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Journal
Proceedings of the Vertebrate Pest Conference, 23(23)

ISSN
0507-6773

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Publication Date
2008

DOI
10.5070/V423110334

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Abstract: Vertebrate pest management characteristically focuses on research and development of control tools and their application. Similarly, integrated pest management (IPM) principles focus on control methods and habitat alteration to reduce risks from pest species. Organizational structure, administrative elements, and program management are rarely identified as key components of IPM or the development and execution of vertebrate pest strategies; however, they should be included when seeking sustainable and cost-effective programs. In urban areas, rodent control programs typically are reactionary and uncoordinated rather than preventative and systematic, resulting in short-term results that cannot be sustained. Use of an environmental management system (EMS), as described by ISO 14001 standards, establishes program structure and priorities for improvement. As part of the EMS, an Aspect Register can be used to identify risk factors and specific mitigation measures; for example, this can be done on a national scale to rank cities at greatest risk of rodent infestations or for program development and execution within an individual city block or building. Emphasis on program and systems management, organizational skills, risk factors, multi-disciplinary training, and prevention is needed as part of vertebrate pest management. Technology often is not the limiting factor; rather it is administrative and management elements for sustainable and effective program execution.

Key Words: commensal rodents, environmental management system, integrated pest management, IPM, ISO 14001, Norway rat, *Rattus norvegicus*, rodent control

Proc. 23rd Vertebr. Pest Conf. (R. M. Timm and M. B. Madon, Eds.)
Published at Univ. of Calif., Davis. 2008. Pp. 186-193.

INTRODUCTION

Research and development for vertebrate pest management characteristically have focused on population dynamics and behavior of the pest species, control tools (e.g., traps and rodenticides), and program elements. This pattern was well demonstrated at the onset of the "Modern Era of Rodent Control" that began in the 1940s during World War II with pioneering work in the U.S. by Davis (1953), Emlen (1947), and Calhoun (1948, 1962) and parallel efforts in the U.K. by Chitty (Chitty and Southern 1954). Subsequently, during the 1960s-1980s, developments in commensal rodent control were exemplified by the work of Jackson (1982), Drummond (1970), and Buckle (Buckle and Smith 1994). The ecology of commensal rodents was established, numerous control tools were developed to match species-specific behaviors, and site-specific applications and program elements were described.

The foundation principle of rodent control relates to the importance of habitat modification to control reproductive rates, and thereby the rate of population growth. Davis (1953) mathematically demonstrated the relationship of habitat to population growth using a sigmoid curve. Rodent populations grow at a predictable rate, slowly at first and then rapidly until rodent numbers approach carrying capacity of the environment and population growth stabilizes (plateaus). Populations are most economically and successfully managed at the lower end of the sigmoid curve where the rate of population growth is slow. Larger populations when partially reduced, with little or no habitat modification, rapidly rebound and once again reach carrying capacity (Emlen et al. 1948). Such concepts of managing population growth evolved into the underlying principle of rodent control programs later deployed in U.S. and European cities during the 1960s-1970s that included surveys, code enforcement, baiting, sanitation improvements, public outreach, and monitoring to lower populations and presumably restrain them at the low end of the sigmoid curve (Davis and Jackson 1981, Drummond 1985, Jackson 1984). Limited and disjointed campaigns, however, simply risked expensive and repetitive failures (as predicted by the sigmoid curve), because of the overarching reproductive and colonizing abilities of the pest species.

During the 1960s and 1970s, the concept of "Rat-Free Towns" was introduced in Europe (Drummond et al. 1977, Gacs et al. 1977, Myllymaki 1969) using defined programs and habitat management. Concurrently during the 1970s, millions of federal dollars were provided annually to U.S. cities to support municipal rodent control programs (Colvin and Jackson 1999).

However, by the mid 1980s in the U.S., federal funding for urban rodent control programs had ceased and university research programs ended (Colvin 1999). The burden shifted to a reactionary and disjointed combination of efforts by residents, pest management professionals (PMPs), and municipalities (Kaukeinen 1994). At about the same time, the concept of combining habitat modification (neighborhood improvements) and control tools (traps, rodenticides) was being described as integrated pest management (IPM). Unfortunately, IPM characteristically was described without focus on program design, administration, roles and responsibilities, and execution. Rather, it was inappropriately described by many as solely a combination of control methods.

