RESULTS OF EIGHT YEARS' EXAMINATION OF THE HABITATS OF RESIDUAL URBAN NORWAY RAT POPULATIONS AFTER ERADICATION

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ABSTRACT: In Budapest (population 2 million) 33 out of 100 buildings were rat-infested in the early seventies. Thus general deratization was decreed to cover the whole of the city in 1971 to 1972. As a result of the global eradication method applied, the rate of rat-infested premises could be reduced below 0.5% annually. After control the sparsely occurring rats could freely choose any of the habitats released for settling. The habitats of Budapest most preferred by Norway rats are presented after a wide-ranging investigation carried out over 8 years. Our examination data support and in some cases reveal the requirements of Norway rats living in Central European large cities as regards to the environment as well as their ethological features. This knowledge may help in improving deratization and especially maintenance operations, thus increasing the efficiency of the fight against rats.

AREA EXAMINED

Budapest, the capital of Hungary lies in an area of 525 km^2 with a population of 2 million. Its 22 administrative boroughs include 220,000 premises. Although pest management before 1970 had effected a certain decrease in the number of rats, still the problem remained unsolved due to treatments having covered only some parts of the territory and completed at different times.

In order to determine the number of live rats and the losses incurred by them, the Public Health Authorities of Budapest effected assessments in 100 industrial units of various sizes and characters allowing the extrapolation of the data obtained to the whole of Budapest in proportion to the area. On the basis of this calculation the number of rats was estimated at approximately 2 million and the losses incurred by them at 300 to 400 million forints (6.4 to 8.5 million $US) yearly (Hercegh 1969, Gács 1974).

In Budapest the Norway rat (Rattus norvegicus Berk.) predominated, while the black rat (Rattus rattus L.) played a minor role.

The size of rat-infested premises were determined by an objective method based on the global eradication techniques, i.e., both assessment and placement of baits were carried out in each of the buildings. Detections of bait consumption by rats indicated a 32.8% rat infestation level in the premises on an average. While rat infestation in the centre of Budapest was approximately 100%, that of the suburbs was considerably lower.

An organized deratization programme covering the whole of Budapest started after long and thorough preparations in spring 1971. In the course of the rat control action carried out by Bábolna Pest Control Centre, baits containing the anticoagulant ingredient coumatetralyl were placed in all of the premises and the appurtenant sewerage system simultaneously. The project consumed 1,632,000 kilos of bait. After cessation of consumption repeated inspections and replenishments of bait were effected. As a result of thorough work the rate of rat infested premises could be reduced below 0.5% by the end of the year 1972 (Burgert 1972, Gács 1974, 1977).

Already during the period of deratization arrangements were made for the organization of follow-up treatments (prevention, maintenance). Maintenance of rat-free state was also done by the Bábolna Pest Control Centre commencing on January 1, 1973. As a result of continuous maintenance applications, which increasingly consisted of preventive measure, the annual rat infestation level continued to diminish (Bajomi 1980a, 1983a). The rate of diminution and the total number of rat occurrences in the 13 years are shown in Figure 1.

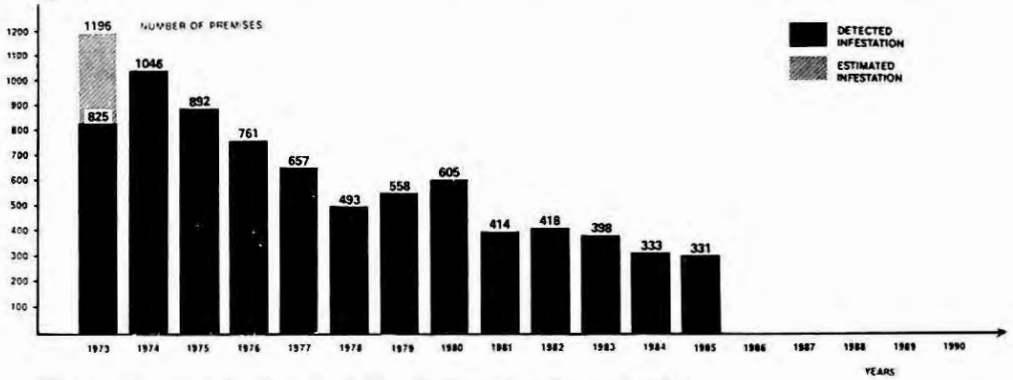

Figure 1. Yearly index of the Budapest rat population as judged by the number of infested premises.

