

UC Agriculture & Natural Resources

Proceedings of the Vertebrate Pest Conference

Title

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Permalink

<https://escholarship.org/uc/item/2bp837rs>

Journal

Proceedings of the Vertebrate Pest Conference, 20(20)

ISSN

0507-6773

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Publication Date

2002

DOI

10.5070/V420110253

Rodent Control as Part of Engineering and Construction Projects

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Abstract: Management of commensal rodent populations requires greater emphasis on long-term planning and maintenance of urban infrastructure. Integration of engineering and biological principles is necessary to effectively accomplish this. Design engineering provides opportunity to include rodent control features within the infrastructure being built. Construction-period rodent control helps prevent community impacts and keep facilities from being completed with pre-existing rodent problems.

Key Words: Norway rat, *Rattus norvegicus*, commensal rodent, urban, infrastructure, construction

Proc. 20th Vertebr. Pest Conf. (R. M. Timm and R. H. Schmidt, Eds.)

Published at Univ. of Calif., Davis. 2002. Pp. 46-52.

INTRODUCTION

Problems with commensal rodents in the United States range from inner-city environments and suburbs to rural towns and farmsteads on agricultural lands. In all cases, the central problem is the habitat and environmental features that promote the presence of these rodents and their reproductive success.

With ever-expanding development, habitat for commensal rodents is expanding similarly at a rapid rate (Colvin 1999). Urban sprawl brings new infrastructure and the need to rehabilitate old infrastructure to support human population levels and the municipal services that people expect. Infrastructure includes buildings, roadways, sidewalks, and the great diversity of utilities that are needed for electricity, water, heat, sewerage, drainage, and communication systems.

Urban sprawl can occur in two directions: 1) in a horizontal plane around an existing city, as formerly agricultural and suburban areas are engulfed with infrastructure or 2) in a vertical plane within a city, as buildings are constructed taller and vacant lots are replaced with development. With each of these scenarios, there are numerous environmental issues.

With either type of urban sprawl, the density of human population is increased per unit area and, with that change, greater human and physical congestion results. This constrains the ability to manage the environment effectively for several reasons. It creates added refuse and storage problems, and difficulty maintaining street and alley cleaning because of parking and other congestion. It also can dramatically increase the presence of food establishments, litter, and associated refuse storage locations and problems. Importantly, it places added strain on the existing infrastructure. The result is the need for effective (long-term) urban planning and timely improvements and maintenance of structural elements and utility systems.

Aging infrastructure and the cost of its replacement is a major and rapidly increasing issue in older cities in the United States. Aging sewer systems, buildings, and sidewalks are directly related to the potential for rodent-related problems since these structures provide living

space and a myriad of travel routes for colonizing, nesting, and access to food resources. Rodents also can add directly to infrastructure decay through gnawing and excavation of travel routes and creation of nest sites. These physical alterations may impact more recent infrastructure and architecture, where people live or work, and also have the potential to impact buildings considered eligible as historic resources.

Commensal rodent problems characteristically are addressed through reactive measures, meaning trapping and poisoning when a certain threshold of intolerance is reached. Often, the perception of when that “reactive threshold” is crossed is based on political agendas, rather than any scientific or public health criterion. A more proactive, and arguably more cost-effective, approach to commensal rodent control is to consider the issue during infrastructure design and construction. However, biologists are rarely knowledgeable in engineering and construction disciplines, and thus they typically find themselves reacting to the outcome of how an environment is designed, built, and managed—rather than preventing the problem from the onset.

There are profound differences in the sciences of engineering and biology. In simplistic terms, it could be said that an engineer “lives to create,” while a biologist “lives to study what evolves.” Engineers may focus on mathematical detail and precision, while biologists revel in uncertainties and variation. It would appear that the reactive approach to environmental and pest management is inherent to a biologist, and thus so is the often lack of effective planning to prevent pest problems. The vocabulary differences between engineer and biologist can be considerable. For example, a “vector” to an engineer deals with the mathematical direction of force whereas, to a biologist, it is an animal that has potential to transmit disease.

