72 (16)	1.492[a]	>0.05
Distance to food vendors within 23 m	16.5 (14)	15.8 (7)	0.525[a]	>0.05
No. accessible refuse sites (containers, dumpsters, bags) within 23 m	0.93 (28)	0.80 (20)	0.221[a]	>0.05
Jump distance to access refuse containers (cm)	54 (16)	56 (16)	0.038[a]	>0.05
No. public refuse containers $\leq$ 0.9 m in height within 46 m	3.8 (18)	3.2 (18)	0.879[b]	>0.05
Light by burrow vs. max. shade in no-rat plot (F stop, 100 ASA)	5.3 (17)	6.9 (17)	1.250[b]	>0.05

[a]Mann-Whitney U-Test
[b]Wilcoxon Test; differences were considered significant when $P<0.05$.

Table 3. Norway rat association with sanitary conditions and landscape elements among landscaped plots in downtown Boston.

Variable	Mean (n) Rat	Mean (n) No-rat	Spearman r*	P
Overall food availability - 1 low, 5 high	2.5 (30)	1.1 (23)	0.508	<0.001
Refuse/litter on ground - 1 low, 5 high	2.7 (29)	1.7 (23)	0.465	<0.001
Plant maintenance - 1 low, 5 high	1.8 (29)	2.3 (23)	0.298	<0.05
Elevation above sidewalk (cm)	31 (30)	33 (23)	0.112	>0.05
Area of plot (m^2)	139 (30)	323 (23)	0.082	>0.05
Area of bare soil (m^2)	7.1 (30)	8.2 (23)	0.078	>0.05
Area of bark mulch (m^2)	18.9 (30)	16.1 (23)	0.029	>0.05

*Correlations were calculated using pooled data for all landscape plots surveyed; values were considered significant when $P<0.05$.

deciding factor for rat infestation. Where it did appear important involved open refuse containers placed adjacent to bench walls (i.e., knee walls, copings, retaining walls), or an open restaurant dumpster on an adjacent property. The abundance of food left by people on the ground within and adjoining the landscaping appeared to be the primary food source cueing infestation.

Fourteen of the 15 rats tested for their excavation ability dug holes in the crushed stone. The mean depth was 5.8 cm, and the maximum was 11.4 cm. Field situations where rats excavated stone mulch and established burrows involved shrub beds with stone less than 7 cm deep.

There was only one confirmed situation where plants provided food for rats. This involved rats repeatedly climbing tall shrubbery and foraging on cranberrybush fruit (*Viburnum opulus*), ≥1.7 m above the ground. [Outside of the plots studied, rats have also been observed in Boston feeding on apples on the ground and blackberries. It was also found that caged rats (with water and lab chow available) readily accepted fruit from honeylocust (*Gleditsia triacanthos*), holly (*Ilex* sp.), scarlet firethorn (*Pyracantha coccinea*), autumn olive (*Elaeagnus umbellata*), cotoneaster (*Cotoneaster* sp.), and hawthorn (*Crataegus* sp.); whereas low acceptance of yew and bayberry (*Myrica* sp.) fruit was observed, and no acceptance of juniper fruit.]

DISCUSSION

Problems with Norway rats in urban landscapes usually are not a result of a single factor, but rather a mosaic of cumulative resources. For that reason, design planning requires that a composite of issues be considered, especially spatial relationships of dense plantings and food sources.

Even when a landscaped area itself does not have sanitation problems, the area may be exploited as harborage when food is available on adjacent properties or sidewalks. For example, dense plantings should be limited especially where the abutting property is a food vendor or where people gather to feed birds. Unfortunately, the landscape designer cannot control the neighborhood land use, maintenance, and sanitary enforcement. Yet, to be successful from a rodent control viewpoint, the surrounding land use and sanitary conditions need to be considered.

The incorporation of rodent control principles into a landscape design is intuitively important to a vertebrate pest specialist. However, aesthetics is the primary goal in landscape architecture. This frequently places the vertebrate specialist and the landscape architect at odds, since aesthetics often translate into dense shrubbery (i.e., rat habitat).

It was found that the incorporation of rodent-proofing into landscape designs generally is novel to property managers and landscape architects. Even when property managers had chronic rat infestations, the primary approach that was observed was a long-term dependence on poisoning rather than habitat alteration. Once property managers were given recommendations for altering their landscapes, some made successful changes within budgetary limits.

Design criteria provided to landscape architects should detail the limiting and separation of potential resources for rats, to the extent necessary and practical, for the particular location. Urban sites abutting food markets, restaurants, and tourist locations warrant the most attention. Windswept designs (those with openness between landscape elements) will be less susceptible to infestation, will collect less debris, and be easier to clean and maintain.

