20-YEAR EXAMINATION OF THE HABITATS OF AN URBAN NORWAY RAT, *RATTUS NORVEGICUS* BERK. (MAMMALIA: MURIDAE) POPULATION

DANIEL BAJOMI, TAMAS MARKOS, AND LASZLO TAKÁCS
Bábolna Bioenvironmental Centre, Budapest, Hungary

Abstract - In 1971-72 a large-scale, city-wide campain against Norway rat was carried out by Bábolna Bio in Budapest. The rat infestation rate of premises fell to an average level below 0.5%. Subsequently a complex maintenance program was undertaken. This comprised preventive and curative measures based on data collection of reports or regular surveys as well as targeted placements of poisonous baits. In baits as active ingredients coumatetralyl and, since 1990, bromadiolone selectively acting anticoagulant compounds were used. Annual rat infestation rates further decreased having attained a minimum 0.08 % yearly level in 1998. The habitat preference of Norway rat in various urban biotops of Budapest was studied. A categorization and code system complex habitats and micro-habitats was elaborated. Since 1978 a computer-assisted, database of rat occurrences in different habitats has been established, and data from a 20-year period (1978-1997) are presented here. Simultaneously with a declining Norway rat occurrences, the overall pattern of habitat preference did not change. Apartment buildings were primarily preferred by rats followed in the order of incidences by family houses, non-food industrial units, public services and open fields, food industrial units and, finally, by public institutions complex habitats. Courtyards and surroundings were frequently inhabited sites, often with extensive underground burrow systems. The rodents colonized different parts of the sewerage system, and in buildings they preferred cellars. Noticable fluctuation of rat incidences were characteristic first of all for family house complex habitat and for the micro-habitat group of the sewerage system.
Key words - Urban rats, habitat preference, control, population fluctuation

INTRODUCTION

Budapest has more than 2 million inhabitants and with its 23 administrative districts covers an area of 525 km^2. Rats caused several hygienic and economic problems, including enormous damages especially in food industry, until the late 1960s. Preliminary investigations estimated ca. 2 million rats to occur in Budapest at that time. The average infestation level of various premises attained 32.8% but the central parts of the city exhibited practically 100% rat occurrence rates (Bajomi, 1983) Norway (brown) rat (*Rattus norvegicus* Berk.) proved the major pest, while the black rat (*Rattus rattus* L.) played a minor role. Previous efforts in rat control restricted to certain areas of Budapest and were practically unsatisfactory.

In 1971 a rat eradication program was undertaken by Bábolna Bioenvironmental Centre, using precisely organized, systemic surveys and placements of anticoagulant poisonous baits. As a result of these control operations the average infestation rate of premises in Budapest fell below 0.5%. Subsequently, starting in 1973, a complex rat-free maintenance system with well-organized preventive and curative measures has been functioning (Bajomi and Vámos, 1983; Bajomi, 1993). This continuous rat control program could further decrease (to 0.08% in 1998) the annual rat infestation rates.

Simultaneously with the development of rat control methods, the behaviour of Norway rat in a typical urban environment was also thoroughly studied (Bajomi, 1983.) Investigations on the habitat preference of this species initiated to create a categorization of special habitats observed as mostly preferred sites by rats in Budapest (Bajomi and Sasvári, 1986). The system of complex habitats and micro-habitats using also special code numbers, provided a rich collection of data and valuable information on Norway rat occurrences in the city. In 1978, a unique computerized database has also been established to assist the performance of more efficient and economic control operations than before. In addition, the more than 10,400 records, accumulated in a rather long period (1978-1997) made possible to carry out accurate analysis of data with the perspective of providing new findings in the biology and ecology of Norway rat.

Proceedings of the 3rd International Conference on Urban Pests.
Wm H. Robinson, F. Rettich and G.W. Rambo (editors). 1999.

In the present paper we wish to publish the first comparative data of a 20-year investigation period, demonstrating the habitat preference of Norway rats in various complex habitats and micro-habitats surveyed regularly in Budapest.

MATERIALS AND METHODS

The rate of infestation by the Norway rat in the total area of Budapest was determined by systemic assessments. Data collection was based partly on exact records of reports on rat occurrence from the public, companies or institutions, partly on objective search for infestation foci by control operators in different premises. In the former case the actual appearance of rats was checked with subsequent thorough inspection of places indicated as rat infested. Many of the examinations were carried out at regular intervals, the frequency of which varied according to the level of rat infestion determined before.

The presence of rats was established by different ways such as: observation of live rats (which can also be reported by the public in written statements); observation of gnawing marks on bait substance or wax blocks; observation of rat footprints and tail tracks, especially on talcum powdered surfaces; notice of rat droppings; detection of exits of rat burrows.

For professional maintenance operations and regular surveys the area of Budapest was divided into 9 sections, with one working team operating in each. Each section was further divided into several smaller units , called working districts where the actual treatments and inspections were carried out. For better comparison between areas of similar or even dissimilar character, observation units, socalled idealized premises were established that served also as a basis of the categorization of rat habitats. Such idealized premises are essentially the following: one traditional building; one apartment building up to 4 staircases; one family house with the land attached; one public building, office, institution irrespective of its nature and size; one small industrial unit with a ground space of up to 2,000 m^2; each 1,000 m^2 area within a large factory; each 1,000 m^2 area of land without buildings.