I would argue that to best manage the environment and associated public health concerns, the involvement of biologists and environmental experts is critical as part of engineering and construction management. This means communication using a common language. It also means integrating biological and environmental issues at the

front-end of land-use planning and the design and execution of construction projects. Engineers should not be expected to intrinsically understand and promote application of biological principles. However, when part of an inter-disciplinary team with biologists, they can effectively write specifications for design features and construction methods and materials that promote environmental protection and long-term management.

The focus in commensal rodent control appears too often to be on the animal itself, whereas the rodent actually should be viewed as an indicator species of environmental degradation or mismanagement. Just as a rare species can be a measure of unique environments, rodent pests should be considered indicators of where environmental management is needed. Management may include sanitation improvements, community outreach, a changed landscape, or proper infrastructure design and construction. In other words, the problem is not so much about the animal, but rather the environment that allows it to be reproductively successful.

The foundation principle of wildlife management is to provide habitat, an essential element when managing rare and endangered species. In contrast, vertebrate pest management is often about eliminating habitat features that sustain reproductive success of an undesirable animal. When considering the design and maintenance of most cities, one could argue that the principles of wildlife management are being applied as if rats are rare or endangered species.

Unless biologists learn to work at the front-end of the process, when human environments are designed, the reactive and largely ineffective approach to environmental management and rodent control will remain. This means that biologists must learn to communicate with engineers, planners, and municipal agencies and be integrated into the process of infrastructure and land-use planning. Biologists also must learn engineering, construction, business, and contractual principles if they are to effectively communicate ideas and have those ideas executed when infrastructure is built. Ultimately, what is constructed is based on a contract, design details, and performance standards.

The term mitigation is commonly used in the engineering and construction industry. Part of the permitting and planning process for a project is to define potential impacts and needed measures to prevent or minimize impacts to natural resources and communities. This may involve public hearings and extensive regulatory review, and preparation of an Environmental Impact Statement. Impact evaluation, alternative analysis, and mitigation typically involve topics such as wetland protection, cultural resources (archaeology and historic structures), air quality, noise and vibration control, water quality, fish and wildlife, erosion control, traffic, and hazardous materials management. In some cases, mitigation has included rodent control (Colvin et.

al 1990, Colvin 2000b), but rarely in a comprehensive manner.

Existing and future construction projects present an opportunity to properly design features and implement rodent control to help prevent environmental and public health problems. Such planning has both long-term and short-term elements: 1) design features to minimize rodent habitat over time and 2) construction-period actions to prevent community impacts during construction and demolition operations.

The purpose of this paper is to describe for biologists the culture of engineering and construction management, and how rodent control can be integrated into it. This paper also is intended to describe rodent control procedures during construction and demolition projects. This information is unique and important as cities age and struggle with infrastructure repair and replacement.

DESIGN ENGINEERING

The design (engineering) side of a project can involve one designer (small project) or multiple subcontractors (designers), each responsible for certain elements of the total project. The design will be based on mandatory requirements specified in the prime contract issued by the owner.

The extent to which the prime contract describes the design can vary by project size and type of contract. For a large project, involving a Program Management (PM) firm, the contract may include just basic project descriptions and the PM being responsible for the preliminary (25%) design (and also various stages of permitting). From that point, or in-total for smaller projects, a designer will be contracted to complete the design and generate "Issued for Construction" (IFC) drawings and specifications. The design contract will specify that the designer must periodically submit drawings and specifications for review and approval by the owner or the owner's representative (PM). This may occur at 75%, 90%, and 100% design levels.

Opportunity to influence design is best at the earliest stages of the project. Designers will be increasingly uncooperative in making changes as the design approaches 100% completion. This is because of the cost and time to integrate new design elements, change drawings, and get owner approval. A single change can affect numerous project elements and drawings. Sometimes, design changes also can require permit modifications and public approvals. Design criteria that relate to rodent control should be integrated early, especially since they are unlikely to be given priority as design nears completion.

