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Light attraction of carabid beetles and their survival in the city centre

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A carabid assemblage attracted on an intensively illuminated advertisement table above a shop window in the centre of Bratislava in August and September 1997 consisted of 40 species. This number was almost the same as in the pitfall trap catches carried out during three growing seasons in 13 sites in Bratislava. Almost 94% of individuals belonged to autumn breeding species inhabiting arable land, while the spring breeders were little represented. Compared with light traps catches performed in other localities by other authors, there was an increased proportion of *Amara apricaria*. In addition the xerotermophilous species *Harpalus tenebrosus* and *H. zabroides* and the rare *Polystichus connexus* were found. Three major periods in flight activity and species composition of the Carabid assemblage were distinguished according to species abundance and presence. A large number of *Pseudoophonus rufipes*, *P. calceatus*, *Dolichus halensis* and *Chlaenius spoliatus* colonised the study site. They used various small caves in the walls, gutter pipe outlets or ants' galleries in the sand between pavement and wall bases as an effective cover. The beetles exhibited a surprising ability to survive in the city centre asphalt desert.

Key words: Coleoptera, Carabidae, light attraction, urban ecology, bionomics, community structure.

Introduction

Light attraction of insects is a well-known phenomenon which is widely used for their collection. Although light trapping is not the usual method for collecting carabids, there are many papers analysing carabid assemblages caught together with other insects in light traps (Miländer, 1972; Široki, 1981; Honěk & Pulpán, 1983; Kádár & Szentkirályi, 1984; Veselý, 1987; Kádár & Erdélyi, 1992; Kádár & Lövei, 1992; Kádár & Szél, 1995; Kádár & Szentkirályi, 1997).

Introduction of new types of light sources had always a considerable influence on the composition of insects attracted to light. For example, in the 1920's, when the electric illumination became to be widely used, such rare carabids like *Agonum gracillipes* began to occur in city centres (Delahon, 1931). Differences in the abundance of individual species were found between light trap (Honěk & Pulpán, 1983) and the pitfall-trap catches. The high attraction of UV light for insects is often used in light traps of various types.

Recently, the variety of new types of light sources of special properties and usage possibilities has increased considerably. Aggressive commercial advertisement and public opinion manip-

Fig. 1. Surroundings of the Suché Mýto street (SM), Michalská street (M) and Primaciálne Námestie (P) square and 13 pitfall trapping localities (1–13) in the Bratislava centre

ulation has found the extremely bright intensive cold light of halogen discharging lamps to be extremely attractive for the human attention. Therefore advertisements illuminated by such lamps appear more and more frequently in both the cities and countryside.

During some evenings, at the turn of July – August 1997, I observed several carabids (mostly the *Pseudophonus* species) sitting on the shop windows and facade advertisements at the corner of Poniemská Ulica and Suché Mýto streets in the centre of Bratislava, which were strongly illuminated by halogen discharging lamps. Because the occurrence of the beetles attracted into city centre to light and their intensive migrations are usual at that time (SHIOKI, 1981; ŠUSTEK, 1981; ŠUSTEK & VAŠÁTKO, 1983), I did not pay special attention to this observation. However, the finding of one individual of the rare *Polystichus connexus* on an illuminated facade on 6 August motivated me to undertake systematic observations at this site almost daily until late autumn. The aim of this paper is (i) to compare the composition of the light-attracted and pitfall-trapped carabids in the city centre, (ii) to show how the usage of new types of light sources may influence the urban carabid fauna and, (iii) to describe some features of their behaviour in the unfavourable city conditions.

Material and methods

The beetles were collected individually around a shop-window and on the ground in the Suché Mýto street, in the city centre of Bratislava (48°9′00″ N, 17°6′29″ E) (Figs 1–3) almost daily from 7 August to 10 November 1997. In addition other more intensively illuminated sites in the city centre were found, but the regular occurrence of carabids was recorded only in two of them (Michalská Ulica street and Primaciálne Námestie square, Fig. 1). Occurrence and behaviour of carabids in these two sites was observed almost daily (for about 30 min), but their aggregations were not disturbed by collecting. Observations of the beetles' behaviour usually started 12–20 min before nightfall, while collecting mostly began about half hour after nightfall and lasted two – three hours, according to the flight activity of insects. For the initial part of the study all the individuals found were collected. Later, from mid September to the beginning of November, the individuals hiding during the day in various galleries dug in the loose material accumulated between wall bases and pavement, in ventilation canals or behind the gutter pipes were let intentionally to observe how long they could survive in such extremely unfavourable habitats.

The pitfall-trapped material obtained at a total of 13 sites (Fig. 1) in the centre of Bratislava in 1981–1982 (ŠUSTEK 1984) and in 1988 (ŠUSTEK, unpublished) was used to compare the structure of carabid assemblages flying to light with those normally occurring in the city centre. Depending on the area of those sites and the ability to hide the traps against the public, 1–2 traps were installed at each site. Because of the similarity and proximity of individual sites (Fig. 1), the material from 1981–1982 and 1988 was pooled in this study (Tab. 1).