In each premise the sewerage system pertaining to it , belongs to the unit in question. For more details see a previous publication (Bajomi and Vámos, 1983).

For the study of the biology and habitat preference of *R. norvegicus* and also in order to standardize the documentation of data, a categorization of habitats was introduced. As a useful convention, the term complex habitat represents the smallest part of the rats living-space, in which environmental conditions are the same but they are different from those of other habitats (Bajomi, 1980). One complex habitat was divided into several microhabitats having generally confined dimensions and some special characteristics. For the whole area of Budapest 6 complex habitats and 90 micro-habitats were described (Table 1). A code system for the designation of particular complex habitats and micro-habitats was also established that can considerably assist to handle easier with particular data enabling also even their sophisticated computerized analysis. Each complex habitat has a code number of its own (1 to 6) and in the case of micro-habitats the other number or numbers designate the micro-habitat in question.

Since 1978 a computer-assisted database of Norway rat occurrences in Budapest has been functioning at Bábolna Bioenvironmental Centre. The individual records comprise the following data: date of registration, location of the site (section, working district), origin of data (e.g. report from the public, observation of the team) and code number of the microhabitat. In the present paper, data of micro-habitats having higher rat-incidence rates than 0.4% are used (Table 4). For purpose of comparison, however, exceptionally a few other data have also been included.

RESULTS

After the large-scale, centrally organized deratization campaign in the early seventies, a complex system of maintenance operations started to function in 1973 in Budapest. This program is based on systemic and aimed surveys, on thorough documentation of information and on a computerized database, a pro-

Proceedings of the 3rd International Conference on Urban Pests.
Wm H. Robinson, F. Rettich and G.W. Rambo (editors). 1999.

Table 1. Code numbers of diferent rat habitats

1	APARTMENT BUILDINGS	2	FAMILY HOUSES	3	FOOD INDUST-RIAL UNITS
11	garrets	21	garrets	31	garrets
12	cellars	22	cellars	32	cellars
121	boiler-rooms	21	boiler-rooms	321	boiler-rooms
122	air-raid shelters				
13	homes	23	homes		
131	workrooms	231	workrooms	331	workrooms
				332	office rooms
				333	storerooms
				334	communal rooms
				335	kitchens
14	auxiliary buildings	24	auxiliary buildings	34	auxiliary buildings
		242	pens, stables		
15	refuse rooms	25	refuse rooms	35	refuse rooms
16	courtyard	26	courtyards	36	courtyards
161	light wells				
17	burrows	27	burrows	37	burrows
18	sewer manholes	28	sewer manholes	38	sewer manholes
181	courtyard sewer drains	281	courtyard sewer drains	381	courtyard sewer drains
		282	sinks		
19	water-meters	29	water-meters	39	water-meters
				391	cable manholes
				392	heating-pipes

4	NON-FOOD-INDUSTRIAL UNITS	5	PUBLIC INSTITUTIONS	6	PUBLIC SERVICES AND OPEN FIELD
41	garrets	51	garrets		
42	cellars	52	cellars		
421	boiler-rooms	521	boiler-rooms		
				631	river-banks
431	workrooms	531	workrooms	632	storm banks
432	office rooms	532	office rooms	633	ships
433	storerooms	533	storerooms	634	areas of demolition work
434	communal rooms	534	communal rooms		
435	kitchens	535	kitchens	635	metro tunnels
44	auxiliary buildings	54	auxiliary buildings		
45	refuse rooms	55	refuse rooms	65	refuse rooms, containers
				651	uncovered rubbish dumps
46	courtyards	56	courtyards		
47	burrows	57	burrows	67	burrows
48	sewer manholes	58	sewer manholes	68	sewer manholes
481	courtyard sewer drains	581	courtyard sewer drains	681	drain-pipes
49	water-meters	59	water-meters		
491	cable manholes	591	cable manholes		
492	heating-pipes	592	heating-pipes	692	heating-pipes

Proceedings of the 3rd International Conference on Urban Pests.
Wm H. Robinson, F. Rettich and G.W. Rambo (editors). 1999.

gram which has also served - since 1978 - also the continuous follow-up treatments against Norway rats at infested sites. A great deal of data have been accumulated on the occurrences of *R. norvegicus* in different premises and other areas of the city demonstrating the preference of the Norway rat in different complex habitats and micro-habitats and also their requirements towards living space and some ecological conditions.

The study of yearly changes of rat infestations may also provide some insight into the population dynamics of this species with special regard to individual habitats. Up to the present altogether 6,391 records have been registered on complex habitat level and 10,417 records are now available concerning particular micro-habitats. For better orientation we use these data in this presentation with some kind of 'simplification' in order to focus on the most important sites where Norway rats have occurred and, as to the numbers of individuals detected, where the data are more informative and reliable.

Table 2. Occurrence of Norway rats in various complex habitats in Budapest between 1978-1997.