Selection of Plant Materials

Certain types of plant materials are more susceptible to rodent infestation and damage than others (Marsh 1991). In California, Algerian ivy (*Hedera canariensis*) and Pampas grass (*Cortaderia selloana*) are two of the most troublesome species for roof rat (*Rattus rattus*) control because of their density; large areas of ice plant (*Carpobrotus edulis*) along California highways also provide food, harborage, and protected movement routes for roof rats (Frantz and Davis 1991). In Italy, climbing plants such as honeysuckle (*Lonicera* sp.) provide optimal conditions for roof rats living in parks (Santini 1987).

The specific plant varieties used for landscaping depend upon climatic and soil conditions, but deciduous shrubs and broadleaf evergreens are preferable to needled evergreens for limiting harborage for Norway rats. Additionally, because of leaf drop, deciduous shrubs do not provide the winter harborage afforded by an evergreen. Evergreens, however, will commonly and appropriately be selected for use in landscaping because of year-round greenery; minimizing their abundance or spreading out their distribution in single or linear patterns will be key to limiting rat harborage.

Plant varieties that naturally grow in a vase-shape or upright fashion are preferable to those that exhibit a mounded shape or spreading downward pattern. For example, plants that have open or airy growth patterns [e.g., winged euonymus (*Euonymus alata*) and rhododendron (*Rhododendron* spp.)] are less likely to have rat burrows underneath than plants with dense growth (e.g., *Taxus* or *Juniperus* spp.). Low growing (prostrate) plants or plants with dense understories (especially juniper) also are more difficult to inspect underneath for rat activity. Where needled-evergreen shrubs are to be used, seek varieties with more openness underneath. This is especially important where littering is expected, so that refuse will not readily accumulate underneath shrubbery and cleaning will be facilitated.

Spacing and Layout

Norway rats prefer burrow locations with overhead cover and associated thigmotropic conditions, as provided by a vertical surface or vegetation (Calhoun 1963). Thus, and as demonstrated by our data, dense contiguous understories should be avoided in a planting scheme. The amount of light under a single shrub appeared to be less important than the contiguous area of shrub cover.

As much as practical, space shrubbery to limit the potential for dense contiguous stands. Dense shrubbery in mass plantings will present the greatest risk, especially if needled evergreens are used. Individual plants or single rows of needled or dense broadleaf evergreens [e.g., boxwood (*Buxus* spp.)] are always preferable to mass plantings (e.g., concentrations of mound-shaped yews). Shrubbery should be planted a minimum of 0.9 m from walls, and so that limbs when fully grown do not touch the walls. Planting in that manner will help limit harborage and provide access for inspection and cleaning. Where ground covers are used, break their distribution into "islands" with crushed stone between them.

Refuse Containers

Although accessibility of public refuse containers to rats did not appear to be a determining factor for landscape infestation, some rats did utilize them as feeding sites. Importantly though, inadequate numbers, distribution, and capacity of refuse containers for the volume of human activity may have contributed to public littering and food availability near rat-infested landscapes.

Specify an adequate number and size of rodent-proof refuse containers. Use containers with top openings at least 0.8 m above the ground; no lower openings (other than a drain hole) should exist. Locate and secure containers at least 1 m from benching, shrubbery, and walls to help limit rodent access and to facilitate cleaning. Strategically place the containers, especially along routes where food is likely to be eaten while people are walking or standing (e.g., radiating outward from food businesses and tourist locations).

Container covers will help prevent wind and animals from removing trash. However, covers increase the time needed to empty containers. A domed lid with a spring-loaded door is one type of cover that can be used to help prevent access by rodents. Dome lids without spring-loaded doors also are available and may be a better choice where covers are implemented because of less maintenance and lower costs. A third alternative is a metal ring cover with a center opening; this offers partial closure and represents a compromise between a dome cover and no cover at all.

The type of refuse container and the need for covers should be determined on a site-specific basis considering the surrounding decor, potential abuse, costs, refuse susceptibility to rodents, level of maintenance, and frequency of collection. However, the container should be made of a heavy-duty material that will not easily rust, crack, or puncture, such as a high density polyethylene; have a secure supporting system to prevent tipping; have a design and placement that allows inspection and cleaning underneath; have any drain hole flashed with sheet metal or screened with hardware cloth; and be placed, where possible, on a paved (rather than soil) surface.

Landscape Plants as Rodent Food

Although refuse (e.g., food litter) was strongly associated with rat activity, our observations suggest that fruits and seeds associated with landscape plants may also be used by Norway rats, particularly with seasonal changes and the onset of winter. For that reason, we recommend choosing varieties which do not produce large amounts of fruit or seed, or which hold their fruit and seed longer. These include 'Shademaster' honeylocust, 'Spring Snow' (non-fruiting) or double-flowered varieties of crabapple (*Malus* spp.), 'Snowball' (sterile) cranberrybush, double-flowered varieties of cherry (*Prunus* spp.), 'Chanticleer' callery pear (*Pyrus calleriana*), 'Macho' Amur corktree (*Phellodendron amurense*), and male ginkgo (*Ginkgo biloba*).