In addition, carabid assemblages from wheat and maize fields representing the most typical crops in the wide surroundings of Bratislava were chosen for comparison as examples of species pools in the potential immigration sources. The material from wheat field was caught in the vicinity of the Dlhá village (48°16′10″ N, 17°23′5″ E,) ca. 40 km NE of Bratislava in 1997 (ŠUSTEK, unpublished), while that from the maize field in the close vicinity of the Sereď town (48°16′21″ N, 17°42′34″ E) ca. 40 km NE of Bratislava in 1982 (ŠUSTEK, 1993). Because of the extreme extent of material, samples from two traps were taken in both cases.

Habitat specification

Suché Mýto street forms the western side of the Hodžovo Námestie square (Figs 1, 2). It is an irregularly shaped frequent crossroad, relatively open, with two – five-floor buildings and with several small flower beds, grassy plots and tree groups. The two floor Grassalkovich's palace separates it from a larger complex of parks.

Michalská Ulica street (Fig. 1) is a narrow street in the pedestrian zone of the historical centre of Bratislava. Traffic is excluded, four-floor buildings are on both sides, and the whole surface has granite pavement. There is no direct contact with any urban greenery.

Primaciálne Námestie square (Fig. 1) is a small closed area within the pedestrian zone in the historical centre. The whole surface has granite pavement, the traffic is excluded. A small grassy bed is in one of streets mouthing into the square. The beetles were concentrated at the foot of illuminated walls of the Primacial Palace.

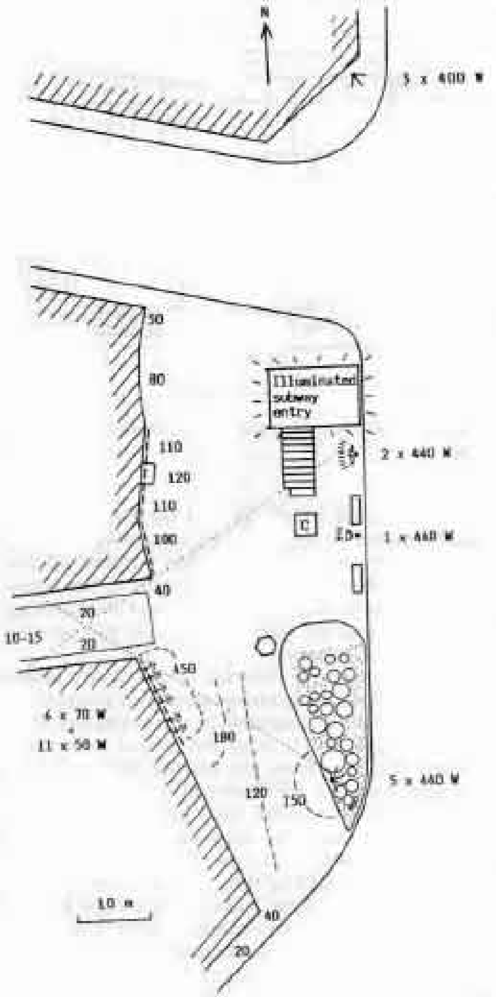

Fig. 2. Detailed scheme of the sampling site in the Suché Mýto street and illumination intensity (in lux) of the walls to the height of ca. 1.2 m, illumination intensity isolines of the pavement surface, number and wattage of the installed lamps (circles – small pines, dotted area – lawn, bold dashed lines – illuminated advertisements, hair-like dashed line – illumination isolines, dotted lines – direct illumination boundaries).

Illumination of the sites

The study site in the Suché Mýto street was illuminated from several sources. The whole square was illuminated by natrium discharging lamps NAV T 150

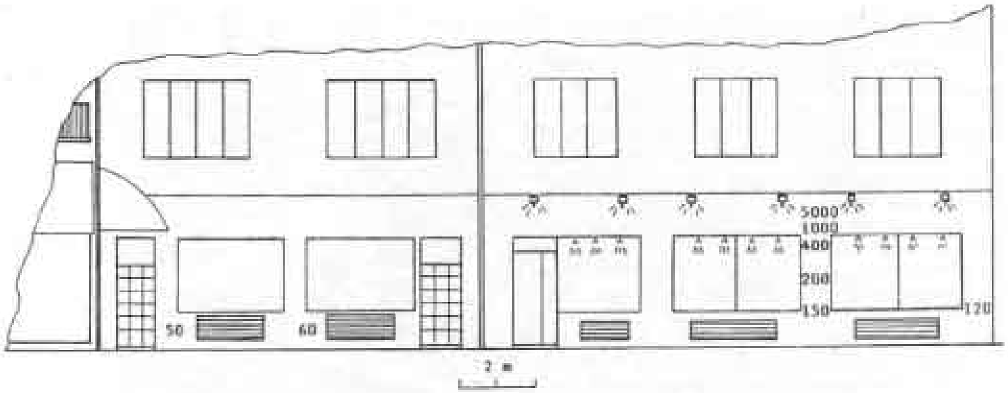

Fig. 3. Lamps placement and illumination intensity (lux) of the wall around the shop window in the Suché Mýto street.