During the 1990s, the principles of urban rodent control and vertebrate pest management were further progressed when 7 square miles of Boston, MA functioned as an urban laboratory during the largest public works project in U.S. history to revitalize transportation systems and infrastructure (Colvin et al. 1990). A coinciding, federally-funded, multi-million-dollar rodent control program integrated control tools, community outreach, and code enforcement but also research on sewer and utility systems and urban design, contract management, and various administrative measures to comprehensively define and manage the program (Colvin et al. 1996). This combined inter-disciplinary effort of research, management, and administration, using biologists, engineers, municipal employees, and pest management contractors on a single team, established a model for urban rodent control programs and was a result of the progressive research and concepts promoted by David E. Davis in the 1940s through William B. Jackson in the 1980s. Many of the strategies used in urban rodent control and program management in the U.S. today evolved from the Boston program that spanned almost a decade and focused on prevention (Colvin 2000).

During the Boston program, the communication and knowledge gap between the research community, municipal employees, and PMPs quickly became obvious. The impediments of program implementation were not part of usual scientist training, and the scientific basis for control measures was not inherent to the municipal workers and PMPs. This dichotomy of knowledge and experience initially created a cultural and political clash that was reconciled through a structured program with effective integration of skills and cross-training.

Today, in the absence of a federally-mandated program, urban rodent control in the U.S. is largely disorganized, under-funded, reactionary, and political (Colvin 1999). Thus, although control technology and the relationship of rodent population dynamics to biotic and abiotic factors (e.g., weather, infrastructure) have been well established over the past 65 years, vertebrate pest programs frequently fail or are unsustainable (Lambopoulos et al. 1999). Davis (1977) argued that a major deterrent in vertebrate pest management was that decisions are made based on politics in direct violation of "biological laws." He also argued that research scientists rarely have the talent to manage vertebrate pest programs. We concur and view this later point as the reason for the lack of research focus on program development, inadequate transfer of science to those involved with program execution, and unsustainable and ineffective programs.

We believe that vertebrate pest programs overall are not limited today by biological laws and technical control methods, but rather by organizational and management skills and administrative elements. The academic curriculums for vertebrate pest scientists in the U.S. never have included the necessary inter-disciplinary subjects for development, execution, and auditing of vertebrate pest programs. This includes, for example, business and contract management, organizational and personnel management, project and facility management, quality assurance, schedule and cost management, media relations, urban design, land use planning, engineering and construction, environmental law and permitting, cultural resources, stormwater and waste management, and public outreach and marketing. Furthermore, without such skills, scientists cannot properly evaluate or effectively improve existing vertebrate pest programs. Applied biological research should be performed in context of inter-disciplinary program management, or the research outcome will not be adequate for resolving pest problems in "real world" situations as repeatedly demonstrated over the past 65 years. Research findings and program development must be integrated, or implementation will be lacking and unsustainable.

It is time that the 1980s concept of IPM, still in use today, is eclipsed by the concept of an Environmental Management System (EMS) and that the science of vertebrate pest management focuses on inter-disciplinary training and development related to program execution. An EMS represents a combination of methods – technical and administrative – with defined policy, objectives, responsibilities, schedules, training, and means for continuous improvement (Woodside et al. 1998). Such a system is based on ISO 14001:2004 as established by the International Organization for Standardization (2007). ISO 14001 was promulgated to help organizations establish structure and improve environmental performance. It systematically helps foster environmental management and sustainable development, which are key factors for the success of any vertebrate pest program and prevention of environmental degradation and reactionary efforts. The purpose of this paper is to describe elements of an EMS and their relationship to preventative, strategic, and sustainable vertebrate pest management.

SYSTEM STRATEGY AND COMPONENTS

The goal is to overcome reactionary programs, ad hoc approaches, and short-term vision and replace them with holistic, structured, and strategic approaches, ideally with measurable targets, and the ability to demonstrate achievement. Several key elements of an EMS are described below, and each must be tailored to the location, pest species, and organization. An EMS can be prepared for an entire city, neighborhood, building, or agricultural operation.

Policy

There must be a solid policy and legal basis for program implementation. Thus policy, legal, and regulatory requirements are the first issues to be addressed and established. They must be known and understood by participants and communicated by senior managers. Priority must be given to writing and updating policies and regulations to reflect the EMS objectives. Success depends on leadership and commitment at all levels of an organization, thereby achieving political support.