Complex habitat	Occurrence of rats	
	Number	%
Apartment buildings	1 920	30.0
Family houses1 123	17.6	
Non-food industrial units	1 012	15.8
Public services and open field	814	12.8
Food industrial units	787	12.3
Public institutions	735	11.5
Total:	6 391	100.0

During the 25-year period (1973 to 1997) of regular rat-free maintenance operations and associated observations in Budapest the infestation rate of various premises by Norway rat decreased continuously and very significantly (Fig. 1). The decline in the number of rat occurrences was especially remarkable

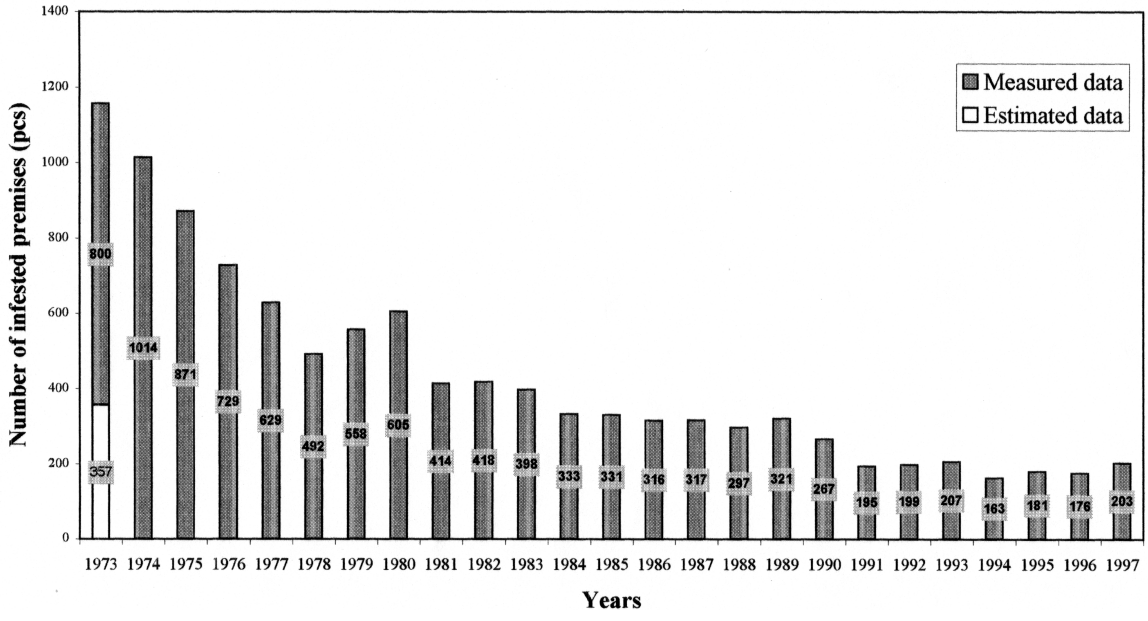

Figure 1. Number of rat infested premises in Budapest between 1978-1997.

Proceedings of the 3rd International Conference on Urban Pests.
Wm H. Robinson, F. Rettich and G.W. Rambo (editors). 1999.

Table 3. Occurrence of Norway rats in various micro-habitats in Budapest between 1978-1997.

Complex habitat	Micro-habitat	Occurrence of rats	
		Number	%
Apartment buildings	Internal sewerage systems a)	1 110	38.3
	Cellars	924	31.9
	Courtyards	394	13.6
	Burrows	310	10.7
	Auxiliary buildings	33	1.1
	Refuse rooms	21	0.7
	Other sites	107	3.7
	Total:	2 899	100.0
Family houses	Courtyards	702	39.1
	Burrows	445	24.8
	Auxiliary buildings	292	16.3
	Internal sewerage systems a)	115	6.4
	Cellars	103	5.7
	Pens, stables	95	5.3
	Refuse rooms	13	0.7
	Other sites	30	1.7
	Total:	1 795	100.0
Non-food industrial units	Courtyards	654	40.5
	Burrows	239	14.8
	Internal sewerage systems a)	227	14.0
	Storerooms	113	7.0
	Workrooms	101	6.2
	Cellars	97	6.0
	Refuse rooms	66	4.1
	Auxiliary buildings	35	2.2
	Other sites	84	5.2
	Total:	1 616	100.0
Public services and open field	Sewer manholes	844	55.6
	River banks	251	16.6
	Storm-water drains	194	12.8
	Burrows	81	5.3
	Uncovered rubbish dumps	51	3.4
	Other sites	96	6.3
	Total:	1 517	100.0
Food industrial units	Courtyards	377	27.8
	Internal sewerage systems a)	248	18.3
	Storerooms	200	14.7
	Workrooms	139	10.2
	Cellars	119	8.8
	Burrows	107	7.9
	Auxiliary buildings	81	6.0
	Refuse rooms	39	2.9
	Other sites	47	3.4
	Total:	1 357	100.0
Public institutions	Courtyards	296	24.0
	Internal sewerage systems a)	351	28.5
	Cellars	172	14.0
	Burrows	120	9.7
	Workrooms	78	6.3
	Storerooms	64	5.2
	Auxiliary buildings	50	4.1
	Refuse rooms	20	1.6
	Other sites	82	6.6
	Total:	1 233	100.0
	Total:	10 417	

a) internal sewage system: sewer manholes and courtyard sewer drains

Proceedings of the 3rd International Conference on Urban Pests.
Wm H. Robinson, F. Rettich and G.W. Rambo (editors). 1999.

Table 4. Most preferred micro-habitats of Norway rats in Budapest between 1978-1997.