An effective way to begin implementing rodent control is to write Design Standards at the very start of a project, to be used by all designers. The standards will define performance expectations and topics related to rodent control that should be incorporated into various

drawings and specifications. This may include descriptions on the spacing and type of shrubbery, type and height of refuse containers, sealing of dry utility systems, sealing of doorways, security and size of refuse storage areas, lighting, drainage, perimeter inspection strips, fencing designs, durability of materials, and sidewalk construction (Colvin et. al 1996). If the project involves a historic district or structure, the design details may require review and approval by the State Historic Preservation Office (SHPO).

The extent to which design standards and rodent control practices are needed varies widely among projects. It depends on what is being constructed, the type of construction, and the associated land use. An urban project, closely associated with residential or mixed land use (commercial/residential), will have greater risk and need for rodent control than solely a natural, commercial, or industrial area with less congestion and availability of food sources. Areas with numerous food establishments, and abutting parkland or waterfronts, also should be given priority. Urban rodent problems are not uniform in their distribution, and the design engineering for new infrastructure must be tailored to the background situation and the intended land use.

Planning of rodent control, for either design or construction, must be based on the project master schedule and the weekly changes to it that can occur. Communication with engineering and construction personnel requires understanding of the schedule, maintained and updated weekly by a Project Controls group. The schedule will show when various design submittals (uniquely numbered sections, drawings, and specifications) are to be completed and each aspect of construction is to begin. Review of drawings must be planned based on that schedule, and specific rodent control design elements, and tasks, should be integrated into it.

Most projects involve completion of the design by an engineering firm and then competitive bidding among construction contractors for the construction phase of the project. In some cases, the project may be a Design-Build project, meaning that one firm (or joint venture) is responsible for both design and construction. A Design-Build project can be a much faster paced and chaotic situation, compared to traditional contracting, with engineering occurring concurrent with construction.

During project design, the operations and maintenance (O&M) manual should be written for the particular facility being constructed. This manual is another opportunity to help ensure long-term pest control measures. The manual should have a section on pest control, with cross-references to other sections such as landscape maintenance and housekeeping.

The cost of mitigation practices and associated design elements also must be considered early in the design phase, thus better ensuring inclusion as the project is planned and executed. Costs must be justifiable and may require detailed cost estimating for review by project

management and the owner. As project costs increase, or schedules accelerate, mitigation measures typically are among the first to face budget cuts or review for justifiable costs. Consistent consideration of both cost and schedule is key to credible and successful integration of rodent control with an engineering or construction project.

Justifying the cost of rodent control to an owner can be difficult, especially given short-term budgets that encompass only project construction. However, the cost should be presented in terms of reduced long-term maintenance following project completion (i.e., less costly weekly/monthly pest control service, fewer structural repairs and re-designs). The cost of rodent control during the construction-phase can be described in context of health and safety for the construction workers, community relations, cost of resolving impacts to abutters, and the potential for negative publicity that can impede overall project cost and schedule.

CONSTRUCTION PLANNING

As design engineering progresses, construction planning progressively increases and so does planning for the construction phase of the rodent control program. Inappropriately, the concern about rodents and construction operations most often focuses only on the mobilization or demolition period. In fact, construction can be divided into three time periods when rodents can cause impacts: 1) when mobilization and excavation begins, rodents can be dispersed to adjacent areas; 2) during construction, rodents can colonize work sites and shift to and from the sites with various changes in construction activities; and 3) as construction demobilizes, rodents can be dispersed to adjacent blocks or remain and infest the completed structure.