Risk Management

Central to the EMS, planning, and scheduling is risk management. An Aspect Register is used to define risks and associated mitigation. The Aspect Register lists (in a spreadsheet) each Aspect (risk factor), its impact if unmitigated, mitigation measures, and the anticipated impact if mitigation is applied. Risk assessment should occur in parallel to planning program objectives and provides focus and resource justification. Qualified personnel can score (index) risks, such as on a scale of 1-5 with 5 being most severe. For example:

Aspect: Illegal waste dumping in the Back Bay neighborhood;
Impact: Increased food sources for rats around Breman Street;
Unmitigated Score: Frequency (2) × Severity (5) = 10;
Mitigation Measure: An additional Code Enforcement officer, third shift;
Mitigated Score: Frequency (1) × Severity (3) = 3.

Unmitigated and mitigated scores can be tabulated for all subjects (risk factors) identified in the Aspect Register. Mitigation can be emphasized, and a composite of mitigation practices established, based on the trends in risk factors. The scores can be assessed periodically and mitigation practices adjusted as the program proceeds.

Risk assessment can be performed in different ways, but it should be done systematically to identify issues among effected disciplines and also specific mitigation measures to be applied and integrated. Risk assessment can even be done on daily work tasks to make sure the field team is executing work safely and per plan. The integration of mitigation measures establishes the holistic approach to sustainable prevention.

Objectives and Targets

The objectives and targets are established based on policy and risks; they drive the process for improving the EMS and reflect unique circumstances. They are set at relevant levels of an organization, specific and measurable where practicable, and assign responsibilities and schedules. The objectives must cover multiple disciplines, and each objective may have multiple targets. Legal, land use management, engineering, construction, research, enforcement, community participation, waste management, control measures, document control, training, and various administrative subjects can all be subjects for objective headings. A matrix (i.e., spreadsheet) is used to capture all objectives, targets, individual responsibilities, and schedule. An example objective with targets is:

Objective 1: Sustain high levels of environmental awareness in the community.
Target 1.1 Action: Prepare outreach materials on seasonal actions; Responsibility: P. Smith; Schedule: Begin April 1, 2008 and complete final June 15, 2008.
Target 1.2 Action: Give presentations to 15 community groups in the Back Bay; Responsibility: M. Jones; Schedule: Begin July 1, 2008 and complete October 30, 2008.

The point of the objective/target matrix is to develop a comprehensive set of tasks and to begin integrating them and their schedules. Key to success of the EMS is system integration, and each objective and target will likely be linked by schedule to another, resulting in a highly interlocking system and schedule. This forms a preventative and holistic strategy.

Organization and Planning

Organizational requirements and resources (personnel, budgets, and equipment) can be estimated and justified based on the objectives and targets and, importantly, further justified based on measurable accomplishments. The organization must be inter-disciplinary, have standard operating procedures (SOPs) and processes, communication paths for internal and external stakeholders, job descriptions, and tracking capabilities (Martin 1998, U.S. Army 2005). A matrix (Excel spreadsheet) should be prepared that lists major work tasks, subject, individual or agency with lead and support responsibilities, geographic location, and priority. Coordination can be facilitated by sorting and distributing data by responsible party, subject, location, or priority score. Schedule milestones (e.g., 60%, 100% complete) can be listed for each task.

A master schedule must be prepared that shows program milestones (referred to as a Level 1 schedule), seasonal actions, as well as more detailed data (a Level 5 schedule when showing daily work tasks). Advanced scheduling, and adherence to it, helps avoid reactionary efforts and wasted resources. Tasks should have clear start and finish dates that are tracked and serve as a basis for accountability. In an inter-agency situation, multiple agencies may have to incorporate activities in their departmental schedules that relate to program objectives and success. Schedule management involves start and end dates, but also the tracking of percent completion as tasks are performed. Scheduling software is available for this purpose.

Inter-agency or inter-departmental coordination and positive relationships are key elements of an EMS. Overall coordination should be centralized, and jurisdictions and responsibilities confirmed in writing. Regularly-held coordination meetings should be inter-disciplinary, focused on objectives and schedule, and result in action items and assignments that are tracked and confirmed completed. In some cases, part of the EMS may be subcontracted, such as community outreach or baiting, and thus contracts must be prepared with defined tasks, schedules, and deliverable products (Colvin et al. 1992).