		Occurrences of rats between 1978-1997	
		Number	%
12	Cellars of apartment buildings	924	8.87
68	Sewer manholes	844	8.10
18	Sewer manholes of apartment buildings	751	7.21
26	Courtyards of family houses	702	6.74
46	Courtyards of non-food manufacturing plants	654	6.28
27	Burrows in family houses	445	4.27
16	Courtyards of apartment buildings	394	3.78
36	Courtyards of food manufacturing plants	377	3.62
181	Courtyard sewer drains of apartment buildings	359	3.45
17	Burrows in apartment buildings	310	2.98
56	Courtyards of public institutions	296	2.84
24	Auxiliary buildings of family houses	292	2.80
58	Sewer manholes of public institutions	278	2.69
631	River banks	251	2.41
47	Burrows in non-food manufacturing plants	239	2.29
38	Sewer manholes of food manufacturing plants	209	2.01
333	Storerooms of food manufacturing plants	200	1.92
681	Drain-pipes	194	1.86
48	Sewer manholes of non-food manufacturing plants	177	1.70
52	Cellars of public institutions	172	1.65
331	Workrooms of food manufacturing plants	139	1.34
57	Burrows in public institutions	120	1.15
32	Cellars of food manufacturing plants	119	1.14
433	Storerooms of non-food manufacturing plants	113	1.09
37	Burrows in food manufacturing plants	107	1.03
22	Cellars of family houses	103	0.99
431	Workrooms of non-food manufacturing plants	101	0.97
42	Cellars of non-food manufacturing plants	97	0.93
242	Pens, stables of family houses	95	0.92
28	Sewer manholes of family houses	94	0.90
34	Auxiliary buildings of non-food manufacturing plants	81	0.78
67	Burrows in open fields	81	0.78
531	Workrooms of public institutions	78	0.75
581	Courtyard sewer drains of public institutions	73	0.70
45	Refuse rooms of non-food manufacturing plants	66	0.63
533	Storerooms of public institutions	64	0.61
651	Uncovered rubbish dumps	51	0.49
54	Auxiliary buildings of public institutions	50	0.48
481	Courtyard sewer drains of non-food manufacturing plants	50	0.48
-	Others	667	6.40
	Total	10 417	100.00

Proceedings of the 3rd International Conference on Urban Pests.
Wm H. Robinson, F. Rettich and G.W. Rambo (editors). 1999.

in the first five years (1973 to 1977). A transitional increase in the size of rat population could be detected in 1979-80 but thereafter, subsequent to the improvement of the efficiency of maintenance operations, the quantity of registered rat occurrences diminished year by year reaching a level at present that is approximately half of that recorded in early 1980s. In some periods (e.g. between 1984 and 1988 or 1991 and 1996) the overall index of rat infestation remained constant.

Norway rats occurred most frequently in apartment buildings complex habitat (Table 2). Approximately half as much specimens of this species were detected in complex habitats of family houses and non-food industrial units and they visited in even lower numbers and practically at very similar incidence rates the three other complex habitats (public services and open fields, food industrial units, public institutions).

Norway rats frequently colonize in buildings where people live or work. From practical point of view it is important to know which micro-habitats within these complex habitats they might prefer (Table 3). In apartment buildings complex habitat Norway rats were most frequently observed in the internal sewerage system and in cellars but some significant occurrence rates were recorded for courtyards and burrows as well. Rats had not utilized the other possible biotopes of this complex habitat. In the complex habitat of family houses there was a high incidence rate of rats in courtyards. In this case Norway rats were often observed in their burrows and also in auxiliary buildings. But the rat occurrences in the cellars as well as in the internal sewerage system or pens and stables were less frequent since these micro-habitats are often missing in family houses. The appearance of rats in refuse rooms or workrooms of apartment buildings or family houses was rather scarce.

In the past Norway rats have been regarded as considerably common animals in different industrial premises but their continuous presence in some significant populations in these complex habitats and also in special habitats of public services and open fields can be demonstrated even nowadays (Table 3). In non-food industrial units as complex habitat the courtyards micro-habitat could be considered as the most rat-infested sites. Burrows and the internal sewerage system were also relatively frequently visited by rats. Norway rats occurred, though at lower incidence rates, in store- and workrooms, cellars and refuse rooms. In the complex habitat of public services and open fields the occurrence of rats was registered mostly in sewer manholes. Rats also preferred riverbanks, and storm water drains was also found to represent a relatively frequently rat-infested micro-habitat.

In food industrial units it was also the courtyards micro-habitat where the majority of rat specimens could be detected. In this complex habitat Norway rats were also common in the internal sewerage system and, although to lesser extent, in storerooms as well. They may sometimes appear in great numbers in other biotopes (especially in workrooms, cellars and burrows), too. In the complex habitat of public institutions rats became established first of all in the internal sewerage system and courtyards as the most favourable micro-habitats for them. They also often visited cellars or appeared at burrows leading to underground nest system. Less typical was their presence in work- and storerooms or auxiliary buildings.

The order of micro-habitat preference of Norway rats is demonstrated in Table 4. If we take into consideration merely those micro-habitats which had rat occurrences above 2.0%, first thing that can be emphasized is the exceptional significance of courtyards laying in diverse complex habitats as well as underground structures as cellars and rat-made burrows. Regarding complex habitats, as we could see before, the importance of apartmant buildings, family houses and industrial establishments is to be primarily mentioned.

Different types of micro-habitats can also be distinguished by their location within a city or a premise. This approach may give some additional information on rat occurrences and can assist to carry out improved control operations. These data are summarized in Table 5. In courtyards and surroundings as in such a group of micro-habitats characterized by similar location, courtyards were preferred by rats to the greatest extent. Burrows were also frequented sites of rats but their occurrence in auxiliary buildings proved to be less typical and was negligible in pens and stables. The colonization of

Proceedings of the 3rd International Conference on Urban Pests.
Wm H. Robinson, F. Rettich and G.W. Rambo (editors). 1999.