Norway rats seek soil areas and downward spaces (for burrowing), debris piles and fencelines (for cover), and nearby food sources (Davis 1953). Construction operations provide this animal with those conditions, sometimes where such resources previously were limited. Large areas of exposed soil may become available for colonization where a concrete surface once existed. Site perimeters become protected linear areas from which rats can forage on the construction site or the adjacent properties and sidewalks. Food litter from construction workers can be common, and public refuse can pile up against fenced perimeters. Excavation and open cuts in existing sewers and other utilities can allow direct access into and out of those systems.

Construction-period rodent control programs can be difficult for several reasons. The environment is not static as with a typical urban program, but rather changes daily as construction methods, topography, and equipment change. The construction work force can change daily, as various crafts are needed, and thus there is an ongoing need to train and inform personnel about housekeeping. Importantly, construction impacts to

abutments can result in neighborhood conflicts and political demands for neighborhood-wide pest control services.

Work sites can be dangerous, and personnel entering need to be properly trained and equipped with personal protective equipment (PPE; hardhat, safety glasses, reflective vest, work boots) and understand construction operations. Sites may have specific check-in procedures. Work along waterfronts may require life jackets, excavations or utility systems may require confined-space training, and a site involving hazardous waste will require Hazardous Waste Operations and Emergency Response Standard (HAZWOPER) training.

Site “walkdowns” should be used well in advance of site mobilization to review the construction route with engineering and construction personnel, including the planned work, the work area limits, and construction methods. Standardized rodent and sanitation (baseline) surveys should be conducted within and adjoining the planned work area, so that the distribution and intensity of the program can be tailored to background conditions. Standard surveys, recorded by premises, include active rodent signs (burrow counts, droppings, etc.) and sanitation conditions (exposed garbage, unapproved refuse storage, over-grown shrubbery/weeds, and debris piles) (Colvin 2000a). Utility systems must be reviewed during planning, including engineering drawings, to determine conditions susceptible to infestation (Colvin et. al. 1998).

The procurement of a pest control company should be based on detailed specifications and performance standards (Colvin et. al 1992). Usually an engineer or environmental compliance person will oversee the work. Quality assurance oversight of pest control contractors is always needed. The pest control company should be contracted to conduct neighborhood surveys, trapping, baiting, work site inspection for sanitation conditions, respond to public complaints, and provide written documentation of findings.

Work sites must not be viewed as islands. Rodents do not acknowledge the work area limits. Public outreach and code enforcement should extend outward from the work site to adjoining blocks. The extent of public outreach and survey depends on local conditions and the potential for neighborhood conflicts during construction. A low-risk program may extend outward one block, while a program involving large-scale construction and congested residential/commercial (food businesses) nearby, and political overtone, may extend outward two to three blocks from construction (Colvin et al. 1990).

Community meetings and flyers can be used to explain the program, enlist participation, and help gauge the needed geographic extent. Municipalities may be willing to provide added code (sanitation) enforcement in adjoining blocks; however, they may want to be reimbursed for such services. Ultimately, protecting the work site from infestation, and avoiding neighborhood conflicts and impacts, depends most on sanitation outside and immediately abutting the work area. Management of public fear and dispelling myths about rodents being

“unearthed” must be a priority, otherwise the construction project will be blamed for new and long-standing problems.

The goal of any construction-period rodent control program is to eliminate existing rodent problems prior to starting construction so that rodents will not be dispersed, and then to protect and monitor the site perimeter to prevent re-infestation. Emphasis is given to strategic and timely execution of the plan, particularly before construction begins. Monitoring must be maintained throughout the entire construction (or demolition) period. The baiting/trapping part of the program may begin 10-14 days in advance for a minor building demolition, or as much as 2 months in advance for a major urban project. The overall program for a large-scale infrastructure project—beginning with public outreach, surveys, and sanitation enforcement—can occur as much as 4-6 months in advance in a highly urbanized area.

Construction often begins each day with a gathering of personnel on site. Safety issues may be discussed as a “tool box” talk. Housekeeping and rodent activity can be discussed, and the craft personnel can be asked to communicate any problems observed. Health and Safety is a team issue on a work site, and rodent control needs to be incorporated into that philosophy.