The EMS planning should cumulate in an Execution and Management Plan that contains the policy, targets and objectives (metrics), risk assessment, responsibilities, procedures, schedules, methods, training outline, and other program elements and descriptions. The plan should be action-oriented, tailored to the pest situation, and periodically updated. The plan must identify the means for continuous improvement. A defined plan is the basis for program execution and ongoing improvement, as well as for political support and funding.

Competence and Behavior

Training and hiring competent and diversely-skilled personnel will establish necessary knowledge to sustain the program and EMS. In an urban situation this entails, for example, pest management personnel being knowledgeable in infrastructure construction and the reading of engineering drawings. Similarly, it entails landscape architects being knowledgeable in design features predisposed to rat infestation, or public works personnel being able to identify conditions posing risk. Cross-training of personnel for mutual understanding of diverse tasks within the EMS will aid its implementation.

The behavior of people ultimately determines the success of a vertebrate pest program and EMS. There must be investment in employee development but also accountability. This includes the people executing the plan and the people who will benefit from it, since often the public and numerous landowners must participate for a program to be successful. Training is highlighted and ongoing within an EMS, because the inherent process is to achieve continuous improvement through awareness, cooperative actions, and a positive culture.

Implementation and Monitoring

Implementation should occur per the Execution and Management Plan and schedule. Interface points with stakeholder leadership and participants should be clear, and Task Forces or Working Groups should be established for specific issues. An inter-disciplinary approach and system integration should be maximized, meaning tight integration of tasks and schedule.

Prevention entails involvement in non-traditional aspects of rodent control, including urban (land use) planning and zoning, permitting for businesses, urban design, and infrastructure construction (Colvin 2002). Such preventative elements should be highlighted in the EMS objectives, Aspect Register, and implementation.

Monitoring must be performed as part of a vertebrate pest program and includes both field and administrative monitoring. It allows for timely adjustment and confirmation that activities are being performed as planned and scheduled. It also helps when timing seasonal actions. Contingency plans should be part of the EMS for discoveries or unanticipated changes in environmental conditions or pest populations.

Continuous improvement can be achieved through: 1) clarifying and enhancing roles and responsibilities; 2) training programs and mentoring; 3) quality assurance/control measures; 4) data analysis; 6) review and updating of objectives, targets, and risk factors; 7) audits and trend analysis; 8) incorporation of lessons learned into work plans; 9) distribution of status reports to managers and stakeholders; 10) consistent documentation; and 11) accountability.

Documentation

An EMS allows for the status and accomplishments of a program to be tracked and demonstrated. This is particularly important when dealing with policy makers and annual budgets. Along with schedule management, documentation can include the outcome of objectives, targets, and risk management. Long-term records on program development and implementation are valuable as staffing changes, allowing better opportunity for sustainability.

In a vertebrate pest program, data collection and management should be a major part of program execution. Information management can include use of a geographic information system with relational databases (von Wahlde and Colvin 1994). Documentation also should include electronically retrievable procedures, budget data, procurement records, correspondence, survey and baiting data, code violations, training records, and photo logs. Documentation should be organized for audit; documented results help assure continuous improvement.

Auditing and Review

Auditing and quality assurance (QA) are driving elements of an EMS. They are the mechanisms for evaluating system effectiveness and achieving continuous improvement. Audits normally are performed by someone outside of the immediate organization who has excellent technical and administrative skills. The audit has the potential to bring new concepts to the program. Improved training, record keeping, scheduling, and field methods may all result from an effective audit. It also can show need for additional funding and help force policy decisions.

The effectiveness and integration of mitigation measures should be evaluated during the audit, as well as during periodic review of objectives and targets by the program manager. The intent is to identify program or system gaps to provide feedback for continuous improvement. The frequency of audit is dependent upon risk assessment and historic performance, and it should be embraced by program participants as a means to enhance structure and sustainability.

Gap analysis (i.e., Trend and Root-Cause analysis) should be used by program managers to identify holes in the mitigation measures, training, communication, and methods used to administer the program (Woodside and Aurrichio 1999). For example, trends in code violations can be evaluated and the root cause of repetitive violations determined to be a lack of public awareness and low fines. The program can be re-focused, objectives and targets improved, and repetitive failure of a certain program element resolved. Similarly, the number of completed work tasks and action items, per schedule and discipline or department, can be quantified.

RANKING RISKS AMONG U.S. CITIES

To begin a national focus on EMS for urban rodent control, we prepared an Aspect Register as an Environmental Risk Assessment tool to rank 32 of the largest U.S. cities for their inherent risk of having rodent problems and thus to help identify mitigation opportunities. Rodents are a symptom of environmental decline, and we considered a variety of environmental conditions that can coincide with rodent problems.