Norway rat in the sewerage system is a well-known phenomenon. In the great majority of cases, the presence of these rodents was demonstrated in sewer manholes. They appeared less frequently at courtyard sewer drains. In houses and buildings rats colonized first of all in cellars. Under suitable conditions they might occur in storerooms and workrooms. In open fields Norway rats were encountered mostly at riverbanks. Rats could often be observed to prepare burrows also in open fields. Considering the refuse storing sites, refuse rooms were mostly preferred by rats. Uncovered rubbish dumps seemed as less appropriate places to settle for these rodents under present conditions.

Table 5. Occurrence of Norway rats in differerent micro-habitat groups between 1978-1997

Micro-habitat group	Number of rat occurrences a)	Code numbers	Micro-habitat	Incidence Rate %
Courtyards and surroundings	4 240	16+26+36+46+56 17+27+37+47+57 14+24+34+44+54 242	Courtyards Burrows Auxiliary buildings Pens, stables Other sites	57.2 28.8 11.6 2.2 0.2
Sewerage system and drainage of buildings	3 094	18+28+38+48+58+68 181+281+381+481+581+681 681	Sewer manholes Courtyard sewer drains Storm water drains Other sites	76.0 17.5 6.3 0.2
Houses, buildings	2 351	12+22+32+42+52 333+433+533 131+231+331+431+531	Cellars Storerooms Workrooms Other sites	60.2 16.1 14.1 9.6
Open fields	382	631 67	Riverbanks Burrows Other sites	65.7 21.2 13.1
Refuse storing sites	225	15+25+35+45+55 651	Refuse rooms Uncovered rubbish dumps Other sites	70.7 22.7 6.6

a) total number of rat occurrences included 10,292 out of 10,417

Table 6 shows the distribution of relative incidences of Norway rat occurrences within the range of different complex habitats. In the micro-habitat group of courtyards and surroundings, courtyards were mostly visited by rats in family houses or in units of non-food industry. Burrows were the most frequented sites in family houses and in apartment buildings. Auxiliary buildings proved to be favourable habitats for rats first of all in family houses. As part of the sewerage system, sewer manholes were preferably visited by the Norway rat in public services and open fields as well as in apartment buildings where these animals often appeared also at courtyard channel heads, exhibiting here much higher frequency of occurrence than in other complex habitats. Regarding houses and other buildings, cellars were found to be favourable sites of rats primarily in apartment buildings and - at significantly lower rates of occurrences - in public institutions, while storerooms and workrooms were similarly good biotopes for this species in units of food industry and - to slightly lesser extent - in those of non-food industry. In the case of refuse rooms, most rodent specimens were detected in non-food industrial plants but they also appeared relatively frequently in units of food industry as well. The occurrence of Norway rats in individual micro-habitats within the same complex habitat is shown in Table 7. Data are also given if rats were detected occasionally in a single micro-habitat of a complex habitat.

Proceedings of the 3rd International Conference on Urban Pests.
Wm H. Robinson, F. Rettich and G.W. Rambo (editors). 1999.

Table 6. Occurrence rate of Norway rats in some frequented micro-habitats belonging to different complex habitats in Budapest between 1978-1997.

Micro-habitat group	Micro-habitat	Number of rat occurrences [a]	Relative incidence in different complex habitats (% of cases)					
			Apartment building	Family house	Food industry	Non-food industry	Public institutions	Public serv., open field
Courtyards and surroundings	Courtyards	2 423	16,3	29.0	15,5	27.0	12,2	n.a. [b]
	Burrows	1 221	25,4	36,5	8,8	19,5	9,8	n.a.
	Auxiliary buildings	491	6,7	59,5	16,5	7,1	10,2	n.a.
Sewerage system	Sewer manholes	2 353	31,9	4.0	8,9	7,5	11,8	35,9
	Courtyard sewer drains	542	66,2	3,9	7,2	9,2	13,5	n.a.
Houses, buildings	Cellars	1 415	65,3	7,3	8,4	6,8	12,2	n.a.
	Storerooms	377	n.a.	n.a.	53.0	30.0	17.0	n.a.
	Workrooms	333	2,1	2,4	41,9	30,3	23,4	n.a.
	Refuse rooms	159	13,2	8,2	24,5	45,5	12,6	n.a.

a) total number of rat occurrences included 9 314 out of 10 417
b) not applicable

Table 7. Simultaneous occurrence of Norway rats in various micro-habitat differerent complex habitats in Budapest between 1978-1997.

Complex habitat a)	Simultaneous rat occurrences in micro-habitats (% of cases)			
	only in one habitat	in two habitats	in three habitats	in four habitats
Apartment buildings	50,2	36,1	11.6	2,1
Family houses	46,9	41,8	10.2	1,1
Non-food industrial units	45,3	44,6	9.0	1,1
Public services and open fields	77,7	21,3	1.0	0.0
Food industrial units	40,4	45.1	12.8	1.7
Public institutions	39.8	42.6	16.5	1.1

a) for the total number of rat occurrences in different complex habitats see Table 1

In the complex habitat of apartment buildings rats occurred mostly in one, to a lesser extent in two micro-habitats. Norway rats visited nearly equally often both one or two micro-habitats in the case of family houses, non-food industrial units, food industrial units and also public institutions with the remark that in the latter complex habitat even the frequency of simultaneous occurrence in three micro-habitats was also noticable. The public services and open fields complex habitat can be characterized primarily by rat infestation in a single micro-habitat.