Construction projects can be susceptible to damage claims from citizens and property owners. Construction should not begin until written and photographic documentation of baseline conditions and community outreach has occurred, and pre-existing problems on and around the planned job site are documented as resolved. Timely response to public complaints is essential to prevent added costs and insurance claims; however, any complaint should be carefully evaluated to prevent numerous requests for “free” pest control services.

“Punch lists” and quality assurance inspections are used during construction, or upon completion of work elements, to help contractually close-out tasks and confirm compliance with contract documents. This should include structural elements and housekeeping items that relate to rodent control (e.g., grouting or concrete placements with tight seams between structural elements – such as sidewalks, the security of doorways and utility systems, proper depth of gravel mulch inspection strips, drainage, erosion controls, and landscaping features).

A properly designed and executed rodent control program can eradicate a rat population from a planned construction area, as demonstrated by the largest and most complex construction project in the history of the United States, the Central Artery/Tunnel Project in Boston, Massachusetts (Colvin and Jackson 1999). However, sustaining success during construction is predicated on work site and neighborhood sanitation practices, close monitoring and strategic placement of monitoring baits/traps, and quick and (appropriately) intense response when rodents or sanitation problems are detected.

Risk Management during Construction

1. Hay (or straw) bales used for erosion control can provide protected harborage for nesting. Remove bales from the work site when they no longer are needed.
2. Maintain erosion controls around storm drain inlets, otherwise soil can build up inside and provide nesting habitat.
3. Use trash containers (e.g., 44-gal.) with domed lids, lined with a plastic bag. Distribute them on all work sites, especially near trailers and lunch break areas; discourage littering.
4. Consolidate lunch-break areas to the extent feasible.
5. Store refuse (food litter) separately in a dumpster that has a secure lid and drain plug, rather than throwing it into an open roll-off container with construction debris.
6. Assign a laborer to cleanup litter daily, especially around site perimeters.
7. Secure deck plates used for temporary cover over street excavations, to help prevent rodent infestation below.
8. Remove debris piles and do not allow excess debris to pile up along fencelines.
9. Manage de-watering operations so that water is properly discharged and not creating localized flooding.
10. Ensure that trucking operations, street-sweeping, and erosion controls are appropriate for keeping soil from fouling storm drains.
11. Ensure that the pest control contractor is aware of activities that may affect pest problems, such as the scheduling of sewer, excavation, or demolition work.
12. Keep personnel from placing trash and garbage inside the walls and ceilings of buildings as they are constructed. This is a common practice, and it can sustain mouse populations and establish an infestation as a new facility is finished and opened for occupancy.
13. Build relationships with abutters, neighborhood groups, and city agencies concerning proper sanitation practices on nearby properties.
14. Document sanitation conditions and rodent activity weekly, on the site and nearby.

Direct Control and Monitoring of Rodents

1. A control program should be divided into "Initial" and "Maintenance" phases. The purpose of the Initial Program is to eliminate existing rodents within, and extending outward from, the planned work site prior to construction start. The purpose of the maintenance program is to ensure that the site will not be re-colonized or the abutting neighborhood impacted.