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EXAMINATION OF HABITATS

Thoroughly planned maintenance applications, which are implemented by only one company, enable a reliable inquiry of rat populations remaining after eradication. Searching of infestation foci, regular and directed assessments, as well as comprehensively and exactly kept registers, all being part of maintenance techniques, allow the analysis of rat occurrences and of the typical character of habitats.

As a result of the deratization of Budapest, the size of the remaining rat population is exceedingly small in relation to the carrying capacity of the environment. Thus living space much larger than necessary is available for the rats. Consequently, the rats may, on principle, choose any vacant space free from any intraspecific competition (Szeky 1975). It may be supposed that in such a case the most favourable areas (habitats) will be colonized by the animals tested. By examining the occupied habitats, important information can be gathered concerning the requirements and habits of rats. Good use can be made of such knowledge in practical rat control.

METHOD OF EXAMINATION

To detect the habitats occupied by rats, the notifications received from the population and the public institutions were checked. Moreover, inspections were effected periodically in the sewers, the major factories, apartment buildings, and in the so-called "barrier zones." The presence of rats in the individual habitats could be best determined by measuring consumption from the poisoned bait. Survey of the habitats preferred was facilitated by the fact that if there was evidence of rats, rodenticides were placed within the buildings, around them, and in the appurtenant sewers (maintenance operations). In the sewers specific bait wax-blocks were used on which the gnawing marks of rats could be clearly recognized. The Health Authorities, who effected supervisory work monthly, also helped in getting acquainted with the habitats preferred.

As standard of investigation served the so-called complex habitat. This 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 1980a,b). Accordingly a complex habitat is, for instance an apartment building, having more than one story, its appurtenant cellar, courtyard and the sewers within the building as well as its flats, staircases and garret. This habitat is typical and differs, for instance, from the complex habitat of a family house or from that of a food manufacturing plant.

At the same time rats live occasionally in a confined area (e.g., cellar of an apartment house) within such habitats of greater size like an apartment building. As a consequence, one complex habitat can be divided in several micro-habitats of different types, the latter being in connection with each other. The most important and best utilizable consequences can be drawn by studying these micro-habitats preferred by rats.

In order to provide an exact registration and analysis of the relatively great number of rat incidences appearing over several years, a code system distinguishing 45 micro-habitats was set up. By means of this procedure, first the complex habitats of 3,355 rat incidences covering the period 1975 to 1978 were evaluated (Bajomi 1983b).

On the basis of our experiences gained, the code system was reworked to achieve a more exact evaluation; thus a new code system including 95 micro-habitats within six main groups was established (Table 1). On repeated investigations on site and in accordance with the types of premises and areas of detection, each of the rat occurrences was given as many code numbers as micro-habitats had indicated the presence of rats. When, for instance, consumptions by rats were noted at bait-points in the cellar, in the courtyard and in one burrow with a family house then this occurrence was given the code numbers 22, 26, 27.

RESULTS

The present processing completed on computer covers the analysis of 3,550 rat occurrences of the period 1978 to 1985. In Budapest Norway rats occurred most frequently in the apartment building - complex habitat at 30.03% (1,066 cases) and in the family house - complex habitat at 17.21% (611 cases) in the 8 years under examination as per Table 2. Rats occurred in nonfood manufacturing plants at 15.24% (541 cases), in food manufacturing plants at 13.35% (474 cases), and in public institution - complex habitat at 13.13% (466 cases). The remaining 392 rat incidences were not detected in complex habitats but in other areas (sewers, riversides, etc.).

The fact that Norway rats did more frequently become established in apartment building - complex habitats than in other ones is most remarkable! It is also interesting to notice that nonfood manufacturing plant - complex habitats were frequented by rats to a greater extent than food manufacturing plant - complex habitats. These peculiarities will most probably depend also on the number of the different types of complex habitats. For this reason these establishments can be generalized only with great caution!