Data that can show yearly changes of Norway rat populations registered in complex habitats and in some micro-habitats. There is a general tendency of continuous decrease in the number of rat specimens, especially until the early 1990s. The yearly changes are sometimes not too strong, in other cases they show interesting alterations.

Proceedings of the 3rd International Conference on Urban Pests.
Wm H. Robinson, F. Rettich and G.W. Rambo (editors). 1999.

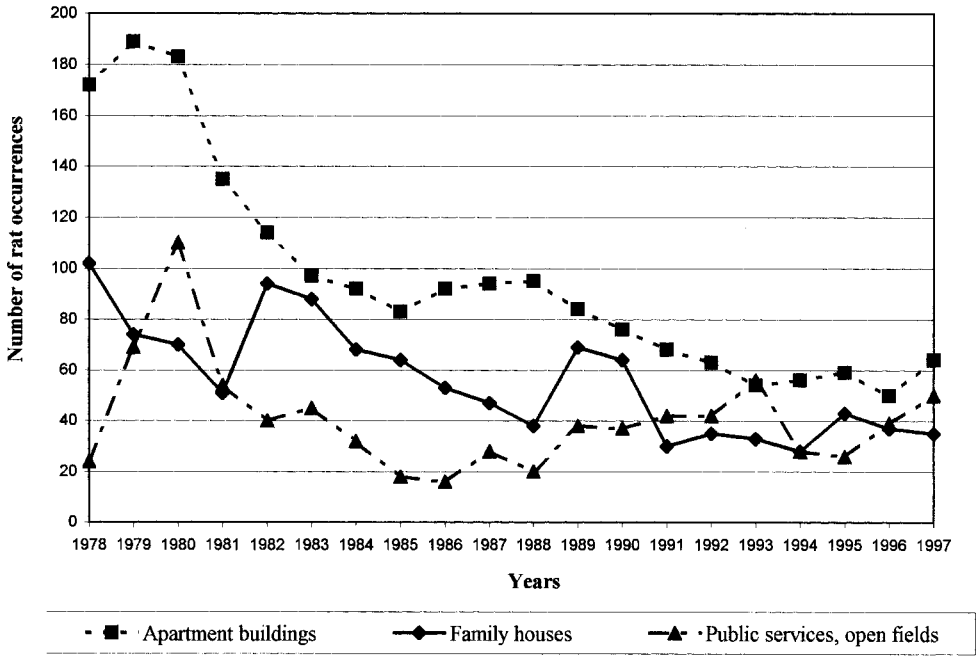

Figure 2. Number of rat infested premises in Budapest between 1978-1997.

Figure 2 shows the yearly changes of rat occurrences in respect of three complex habitats. In apartment building complex habitat rat population (as to records on occurrences) in Budapest - after a moderate transitional increase in 1979 and 1980 - continuously decreased. The complex habitat of family houses showed - along with an obvious general decrease in the number of animals - an interesting fluctuation of Norway rat populations. The changes exhibited a slight regular dynamics with a periodicity of 6 or 7 years but the higher occurrence rates were smaller and smaller as the time advanced. In the public services and open fields a similar population increase occurred in 1979-80, 1982-83, 1988-89 and 1993.

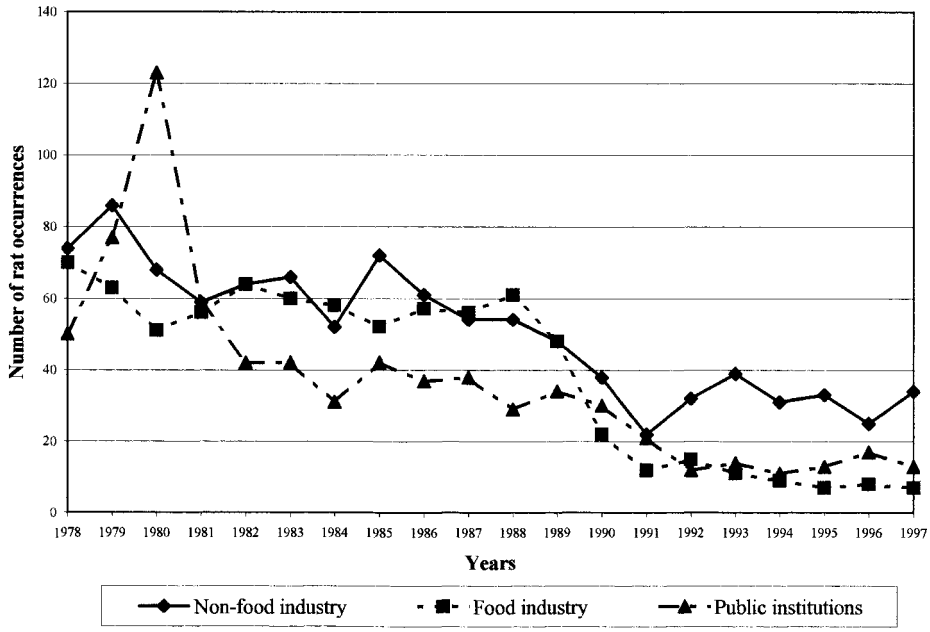

Figure 3. Yearly changes of Norway rat occurrences in some complex habitats (buildings, public services and open fields) of Budapest between 1978-1997.