Inspection Strips

Plantings immediately adjacent to walls are not always well maintained, probably because of confined access; they also may be planted too close to walls from a rodent control viewpoint. Thus, such areas can become overgrown and ideal for rats. To eliminate exposed soil for rodent burrowing along a wall, an inspection strip should be established; these have been described by Imholte (1984), Frantz and Davis (1991), Olkowski et al. (1991), and Timm (1991) using varying widths, depths, and diameter of stone. Inspection strips also provide access to inspect for rat activity, suppress weeds, and ensure space for bait station or trap placement.

Use an inspection strip along walls and fence lines, especially where plantings are extensive or local conditions are conducive to rat activity. Specify crushed stone (diameters of 6 mm to < 19 mm are acceptable), preferably rounded, out to a minimum of 25 to 30 cm from walls and down to a depth of 13 to 18 cm. Use steel or wood edging to confine crushed stone and to help prevent lawn mowers from throwing stones (10 cm deep x 3 mm thick; stakes 46 cm long every 61 cm).

Do not use an impervious layer underneath the crushed stone because of impacts to drainage, and thus the building foundation. Instead, use polypropylene landscape fabric or perforated polyethylene; both are permeable to water and air and also will suppress weeds. (The landscape fabric will also help limit intrusion of soil into the stone layer over time; see Williams and Williams 1991 for a review of landscape fabric.) Using stone ≥ 19 mm in diameter is also not recommended because of the potential for it to be thrown by people. A smaller and more rounded stone creates a better collapsing effect as a rat attempts to excavate; it also should collect less debris than larger stone, be easier to keep clean, and be more aesthetic.

Mulch

Use mulch for weed control in areas not covered by sod. This can include either bark or stone mulch, but landscape fabric should be used underneath. An even layer of crushed stone, 10 cm deep underneath shrubbery, also can be used to inhibit rat burrowing. However, the stone mulch will have limited rodent-proofing value if the shrubbery remains overgrown or if the layer of crushed stone used around the shrub base is too thin. Although a deeper layer is desirable to better inhibit burrowing, it is not recommended around shrubbery because of potential oxygen stress to roots. In soil areas without plants, a stone layer can be spread 13-18 cm deep and used to limit rat infestation.

Fences, Walls, and Benching

The association between fence lines and urban rat problems has been described by Orgain and Schein (1953). Thus, limit fences and walls where possible and space shrubbery and benches away from them. Where fencing is used, ideally install it in pavement or use an inspection strip. A radius (curved) installation pattern is preferable to one with corners because of the potential for litter/debris accumulation and to facilitate mowing.

Bench walls are frequently used to encircle or retain landscaped areas. Because people commonly sit on these low walls while eating, food litter may collect in adjacent shrubbery (especially if densely planted). Also rats will burrow along the top edge of bench walls, especially when shrubbery overhangs them; thus space shrubbery back to allow openness along bench walls. Locate free-standing benches in more open areas, rather than abutting dense shrubbery, and situate a refuse container nearby (but at least 1 m distant).

Planters

Within small planters that are susceptible to rat burrowing, use hardware cloth (6 mm openings, 17 gauge, galvanized screening) within the entire planter below the soil surface (e.g., 8 cm, but as close to the soil surface as practical while still allowing plant growth). Roots of ground covers and flowers can grow downwards through the hardware cloth while rats will have a difficult time establishing burrows. Where shrubs are being planted, cut an "X" in the hardware cloth and insert the root ball through it. Once the transplant is set, press the hardware cloth back towards the plant base and trim it to fit snugly.

Water Management

Lore and Flannelly (1982) stressed the importance of eliminating water sources as part of Norway rat control. For that reason, grade landscapes so that water does not pond. This is especially important around faucets, sprinkler systems, fountains, and areas receiving runoff. Place crushed stone where water tends to accumulate in small pools on soil surfaces, such as around drinking fountains. Design and install irrigation systems to reduce the potential for leakage at joints.

Maintenance Considerations

The resources that are necessary and available to maintain a landscape should be part of design considerations. Landscaping that has excellent aesthetics when completed may degrade into an overgrown patch with rats if the maintenance budget has not been considered during design. It was observed that government institutions in particular had problems with landscaping and rat activity, and this appeared directly related to limited budgets for maintenance.

Once a rat infestation is established in landscaping, institute poisoning/trapping followed by habitat alteration. This typically requires thinning, pruning, or complete removal of dense or overgrown shrubbery. As part of standard maintenance procedures, include pruning of lower limbs to maintain openness underneath, emptying of refuse containers and clean up of litter before nightfall, repair and replacement of refuse containers, and inspections for rat activity. Daily removal of litter and limiting accessible refuse is essential. Maintenance personnel should be trained to identify rat burrows, runways, and droppings so timely control practices can be implemented.

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