A more interesting conclusion can be drawn by studying those micro-habitats which are preferred by Norway rats living practically without any intraspecific competition. According to our investigations 3,550 rat occurrences were detected in 5,795 micro-habitats. Naturally there is a possibility for one rat to visit even several micro-habitats simultaneously. Considering that the rats were allowed to visit the individual micro-habitats and to settle at choice, this will be characteristic of their requirements towards the living-space and of their behavioural habits in urban environments.

Table 1. Code numbers of rat habitats.

1. IN APARTMENT BUILDINGS	2. IN ONE-FAMILY HOUSES	3. IN UNITS OF FOOD INDUSTRY	4. IN OTHER PLANTS	5. IN PUBLIC INSTITUTIONS	6. IN PUBLIC SERVICES AND IN OPEN FIELD
11 garrets	21 garrets	31 garrets	41 garrets	51 garrets	
12 cellars 121 boiler-rooms 122 air-raid shelters	22 cellars 221 boiler-rooms	32 cellars 321 boiler-rooms	42 cellars 421 boiler-rooms	52 cellars 521 boiler-rooms	
13 homes 131 workrooms 134 toilets 135 kitchens	23 homes 231 workrooms 234 toilets 235 kitchens	 331 workrooms 332 office-rooms 333 storerooms 334 communal rooms 335 kitchens	 431 workrooms 432 office-rooms 433 storerooms 434 communal rooms 435 kitchens	 531 workrooms 532 office-rooms 533 storerooms 534 communal rooms 535 kitchens	631 river-banks 632 storm banks 633 ships 634 areas of demolition work 635 metro tunnels
14 auxiliary buildings	24 auxiliary buildings 242 pens, stables	34 auxiliary buildings	44 auxiliary buildings	54 auxiliary buildings	
15 refuse-rooms	25 refuse-rooms	35 refuse-rooms	45 refuse-rooms	55 refuse-rooms	65 street refuse containers 651 uncovered rubbish dumps
16 courtyard 161 light wells	26 courtyards	36 courtyards	46 courtyards	56 courtyards	
17 burrows	27 burrows	37 burrows	47 burrows	57 burrows	67 burrows
18 sewer manholes 181 courtyard channel head	28 sewer manholes 281 courtyard channel head 282 sinks	38 sewer manholes 381 courtyard channel head	48 sewer manholes 481 courtyard channel head	58 sewer manholes 581 courtyard channel head	68 sewer manholes 681 drain-pipes
19 water-meters	29 water-meters	39 water-meters 391 cable manholes 392 heating-pipes	49 water-meters 491 cable manholes 492 heating-pipes	59 water-meters 591 cable manholes 592 heating-pipes	692 heating-pipes

Table 2. Occurrence of Norway rats in various complex habitats in Budapest between 1978-1985.

COMPLEX HABITAT	Number of rat occurrences	Incidence rate %
Apartment buildings	1066	30.03
Family houses	611	17.21
Nonfood manufacturing plants	541	15.24
Food manufacturing plants	474	13.35
Public institutions	466	13.13
Others/noncomplex habitats	392	11.04
TOTAL	3550	100.00

Micro-habitats showing the highest rate of rat incidence, i.e., those mostly preferred, are demonstrated in Table 3. From this it appears that in Budapest Norway rats occurred most frequently in sewer manholes at an absolute rate of 8.51% (493 cases) and in the cellars of apartment buildings at 8.47% (491 cases).

Table 3. Micro-habitats preferred by Norway rats in Budapest between 1978-1985.