Proceedings of the 3rd International Conference on Urban Pests.
Wm H. Robinson, F. Rettich and G.W. Rambo (editors). 1999.

Figure 3 shows data of other three complex habitats. The simplest case is that of food industry, with a general decreasing tendency of rat infestations interrupted by a sudden decline in yearly data after 1988-89. Changes of rat occurrences in non-food industry complex habitat can be characterized by a very similar curve but after 1991 Norway rat populations seem to remain here at a stabilized but not very high level. In public institutions, after an unexpected strong but transitional increase of rat population in 1979-80, rat occurrences continuously diminished reaching finally a very low level at the end of observation period.

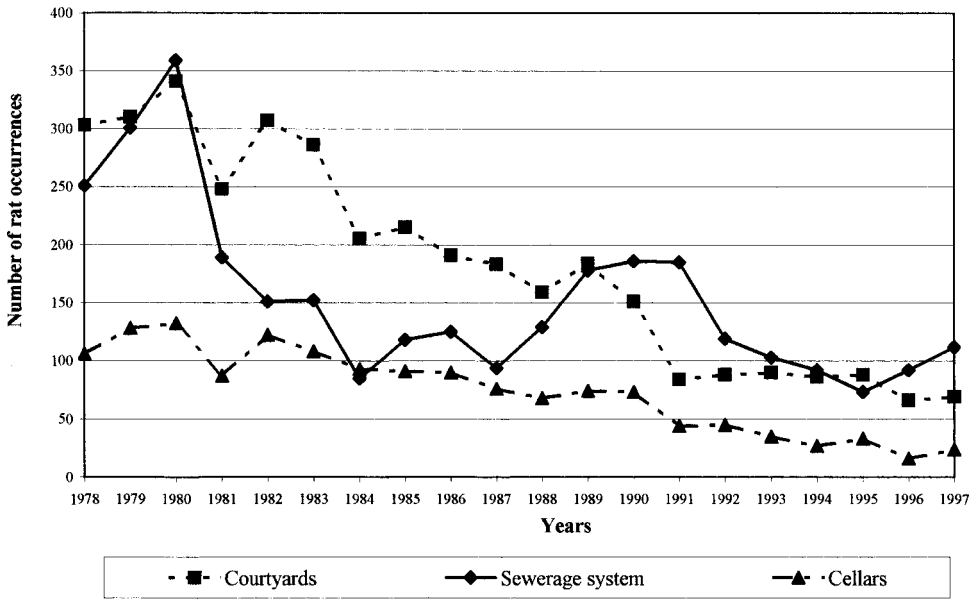

Figure 4. Yearly changes of Norway rat occurrences in some micro-habitat types (courtyards, sewerage system, cellars) of Budapest between 1978-1997.

Figure 4 shows the yearly changes of Norway rat populations in three groups of micro-habitats. Some interesting dynamics in numbers of occurrences can be observed regarding courtyards and the sewerage system. A few peaks (in 1980 and 1989-91) seems here to be also typical. As to the numbers of rats observed in cellars, data reflect a continuous and steadily decreasing tendency in the size of this fraction of Norway rat population.

DISCUSSION

In an urban environment as the spacious territory of Budapest possessing a great variety of habitats, Norway rats have established a relatively large and stable population already in the historical past. After the successful deratization action carried out in 1971-72, the subsequent follow-up maintenance program has aimed to attain and sustain a low, acceptable level of rat population. The parallel running investigation of the biology of these rodents and the uninterrupted monitoring of rat occurrences by using also a precise categorization and code system of rat habitats, have significantly contributed to the improvement and more economic performance of control measures. In addition, these efforts have assisted also to obtain interesting findings of scientific significance (Bajomi, 1980, 1983; Bajomi and Vámos, 1983). In 1978, a computerized database was established to make this rich documentation suitable also for any kind of detailed analysis of the habits and ecology of Norway rats in different habitats of Budapest. Results accumulated in the first 8 years have already been published (Bajomi and Sasvári, 1986). Present paper provides an extension of that previous study covering in this case a longer period of 20 years. Results give an interesting insight into the behavior of a still noticable rodent

Proceedings of the 3rd International Conference on Urban Pests.
Wm H. Robinson, F. Rettich and G.W. Rambo (editors). 1999.

population in a continuously changing urban environment being also under the influence of diverse ecological factors and anthropogen effects as well as in the constant pressure of preventive and curative control measures.

In the whole area of Budapest the size of Norway rat population infesting various premises reduced significantly, especially in the first 5 years (see Fig. 1). After a slight intermittent increase (in 1979-80), the infestation rate stabilized first in the 1980s, thereafter, subsequent to a further decline in the 1990s again, on a relatively low level. The yearly changes in various complex habitats and micro-habitats exhibited temporal patterns sometimes considerably different from each other. By comparing present data with those published previously (Bajomi and Sasvári, 1986) it seems that the ‚accommodation' of Norway rat in various complex habitats and micro-habitats of Budapest has remained the same. Nevertheless, it appears that rats feel in some biotops more comfortable than in others, and while from some habitats they seem to retire, in others establish refuges. Due to the extensive maintenance operations rodents are unable to extend their space of life in the city to a significant degree but in some habitats they may stabilize their existence.