To build the Aspect Register for rodent risk factors, we principally used the latest U.S. Census Bureau statistics (U.S. Census Bureau 2006) and chose cities for which comparable statistics were available. Selection was made of 14 factors that we considered relevant, based on our experience and the literature, and likely to best represent indirect measures of commensal rodent risk. Aspects or categories included: human population and density, percent of impoverished residents, city age, extent of port and transit facilities, and city revenues. Also included were city expenditures on housing, community development, streets and sewers, solid waste management, utilities (including water, electricity, and transit systems). Climatic aspects in the Register included yearly total inches of rainfall, and total days of rain and sunshine. In addition, a manufacturer of frequently used rodent control products provided sales figures by city to allow for a direct measure of resident responses to rodent problems.

The revenue and individual spending categories were converted to a per capita basis to allow for comparisons among cities. Where lower values would favor more rodents, those statistics were converted to inverse values so

Table 1. Urban Aspect Register for ranking rodent risk in 32 U.S. cities.

	/------PEOPLE FACTORS						------/	/-----CITY FACTORS		------/	/------CITY REVENUE & SPEND					------/
CITY	Population (1000s); 2005	Pop. Rank	Pop. Density 1000/sq mi	Density rank	Control Product Sales Rank	% Families Below Poverty Level	Family Poverty Level	Founding Date	City Age Rank	Transport. Hub Rating	Total City Revenue Per Capita $$	City Revenue Per Capita Rank	Rank Per Capita Structural Spend	Rank Per Capita Spend on Sewerage	Rank Per Capita Spend on Solid Waste	Rank Per Capita Spend on Utilities
Column 1	**Column 2**	**Column 3**	**Column 4**	**Column 5**	**Column 6**	**Column 7**	**Column 8**	**Column 9**	**Column 10**	**Column 11**	**Column 12**	**Column 13**	**Column 14**	**Column 15**	**Column 16**	**Column 17**
New York, NY	8143	17.18	26.4	8.80	2.55	17.4	4.52	1625	7.49	10.0	7478.4	1.34	0.87	1.32	2.30	0.48
Houston, TX	2017	4.26	3.3	1.10	3.86	16.7	4.34	1837	3.33	10.0	1464.6	6.83	4.20	3.10	9.24	0.08
Boston, MA	559	1.18	12.2	4.07	11.43	16.5	4.29	1630	7.39	10.0	4814.0	2.08	1.96	1.10	2.94	2.15
Louisville, KY	556	1.17	4.1	1.37	4.61	17.9	4.65	1780	4.45	0.0	1343.5	7.44	3.75	10.01	7.90	1.56
Philadelphia, PA	1463	3.09	7	2.33	7.51	22	5.71	1682	6.37	10.0	4026.0	2.48	2.72	1.70	4.47	0.60
Baltimore, MD	636	1.34	7.7	2.57	7.13	19.3	5.01	1729	5.45	10.0	4276.7	2.34	2.02	2.23	3.54	2.45
Washington, DC	551	1.16	9.1	3.03	16.92	16.9	4.39	1790	4.25	5.0	12715.1	0.79	1.53	1.34	3.64	1.96
Chicago, IL	2843	6.00	12.7	4.23	1.73	18.1	4.70	1770	4.65	5.0	1973.3	5.07	1.55	5.64	4.29	0.08