MICRO - HABITAT Code	Denomination	Number of rat occurrences	Incidence rate* %
68	Sewer manholes	493	8.51
12	Cellars of apartment buildings	491	8.47
26	Courtyards of family houses	396	6.83
18	Sewer manholes of apartment buildings	388	6.70
46	Courtyards of non-food manufacturing plants	377	6.51
16	Courtyards of apartment buildings	277	4.78
36	Courtyards of food manufacturing plants	256	4.42
27	Burrows in family houses	225	3.88
56	Courtyards of public institutions	214	3.69
17	Burrows in apartment buildings	187	3.23
58	Sewer manholes of public institutions	160	2.76
631	River-banks	154	2.66
181	Courtyard channel heads of apartment buildings	142	2.45
38	Sewer manholes of food manufacturing plants	138	2.38
52	Cellars of public institutions	122	2.11
24	Auxiliary buildings of family houses	120	2.07
331	Workrooms of food manufacturing plants	114	1.97
47	Burrows in non-food manufacturing plants	111	1.92
48	Sewer manholes of non-food manufacturing plants	98	1.69
57	Burrows in public institutions	88	1.52
32	Cellars of food manufacturing plants	86	1.48
22	Cellars of family houses	84	1.45
333	Storerooms of food manufacturing plants	79	1.36
37	Burrows in food manufacturing plants	76	1.31
431	Workrooms of non-food manufacturing plants	74	1.28
531	Workrooms of public institutions	74	1.28
42	Cellars of non-food manufacturing plants	63	1.09
28	Sewer manholes of family houses	59	1.02

Number of occurrences in total: 5795

*Only incidences greater than 1.00 are indicated!

The next most frequent occurrences were detected in the courtyards of family houses (396 cases = 6.83%), internal sewer manholes of apartment buildings (388 cases = 6.70%) and courtyards of nonfood manufacturing plants (377 cases = 6.51%). Frequent colonizations were observed in the courtyards of

apartment buildings (277 cases = 4.78%), in the courtyards of food manufacturing plants (256 cases = 4.42%) and in the courtyards of public institutions (214 cases = 3.69%).

Rats were noticed in the burrows of nest systems built in the courtyards of family houses in 225 cases = 3.88%. In the courtyards of public institutions the rate of occurrence was 3.69% (214 cases), while in the burrows of the courtyards of apartment buildings 187 cases (3.23%) were registered. It was found that rats frequently build nests dug into the ground in family houses without any cellar that is obvious. The fact, however, that the same occurs nearly as frequently in apartment buildings with large cellars, is surprising.

Rats were quite frequently observed on riversides and brooksides in 154 cases (2.66%). Rats also like the sewerage systems within buildings because they colonized in courtyard channel heads of apartment buildings in 142 cases (2.45%), and in the sewer manholes of food manufacturing plants in 138 cases (2.38%). Micro-habitats frequented to a lesser degree are shown in Table 3.

Table 4 informs about which of the micro-habitats within the individual complex habitats are particularly preferred by rats. From this it appears that in the apartment building - complex habitat the Norway rat was found most frequently (9.16%) in the internal sewerage system (manholes, courtyard channel heads) and in underground areas (cellar, boiler room, air-raid shelter) (8.66%). They often were found in courtyards (4.92%) and in underground nests built in the ground of courtyards, in burrows (3.23%).

Within the family house - complex habitat rats are observed most frequently in courtyards of the buildings (6.83%), also living in burrows (3.88%). They also prefer (2.93%) auxiliary buildings, pens, stables, and refuse-rooms of family houses.

In nonfood manufacturing plant - complex habitats, rats occurred most frequently (6.51%) at bait-points set up in courtyards, then (2.12%) in diverse workrooms and office-rooms as well as in storerooms within buildings. A similarly greater number of rats (1.98%) were found in the interal sewerage system of premises (sewer manholes, channel heads) and in underground nests, in burrows (1.92%).

In Budapest within the food manufacturing plant - complex habitats Norway rats were observed most frequently (4.42%) in the courtyards between the buildings, then (3.33%) in workrooms and storerooms. Also remarkable is their establishment (2.71%) in the sewerage system within premises (manholes, courtyard channel heads). Their rate of incidence in cellars was 1.50%.

Within the public institution - complex habitats, they most frequently occur in courtyards (3.69%), then in the sewerage systems (3.30%), and at 2.18% in the cellars and boiler rooms. Remarkable is their incidence (1.79%) in workrooms and office-rooms as well as in various burrows in the surroundings of buildings (1.52%).