The most numerous populations of Norway rat occurred in apartment buildings complex habitat but their abundance decreased steadily until the early 90-ies. Rat colonized here - preferably in one micro-habitat - in the underground parts of buildings (internal sewage system, cellars) but occupied also courtyards where they made burrows leading to nest system in the ground. It is peculiar that the presence of Norway rats in cellars has become less significant year by year. In industrial establishments and public institutions complex habitats courtyards with underground burrows and elements of the sewerage system proved to be the most frequented micro-habitats. In these premises rats were also found to occur in storerooms and workrooms infesting, therefore, simultaneously two (or even three) neighbouring micro-habitats. Thus it appears that rats could settle in these complex habitats, especially in public institutions and food industrial units as relatively spacious territories for their life. Nevertheless, all of these rodent populations reduced more-or less steadily in size during the 20-year observation period. After 1989, the dramatic changes in the industrial sphere of Hungary that were inevitable in Budapest as well, resulted in closing many industral units or in reconstructions and altered technology, all of which diminished the chance of Norway rats to survive in these areas. These changes were rather noticeable in the food industry.

Family houses and public services and open fields complex habitats can be regarded as real buffer zones or sites of good refuges in rat-inhabited territories of Budapest. Their rodent populations are in general moderate in size but - from the beginning of 1980s - remained on a definite average level, irrespective of some noticeable temporal fluctuations. In family houses courtyards were found as most infested sites were rats often prepared also burrows as parts of extensive underground nest system. The animals sometimes visited auxiliary buildings but to lesser extent also cellars or pens and stables. In this complex habitat Norway rats might occupy even two micro-habitats simultaneously. Significant number of rat occurrences was registered in some parts of the sewerage system, first of all in sewer manholes both in public areas or inside the premises. From this ideal “network” Norway rats could readily invade other favourable, mostly neighbouring habitats. Riverbanks and brooksides can sustain, primarily in underground burrows, some fractions of the rat population in Budapest but the overall dimensions of these biotypes in the city are relatively restricted. Nevertheless, they may expose their vicinity to constant risk of re-infestation by rats.

The analysis of data on Norway rat occurrences for an earlier 8-year period (1978 to 1985) revealed practically the same order of habitat preference both as to complex habitats and micro-habitats (the latter also within particular complex habitats). In a previous paper published on the basis of data collected between 1974 and 1977 (4 years) the relative significance of some most important Norway rat habitats was already established (Bajomi, 1983). Thus present data confirm most of those former statements on the spatial distribution and ecological requirements of this rodent species.

Proceedings of the 3rd International Conference on Urban Pests.
Wm H. Robinson, F. Rettich and G.W. Rambo (editors). 1999.

The maintenance of practically rat-free state in Budapest focuses on destroying - as far as possible - the remaining Norway rat population as well as on preventing both its passive introduction by transportation and active invasion from the neighbouring areas. It consists of two main types of rat control: 1) preventive measures and 2) curative measures (Bajomi and Vámos, 1983). In the framework of control operations systemic surveys (along with precisely organized and in a computerized database registered data collection) and treatments with environmentally safe poisonuos baits are carried out. As active bait substances anticoagulant rodenticides (0.06% coumatetralyl and - since 1990 – 0.005% bromadiolone) are used.

Continuous preventive measures are set up at special premises or areas where the risk of rat re-appearance and repeated infestion is the highest. These sites are: penetration gates (e.g. railway stations, slaughter houses); protective zones (along riverbanks and brooksides, previously also at the administrative boundaries of the city), premises highly endangered by rat infestation (primarily industrial units), sewerage system of the city. Curative measures also include surveys and targeted bait placements. The necessity of these maintenance operations is assessed on the basis of different sources of information such as: reports, complaints from the public, owners of premises and different authorities (confirmed by subsequent inspection of control operators), well organized system of regular surveys performed by trained operator teams on the whole area of the city.

The latter actions (check of particular bait points for consumption, laying new poisonous baits, questioning of people etc.) - carried out in special “working districts” - depends on some features of the area in question, including also the general infestation rate observed in the previous 5 years.

The average rat infestation rate has declined to 0.08% in the last few years. From the viewpoint of practice this situation, the practically rat-free state of Budapest means that Norway rats do not cause health, economic and general feeling problem any more.

ACKNOWLEDGEMENT

Authors express their sincere thanks to Dr.L.Varjas for his contribution in the analysis and evaluation of data.

REFERENCES CITED

Bajomi, D. 1980. Deratization of Budapest and five years of follow-up control measures. Ninth Vertebrate Pest Conference, Fresno, Calif., USA, March 4-6,1980, pp. 124-129.

Bajomi, D. 1983. Examination of the habitats of residual urban Norway rat populations after eradication. Parasit. hung. 16: 131-135.

Bajomi, D. 1993. Rat-free city. Chronology of a rat control programme with lasting success. Public Health 10, 13-19.

Bajomi, D. and K. Sasvári. 1986. Results of eight years’ examination of the habitats of residual urban Norway rat populations after eradication. Salmon, T.P., ed., Proc. Twelfth Vertebrate Pest Conf., San Diego, Calif., USA, March 4-6, 1986, pp. 66-74.

Bajomi, D. and G. Vámos. 1983. A rat-free state in Budapest. Experiences gained during its maintenance. Environmental Health 91(10): 263-268.