El Paso, TX	599	1.26	0.3	0.10	3.67	24.6	6.39	1848	3.12	0.0	981.6	10.19	5.17	3.59	10.01	1.47
Milwaukee, WI	579	1.22	6.2	2.07	3.01	21.8	5.66	1846	3.16	5.0	1114.0	8.98	1.44	2.28	2.65	4.56
Long Beach, CA	474	1.00	9.1	3.03	4.22	23.9	6.21	1888	2.33	10.0	2561.2	3.90	1.44	8.53	2.07	0.87
Detroit, MI	887	1.87	6.4	2.13	9.59	29.1	7.56	1701	6.00	5.0	4782.4	2.09	1.47	0.45	2.80	0.55
Ft. Worth, TX	624	1.32	3.5	1.17	6.96	14	3.64	1856	2.96	0.0	1104.2	9.06	5.39	2.07	6.56	1.25
San Antonio, TX	1257	2.65	2.8	0.93	4.46	17	4.42	1718	5.67	0.0	1930.0	5.18	5.24	1.69	7.93	0.31
Seattle, WA	574	1.21	6.8	2.27	11.22	12.2	3.17	1867	2.75	10.0	3623.7	2.76	1.70	0.96	1.54	0.22
Los Angeles, CA	3845	8.11	7.9	2.63	4.27	15.8	4.10	1781	4.43	5.0	2710.5	3.69	2.68	1.61	5.35	0.47
Portland, OR	533	1.12	3.9	1.30	12.78	11.2	2.91	1851	3.06	5.0	4913.7	2.04	1.78	0.65	2.76	2.41
Dallas, TX	1214	2.56	3.5	1.17	3.58	18.7	4.86	1856	2.96	0.0	1532.9	6.52	4.15	2.08	7.34	1.97
Memphis, TN	672	1.42	2.3	0.77	2.92	21.5	5.58	1819	3.69	0.0	4392.9	2.28	7.51	4.13	4.44	0.18
San Jose, CA	912	1.92	5.2	1.73	4.17	9	2.34	1777	4.51	0.0	1819.1	5.50	1.21	1.80	4.05	10.00
Nashville, TN	549	1.16	1.2	0.40	4.38	14.3	3.71	1779	4.47	0.0	4770.5	2.10	4.74	4.19	7.09	0.22
San Francisco, CA	739	1.56	16	5.33	6.37	7.7	2.00	1776	4.53	10.0	8106.9	1.23	1.07	1.76	2.76	0.27
Charlotte, NC	611	1.29	2.5	0.83	5.10	9.4	2.44	1755	4.94	0.0	1777.4	5.63	2.21	3.50	4.96	0.94
San Diego, CA	1256	2.65	3.8	1.27	1.85	8.8	2.29	1769	4.67	10.0	1952.2	5.12	1.60	0.86	6.61	1.39
Oklahoma City, OK	531	1.12	5.3	1.77	6.95	9.2	2.39	1889	2.31	0.0	1423.7	7.02	2.75	1.97	5.39	1.88
Columbus, OH	731	1.54	3.4	1.13	4.31	13.3	3.45	1812	3.82	0.0	1589.6	6.29	3.02	1.12	5.32	1.73
Jacksonville, FL	783	1.65	1	0.33	0.49	10.3	2.68	1832	3.43	10.0	3305.2	3.03	2.71	0.41	3.37	0.22
Indianapolis, IN	784	1.65	2.2	0.73	4.74	11.4	2.96	1821	3.65	0.0	2783.2	3.59	1.32	1.20	6.18	0.48
Austin, TX	690	1.46	2.4	0.80	3.62	11.8	3.06	1830	3.47	0.0	2527.5	3.96	2.72	1.69	4.78	0.29
Phoenix, AZ	1462	3.08	3	1.00	2.14	12.8	3.32	1881	2.47	0.0	1762.0	5.68	4.76	1.96	5.46	1.59
Denver, CO	558	1.18	3.6	1.20	8.34	10.6	2.75	1858	2.92	0.0	3958.8	2.53	1.99	2.07	2.76	0.91
Las Vegas, NV	545	1.15	4.1	1.37	2.20	8.8	2.29	1905	2.00	0.0	1198.2	8.35	2.65	4.43	2.76	0.40
Averages	1193.03	2.52	5.90	1.97	5.53	15.38	3.99	1798.69	4.08	4.06	3272.28	4.53	2.79	2.55	4.79	1.37
Sources	Table 31* incorporated urban area 2005 data	Calculated	2005 Census Bureau	Calculated	Calculated from Mgfr. Data	table* 689 2004 data	Calculated	Almanac	Calculated	Assigned	Calculated f/ Table 446*	Calculated	Calculated	Calculated	Calculated	Calculated
												------from Tab. 449:SAUS07				------

*Source: U.S. Census Bureau,. 2006. Statistical Abstract of the United States: 2007. The National Data Book,126th Edition. ISBN 0-16-076301-0, 1000 pp.