2. Once construction begins, a sentinel program should be used around site perimeters, extending outwards, to monitor and protect the control zone.
3. Jersey (concrete) barriers along site perimeters can be used as protected baiting or monitoring locations; rats will use the key-hole space underneath the barrier as a travel route. Chain-link fencing around site perimeters can be used to secure bait stations.
4. Portions of the work site closest to restaurants, residences, and refuse storage areas are most susceptible to infestation and require close monitoring. A non-toxic bait block can be effective for monitoring; locations should be flagged and mapped.
5. Waterfront edges and piers can provide a direct movement route to construction sites and must be monitored closely.
6. Construction trailers, especially those with skirts in cold weather conditions, can provide living space underneath for rats. They must be secured and monitored.
7. For building demolition, rodent control should precede mobilization for remediation work (asbestos, lead paint removal). Once control is demonstrated, pest control should be shifted to the site perimeter while the remediation and demolition contractors perform their work.
8. Rodent control must extend to subsurface areas when utility systems will be disrupted. Specific procedures and timing of subsurface baiting must be followed (Colvin et al. 1998). An activity such as street paving does not require baiting of sewer systems, but inspection and treatment of catch basins leading into storm drains would be prudent.
9. Trapping will be needed for quick response to public complaints or infestations on work sites. This may require trap placement following the day shift and retrieval at dawn.
10. Bait stations will need to be strategically placed and secured, particularly at the inside corner of work sites, and where heavy equipment or materials will not crush them. It is not appropriate to systematically space bait stations around an entire site perimeter.
11. Wooden (trap) boxes that look like over-sized bait stations can be constructed to hold a snap trap, as an alternative to baiting in public areas and along site perimeters.
12. Nighttime observations can be helpful in detecting rat activity and feeding and movement patterns. Construction personnel should be encouraged to report observations.
13. Control practices need to be adjusted seasonally, with emphasis in late winter and early spring to help prevent annual increases.

POPULATION DYNAMICS

Public comments on local rat problems often include reference to increased numbers following construction or demolition activity. For example, during extensive public hearings in New York City in 2000, testimony was given that construction sites were sources of rats and inadequate sanitation. Construction operations undoubtedly can cause, or contribute to, local changes in rat populations. However, in some cases it appears that public complaints about neighborhood rat problems, being the result of construction, are based upon misinformation and myths or political opportunity to blame someone else for a pre-existing or growing problem.

The population dynamics and behavioral ecology of rats has been well documented (e.g., Davis 1953), and that information can be applied to circumstances involving construction. Two behavioral situations are particularly relevant: 1) forced dispersal from work sites to neighboring areas (because of excavation or site changes) and 2) passive colonization of work areas from neighboring blocks (because of normal dispersal behaviors and the availability of resources on or abutting the work site). In the first case, rats would face competition from existing populations and thus would be predicted to have lower survival and reproductive rates. In the second case, rats may not have much competition as new habitat is created; thus the opposite outcome would be expected, meaning a relatively high rate of reproductive success by colonizing animals.

Davis and Christian (1956) and Calhoun (1948) performed experiments involving the introduction of "alien" Norway rats (*Rattus norvegicus*) into city blocks that had existing rat populations. In both studies, population dynamics were altered and rat populations declined or stopped growing. There was high incidence of mortality among both alien and resident rats; some aliens were incorporated into the population while others returned to their home block when it was adjoining. Davis and Christian (1956) reported that reproductive rates remained low for about two months within the block where the introductions occurred. Thus, although construction (without rodent control) may cause dispersal and an initial period of neighborhood impact, the neighborhood rat population may stabilize thereafter, for several weeks, at a level lower than or equal to the numbers present prior to the introduction event. This population change can be attributed to the social dynamics and competition within rat populations. Emlen et al. (1948) described invasion as a small factor in population growth.

A public concern during construction is rats being displaced widely to infest new areas. Although Norway rats tend to remain in their resident block, Davis et al. (1948) predicted that radical environmental change could cause extensive movements. Home range in a congested urban area typically is less than 100 feet, and Davis et al. (1948) found that rats seldom cross roads. Davis (1953) reported that although Norway rats are capable of

travelling (wandering) miles and colonizing new and adjacent areas, movement between urban residential blocks usually is low (in one case, 1 of 312 recaptured rats changed blocks). Rats that colonize or exist within a construction site likely would show similar attributes, remaining within the site as long as resources are available. If reproductive success on the work site is high and carrying capacity exceeded, some individuals would be expected to seek adjacent areas to colonize, given normal social behaviors and resource competition.