By applying the code system we are able to examine the total occurrence of Norway rats in micro-habitats of the same type, irrespective of the complex habitat which they belong to. As it is shown in Table 5, rats occurred most frequently (38.22%) in the surroundings of buildings (courtyards) and in underground burrow systems of courtyards. Rat occurrence outdoors was established by determining the consumption from the baits placed in so-called large boxes. Although in this case the percentage error of the method of examination is the highest, considering the unexpected incidence, we can safely say that Norway rats are most frequently found in the surroundings of buildings and in courtyards.

In Budapest the second most frequented habitat was the sewerage system, which is not surprising at all. The rat incidence rate was half of that (14.98% = 868 cases) in the underground parts (cellars, air-raid shelters, boiler rooms) of different buildings. In the overground parts of the same buildings rats were found in 517 cases (8.92%). In the garrets, on the other hand, a minimum rate of incidence was detected (3 cases = 0.05%), which agrees with our knowledge of the Norway rat's pattern of life. Their rate of occurrence in various auxiliary buildings was 4.33% (251 cases).

In open field (riversides, storm banks, etc.), colonization of the Norway rat was confined in the majority of cases to riversides and brooksides. Its occurrence within the other micro-habitats is small, indicating that the Norway rat is able to live in various kinds of environment but those just mentioned are not preferred.

Interesting conclusions can be drawn by investigating the number of micro-habitats within one complex habitat visited simultaneously by rats. From Table 6 it appears that there is a difference between the various types of the complex habitat concerning how many of their micro-habitats are colonized by rats simultaneously. Consequently within an apartment building complex habitat and outdoors a much larger number of rats will settle in one micro-habitat than in two or more habitats. In family houses, nonfood manufacturing plants, food manufacturing plants and public institutions, on the other hand, Norway rats occur approximately as frequently or more frequently in two micro-habitats simultaneously than in one micro-habitat. The simultaneous incidence in three or four micro-habitats occurs much less, which practically cannot be observed with establishments outdoors at all. The relative incidence within a complex-habitat is demonstrated in Figure 2.

Table 4. Occurrence of the Norway rats in various complex habitats between 1978-1985.

COMPLEX HABITAT	MICRO-HABITAT	Occurrence of rats Number	%	Total Number	%
Apartment buildings	Garrets	1	0.02		
	Cellars, boiler-rooms, air-raid shelters	503	8.66		
	Living- and workrooms	27	0.47		
	Toilets	14	0.24		
	Auxiliary buildings, refuse-rooms	25	0.43		
	Courtyards	285	4.92		
	Burrows	187	3.23		
	Sewer manholes, courtyard channel heads, water-meters	531	9.16	1572	27.13
Family houses	Garrets	2	0.03		
	Cellars	84	1.45		
	Living- and workrooms	9	0.16		
	Toilets	5	0.09		
	Auxiliary buildings, pens, stables, refuse-rooms	170	2.93		
	Courtyards	396	6.83		
	Burrows	225	3.88		
	Sewer manholes, courtyard channel heads, water-meters	70	1.21	961	16.58
Nonfood manufacturing plants	Cellars, boiler-rooms	69	1.19		
	Workrooms, office-rooms, storerooms	123	2.12		
	Dressing-rooms, bathrooms, kitchens	11	0.19		
	Auxiliary buildings, refuse-rooms	36	0.62		
	Courtyards	377	6.51		
	Burrows	111	1.92		
	Sewer manholes, courtyard channel heads	115	1.98		
	Cable manholes, heating-pipes	15	0.26	857	14.79
Food manufacturing plants	Cellars, boiler-rooms	87	1.50		
	Workrooms, storerooms	193	3.33		
	Dressing-rooms, kitchens	8	0.14		
	Auxiliary buildings, refuse-rooms	40	0.69		
	Courtyards	256	4.42		
	Burrows	76	1.31		
	Sewer manholes, courtyard channel heads, water-meters	157	2.71		
	Cable manholes, heating-pipes	5	0.08	822	14.18
Public institutions	Cellars, boiler-rooms	126	2.18		
	Workrooms, office-rooms, storerooms	104	1.79		
	Dressing-rooms, bathrooms, kitchens	23	0.40		
	Auxiliary buildings, refuse-rooms	30	0.52		
	Courtyards	214	3.69		
	Burrows	88	1.52		
	Sewer manholes, courtyard channel heads	191	3.30		
	Cable manholes, heating-pipes	13	0.22	789	13.62
Others	/outdoors, on riversides, in the sewers etc./	794	13.70	794	13.70
			TOTAL	5795	100.00