Table 1 (continued)

/------CLIMATIC FACTORS					------/	/------RESULTS		------/
Annual Inches Rainfall	Annual Rainfall Rank	Total Yearly Av. Rain Days	Rain Day Rank	Annual Av. % Sunshine	Sunshine Rank	Cities	Sums	**City Rank for Rodent Risk**
Column 18	**Column 19**	**Column 20**	**Column 21**	**Column 22**	**Column 23**	**Column 24**	**Column 25**	**Column 26**
49.7	6.06	121	6.91	64.1	6.68	New York, NY	76.5	1
47.8	5.83	105	6.00	55.9	5.82	Houston, TX	68.0	2
42.5	5.19	127	7.26	55.1	5.74	Boston, MA	66.8	3
44.5	5.43	124	7.09	53.4	5.56	Louisville, KY	65.0	4
42.1	5.13	117	6.69	56.2	5.85	Philadelphia, PA	64.7	5
41.9	5.11	115	6.57	58.4	6.08	Baltimore, MD	61.8	6
39.4	4.80	113	6.46	55.3	5.76	Washington, DC	61.0	7
36.3	4.42	125	7.14	51.8	5.40	Chicago, IL	59.9	8
9.4	1.15	49	2.80	80.3	8.36	El Paso, TX	57.3	9
34.8	4.25	125	7.14	52.1	5.43	Milwaukee, WI	56.9	10
12.9	1.57	32	1.83	90.1	9.39	Long Beach, CA	56.4	11
32.9	4.01	135	7.71	49.3	5.14	Detroit, MI	56.4	12
34.7	4.24	79	4.51	63.6	6.63	Ft. Worth, TX	55.8	13
32.9	4.01	82	4.69	81.0	8.44	San Antonio, TX	55.6	14
37.1	4.52	155	8.86	38.4	4.00	Seattle, WA	55.2	15
13.2	1.60	35	2.00	72.1	7.51	Los Angeles, CA	48.5	26
37.1	4.52	153	8.74	38.9	4.05	Portland, OR	53.1	16
34.7	4.24	79	4.51	63.6	6.63	Dallas, TX	52.6	16
54.7	6.66	107	6.11	58.6	6.10	Memphis, TN	51.8	18
14.4	1.76	65	3.71	82.2	8.56	San Jose, CA	51.3	19
48.1	5.87	119	6.80	57.0	5.94	Nashville, TN	51.1	20
20.1	2.45	63	3.60	71.2	7.42	San Francisco, CA	50.4	21
43.5	5.31	113	6.46	58.6	6.10	Charlotte, NC	49.7	22
10.8	1.31	41	2.34	72.1	7.51	San Diego, CA	49.5	23
35.9	4.37	83	4.74	64.4	6.71	Oklahoma City, OK	49.4	24
38.5	4.70	137	7.83	47.9	4.99	Columbus, OH	49.3	24
52.3	6.38	116	6.63	60.5	6.30	Jacksonville, FL	47.6	27
41.0	5.00	126	7.20	51.2	5.33	Indianapolis, IN	44.0	28
33.6	4.10	80	4.57	82.1	8.55	Austin, TX	43.1	29
8.3	1.01	36	2.06	81.1	8.45	Phoenix, AZ	43.0	30
15.8	1.93	89	5.09	67.1	6.99	Denver, CO	40.7	31
4.1	0.50	26	1.49	81.0	8.44	Las Vegas, NV	38.0	32
32.7	3.98	96.00	5.49	62.96	6.56		54.08	
Table 380* 30-year avg 1971-2000	Calculated	Table 382* 30-70 yr records through 2004	Calculated	Table 384* 30-70 yr records through 2004	Calculated		Calculated sum of rankings	

that scores consistently equaled more risk. Rankings per category were established in relation to the lowest value in that category, with other values calculated to a two-decimal place multiple of the low value. Finally, ranking values in each category were multiplied or divided by a constant so that all numerical values were in the same scale, providing for approximately equal weighting in the overall tabulations.

The Register (Excel spreadsheet) allowed for ranking and sorting by any individual risk factor, or by any combination of factors, to compare cities. Within a city, it also showed the overall impact in ranking if mitigation was applied, such as increasing per capita spending on infrastructure.