In my observations on construction sites, rats can readily live among construction equipment and operations. They remain within their home ranges even during heavy equipment use and flee only when their living space is directly impacted. Rats are most likely to impact an adjacent property (or block), than a location more distant. Removal of harborage or jersey barriers on a site perimeter, or direct disruption of a sewer line, are examples when rats may disperse to another part of the job site or the abutting area. The greatest risk for neighborhood impact may actually be at the end of the job, when the work site is demobilized and fenceline cover is removed, precipitating rodent dispersal.

Orgain and Schein (1953) documented, and Davis (1953) further described, multiple factors within the physical environment that affect the distribution, carrying capacity, and thus abundance of Norway rats. These included the condition of buildings, breaks in pavement, presence of fences, and food availability. They found that removal of fences helped to reduce carrying capacity (rat populations). Construction sites typically are fenced or barricaded, making perimeters predisposed to debris clutter, refuse build up, and colonization by rats.

Exposed soil for burrowing frequently is limited in an urban landscape capped largely with concrete and asphalt. Construction operations, by their nature, involve soil disturbance and increased area of exposed soil. They also can involve cuts in pavement, providing protected access to soil underneath. These conditions can enhance local carrying capacity for rats, and thus the potential for colonization and population growth. Although construction can displace rodents, the more chronic problem during construction actually is the potential movement of rats towards the construction area from adjoining properties and colonization of site perimeters.

Public claims of construction causing widespread neighborhood rat (or mouse) infestations, blocks from construction, typically are a result of localized conditions and political agendas rather than construction. Long-term sign of infestation, degraded sanitation conditions, or localized infrastructure (e.g., sewer) decay usually can be found. Valid complaints may occur within the abutting one to two blocks but, at many locations, long-term sign of rodent activity may be present because of pre-existing sanitation and structural problems. Obviously, sanitation and harborage problems must already exist for a rodent population to sustain in any neighborhood.

Spatial relationships among elements within an urban landscape, whether under construction or fully completed, must be considered when planning rodent control (Colvin et al. 1996). Preferred features, in close proximity to each other, enhance the likelihood of infestation. Construction sites can increase carrying capacity for rodents because of greater availability of physical features (harborage), but then food becomes the most likely limiting factor. For that reason, sanitation on the work sites must be maintained. The greatest risk of rat activity exists where refuse in public areas is abundant and spatially close to the (fenced) work site.

Rat populations respond to new habitat and resources in a mathematically predictable pattern, describe by a s-shaped or logistic curve (Davis 1953). That curve begins slowly, but the rate of population growth can excel and eventually it will plateau at the carrying capacity of the environment. Physical features, and particularly food availability, affect that capacity. A new construction site may have little or no rodent activity to start; however, with increased carrying capacity (i.e., additional harborage and food sources), reproductive rates of colonizing rodents may suddenly become rapid and a substantial population can result.

Similarly, a newly completed building may only have a minor (residual) mouse population once finished, but that population may expand substantially according to the logistic curve as the building is occupied by people and food sources become broadly available. The outcome may be a surge of rodent activity one to two years after building completion. For these predictable reasons, environmental carrying capacity must be managed from the project start, and there must be prompt response to any rodent infestation and identification of causative factors (structural design, maintenance, and sanitation). Such focus is important during construction but must extend through operation of the completed facility. When a problem occurs, resolution may require immediate change in the physical design of the facility (or landscape) to reduce the potential for predictable population growth and thus repetitive problems.

SUMMARY

A large and sustainable rodent control program cannot be accomplished without technically qualified personnel, effective contract and program management, and consistent public and political support. Incorporating rodent control principles into design engineering and construction management will help establish a long-term, pro-active, and economical strategy.

By combining the technical skills of engineers regarding infrastructure, with the knowledge of biologists concerning environmental management, the most predictive and successful rodent control programs can be

implemented. However, underlying such an interdisciplinary approach must be the firm understanding of population dynamics and the behavioral ecology of rodents; thereby, a truly predictive strategy can be developed and implemented. Most importantly, there must be understanding of the human, social, and political arenas that make building, restoring, and managing urban environments complex.

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