CONCLUSIONS

On extensive examination of the habitats after the deratization of Budapest, the majority of the Norway rat populations were observed within the apartment building - complex habitats. The occurrence within the other complex habitats was approximately the same. It is surprising that there were not more rats in the food manufacturing plants than in the other ones.

Table 5. Total occurrence of Norway rats by micro-habitats of the same character in Budapest between 1978-1985.

Place of occurrence	MICRO - HABITAT Code	Denomination	Occurrence of rats Number	%	Total Number	%
Courtyards of buildings	16+26+36+46+56	Courtyards	1520	26.23		
	161	Light wells	8	0.14		
	17+27+37+47+57	Burrows	687	11.85	2215	38.22
Sewers	18+28+38+48+58+68	Sewer manholes	1336	23.05		
	181+281+381+481+581	Courtyard channel heads	217	3.75		
	681	Drain pipes	55	0.95	1608	27.75
Cellars	12+22+32+42+52	Cellars	846	14.60		
	122	Air-raid shelters	3	0.05		
	121+221+321+421+521	Boiler-rooms	19	8.33	868	14.98
Rooms within buildings	13+23	Homes	27	0.46		
	131+231+331+431+531	Workrooms	271	4.68		
	332+432+532	Office-rooms	1	0.02		
	333+433+533	Storerooms	157	2.71		
	134+234+334+434+534	Toilets, dressing-rooms	48	0.83		
	135+235+335+435+535	Kitchens	13	0.22	517	8.92
Auxiliary buildings	14+24+34+44+54	Auxiliary buildings	207	3.57		
	242	Pens, stables	44	0.76	251	4.33
Open field	67	Burrows	20	0.35		
	631	River-banks	154	2.66		
	632	Storm banks	10	0.17		
	634	Areas of demolition work	12	0.21	196	3.39
Refuse areas	15+25+35+45+55	Refuse-rooms of buildings	50	0.87		
	65	Street refuse containers	2	0.03		
	651	Uncovered rubbish dumps	29	0.50	81	1.40
Public institutions	19+29+39+49+59	Water-meters	4	0.07		
	391+491+591+691	Cable manholes	26	0.45		
	392+492+592+692	Heating-pipes	15	0.26		
	635	Metro tunnels	9	0.15	54	0.93
Garrets	11+21+31+41+51	Garrets	3	0.05	3	0.05
Ships	633	Ships	2	0.03	2	0.03
			TOTAL		5795	100.00

Table 6. Simultaneous occurrence of Norway rats within various micro-habitats in Budapest between 1978-1985.

Complex habitat	Simultaneous occurrence within the micro-habitats number of cases: In one micro-habitat	In two micro-habitats	In three micro-habitats	In four micro-habitats	Total
Apartment buildings	543	369	126	28	1066
Family houses	294	242	71	4	611
Nonfood manufacturing plants	255	226	54	6	541
Food manufacturing plants	191	209	64	10	474
Public institutions	177	201	81	7	466
Others/noncomplex habitats/	354	35	3	0	392
TOTAL	1814	1282	399	55	3550

The most striking habitats of the micro-habitats especially preferred by rats are: sewers (manholes), cellars of apartment buildings, courtyards of family houses, sewers of apartment buildings and courtyards