When the individual 14 rankings in the Aspect Register were summed per city, to provide a cumulative score (Table 1), the top ten rankings for risk of having rodent problems were: 1) New York, NY; 2) Houston, TX; 3) Boston, MA; 4) Louisville, KY; 5) Philadelphia, PA; 6) Baltimore, MD; 7) Washington, D.C.; 8) Chicago, IL; 9) El Paso, TX; and 10) Milwaukee, WI. The data were then evaluated to determine the factors that contributed most to risk and the mitigation strategies that could help solve underlying causes. By any measure, New York City represented a special case with the largest U.S. urban population, greater city age, and higher population density when compared to other cities. It is probably not necessary to construct predictive assessments to confidently predict that New York would be near the top of U.S. cities at risk from conditions favoring commensal rodents. Population density also helped contribute to Boston and Chicago being in the top 10, but 6 of the top 10 cities were under 1 million in population, and 3 were below the group average in density. Age was also a factor, with 4 of the top cities over 300 years old; 11 others studied were over 200 years old with associated problems of older infrastructure, and thus limitations on good land use design and planning.

Clearly, multiple factors in combination contributed to the rankings. Lower than average city revenue or spending on critical infrastructure factors contributed to higher scores for some cities. Warm, wet weather was an important factor for some cities, as it could lead to more vegetation cover, increased deterioration of structures, and higher rodent survival and reproductive rates.

Infrastructure categories in the Aspect Register represent critical risk factors for which mitigation should be evaluated, prioritized, and monitored within an EMS. This includes capital improvement projects involving sewers, sidewalks, and other physical urban features. Expenditure on buildings and streets, particularly in older neighborhoods (including subsidized housing projects), is critical to help prevent features conducive to rodent infestation. Other critical areas include dock and freight-handling facilities that may 'import' rats or have structures and stored or spilled goods that sustain them.

Municipal expenditures in some categories, such as sewerage, become critical in older cities with antiquated brick systems or combined storm and sanitary systems (Colvin et al. 1998). Modern sewer systems can have minimal rodent problems by virtue of their construction. Older cities need to prioritize renovation and maintenance of older sewer and utility systems; such systems can be inhabited by large rat populations with the ability to move about underground and emerge to do damage and then escape back underground. Underground populations also provide a source of rats to chronically colonize and re-infest surface areas, resulting in repetitive failures in surface control measures when not combined with subsurface efforts.

Older neighborhoods with dilapidated structures plague many urban areas. Such locations require greater and sustained environmental improvement, including renovation and demolition. Municipal refuse collection programs and public awareness of sanitation codes must be a priority with resource allocation to provide adequate containers, frequent pick-up, and code enforcement. Vegetation maintenance (in housing areas, right-of-ways, and commercial areas) and elimination of unchecked growth in vacant lots is important for reducing rodent food and harborage, as well as cutting the potential for crime, litter, and vagrancy. Urban development and the increasing abundance of restaurants warrant emphasis on urban design, land use planning, permitting for waste management, public outreach, and regulatory compliance.

An Aspect Register could be created for different areas of a city, allowing more specific aspects to be assessed including direct measurements of rodent populations. Critical locations for investigation and management could include restaurant districts, parks, residential areas, and waterfronts. Municipalities that are not receiving adequate revenues or expending sufficient resources on critical infrastructure and services need to evaluate their revenue sources and budgeting, and reprioritize their expenditures for sustainable development and environmental improvements to improve overall community health. Surveys in city target areas can be done before and after mitigation to assess progress (Centers for Disease Control and Prevention 2006).

Use of an Aspect Register allows municipal authorities, and the communities they serve, to better identify and understand their specific risk factors. It creates public awareness of vulnerabilities and needs. It also helps cities and community groups prioritize actions and resources for mitigating causative factors, ultimately enhancing environmental conditions, and thus having best opportunity for pest prevention and sustainable improvement.

As cities age, correspondingly greater weight needs to be given to those factors associated with infrastructure. Attention also must be given to trends of climate change, increased congestion and waste management, and growing urban areas with low-income residents. Principles of sustainable development and investment in long-term environmental management will be required to mitigate the growing risk from harmful pest rodents.

SUMMARY

The United States exemplifies the global trend toward urbanization with distended metropolitan areas that house over eighty percent of today's population, and that number is growing (U.S. Census Bureau 2006). We expect vertebrate pest problems to increase significantly in the 21st Century as a result of development (loss of natural areas, urban sprawl), global transportation systems, human population growth and congestion, aging infrastructure, increased solid waste, and climate changes. Historic approaches to rodent control emphasized technology and associated research, but repetitive failures in vertebrate pest programs demonstrate the need to develop inter-disciplinary and structured programs. Research, development, and execution of an EMS should be the future focus in vertebrate pest management in the U.S. and elsewhere to overcome historic problems with delivery of effective, strategic, and sustainable programs.

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