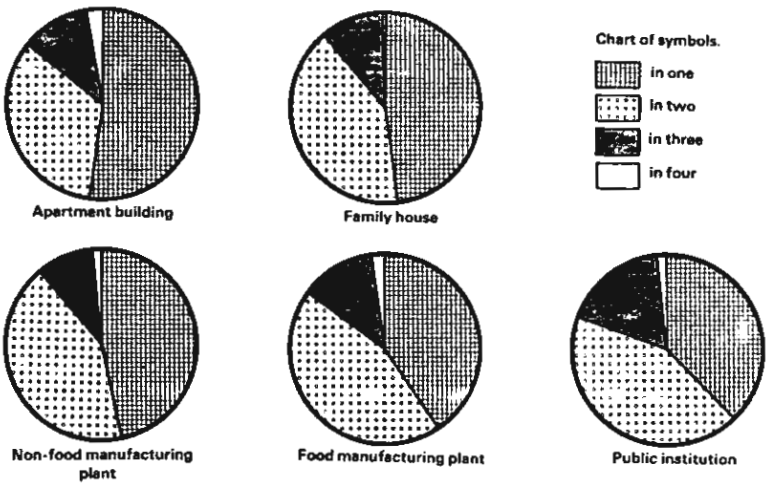

Figure 2. Simultaneous occurrence of Norway rats within various micro-habitats in Budapest between 1978-1985.

of nonfood manufacturing plants. It is astonishing that rats often build up underground nests even in the courtyards of apartment buildings and colonize quite frequently along riversides.

The relative incidence of rat occurrences within the individual complex habitats is demonstrated on Figure 3. It shows the sites within one complex habitat where rats settle most frequently. This figure can be utilized well when assessments and control operations are effected as it indicates the spots where trials of rats should be searched for and rodenticides be placed to achieve optimal consumption.

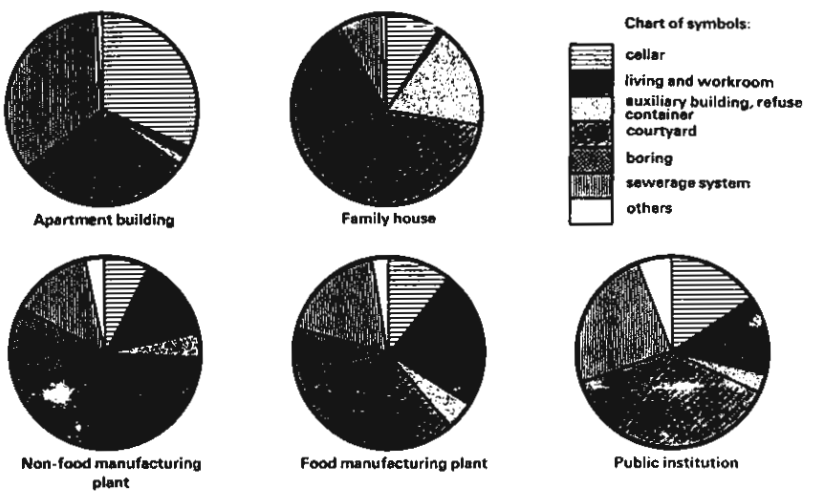

Figure 3. Relative incidence of Norway rats by micro-habitats within the individual complex-habitats.

The total analysis of rat occurrences detected within micro-habitats of the same type revealed that in Budapest the Norway rat prevailed living mainly over ground in the surroundings of buildings and in nest systems built up underground in the courtyards. Then followed the occurrences in the sewerage system providing runways and food sources equally. Other preferred micro-habitats are the underground parts of apartment buildings (cellars, boiler rooms, air-raid shelters). A striking incidence of rats can be observed in the auxiliary buildings of family houses and on riversides.

Rats colonizing within the apartment building - complex habitat and in open field live mostly in one micro-habitat simultaneously. This means that they can invade territories in favourable locations and that is why these areas are relatively small. As for the other complex habitats, the simultaneous occurrence in one and in two micro-habitats is more frequent. In these locations their territory is somewhat larger, but it rarely occurs that the territory of the rats would extend to four micro-habitats simultaneously which would prove favourable conditions for them.

Our examination data support and in some cases reveal the requirements of Norway rats living in Central-European large cities towards the environment as well as their ethological features. This knowledge may help in improving deratization and especially maintenance operations, thus increasing the efficiency of fight against rats.

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