(for the technical parameters see the OSRAM catalogue) installed on six 10 m high poles situated in the square centre and four NAV T 400 installed on five 24 m high poles (Fig. 2). A set of three or five lamps was on each pole. One pole stayed just at the sampling site. All produced the typical orange light with one-line spectrum of ca. 600 nm.

The beetles were collected in two closely neighbouring sites – on a grey house facade with a large Coca cola advertisement illuminated by three reflectors IP 65 with one HQIT/400/D lamp and around three shop-windows (Fig. 2). From the exterior these windows were illuminated by six Disano 1131 Punto reflectors with one HQI TS 70/NDL lamp targeted on a white-grey shop-sign above the shop-windows and giving a strong brightly white cold light. The shop-windows interior was illuminated by three or four 41870 FL BLII EXZ halogen low-voltage bulbs giving a warm slightly orange light (Fig. 3). Some lamps installed in the shop-window interior illuminated intensively also the pavement surface up to a distance of 1–2 m from the wall. The illumination intensity of the facade or pavement surface ranged from 120 lux to 1,500 lux (Figs 2, 3), in the more remote buildings decreasing to 40–50 lux, while in the adjacent streets it dropped to 10–15 lux. The illumination of the catching site was still strengthened by many fluorescent lamps installed inside the shop and mostly switched on up to about 22 h.

Results and discussion

Structure of the Carabid assemblages

Altogether 40 species occurred in the Suché Mýto street (Tab. 1). The most abundant were *Trechus quadristriatus* (36.73%), *Pseudophonus rufipes* (16.58 %), *Amara consularis* (11.16%), *Pseudophonus calceatus* (9.07%), *Calathus melanocephalus* (4.16%), *Dolichus halensis* (3.41%), *Ophonus puncticeps* (3.44%), *Calathus cinctus* (2.64%), *Calathus ambiguus* (1.60), *Clivina fossor* (1.36), *Amara apricaria* (1.28). These 11 species (27.5% of all species) represented 90% of the total catch.

With regard to the autecology of individual species, majority of them (77.5% represented by 98.55% of individuals) were typical open landscape species reaching often high abundance in different fields in lowlands, highest in maize, less in cereals. Some of them exhibit a preference for heavy soils with increased humidity (*Pterostichus macer*). Three species of this group, viz. *Ophonus diffinis*, *Harpalus tenebrosus*, *H. zabroides*, are rare xerotermophilous elements in the Central European fauna. Only a few species (10% representing only 0.64% of individuals) were typical inhabitants of water shores or wetlands (*Chlaenius spoliatus*, *Ch. tristis*, *Bembidion guttula*) or also of some flood plain forests (*Badister peltatus*). The species *Loricera pilicornis*, *Pterostichus melanarius* and *Notiophilus rufipes* are eurytopic. *Agonum gracilipes* is considered to be eurytopic, but its proper life mode is little known.

The assemblage consisted of 45.00% spring breeding species, 47.50% autumn breeding species and of 7.50% species with a plastic reproduction type. Quantitatively, however, the autumn breeding species were predominant (93.91%). Only 5.52% of individuals belonged to spring breeders and 0.32% to species with plastic reproduction type. The predominance of the autumn breeders was in accordance with the sampling period in late summer and in autumn.

Table 1. Species survey of carabids caught on light in the Suché Mýto street, in pitfall traps at other 13 sites in the Bratislava city centre and in two fields in wider surroundings of Bratislava.

Species	Breeding type	Catches on light		Pitfall traps in centre of Bratislava						Fields			
				1981–1982		1988				wheat		maize	
		A	D	A	D	A	D	SN	P	A	D	A	D
Agonum gracilipes (Duftschmidt, 1812)	SP	1	0.08	1	0.10			1	7.69				
Agonum viridicupreum (Goeze, 1777)	SP									1	0.03		
Amara aenea (De Geer, 1774)	SP	3	0.24	14	1.46	4	4.21	7	53.85	4	0.12		
Amara apricaria (Paykull, 1790)	AU	16	1.28			7	7.37	1	7.69			28	0.37
Amara bifrons (Gyllenhall, 1810)	AU											1	0.01
Amara consularis (Duftschmidt, 1812)	AU	145	11.16	1	0.10			1	7.69			2	0.02
Amara convexiuscula (Marsham, 1802)	AU											1	0.01
Amara familiaris (Duftschmidt, 1812)	SP			11	1.14	1	1.05	4	30.77			2	0.02
Amara chaudoiri incognita Fassati, 1946	SP									2	0.06		
Amara ingenua (Duftschmidt, 1812)	SP											1	0.01
Amara ovata (Fabricius, 1792)	SP									1	0.03		
Amara saphyrea (Dejean, 1828)	SP									1	0.03		
Amara similata (Gyllenhall, 1810)	SP												
Amara majuscula Chaudoir, 1850	SP	18	1.44										
Anchomenus dorsale (Pontoppidan, 1763)	SP	2	0.16	35	3.65	8	8.42	8	61.54	684	20.43	80	1.05
Anisodactylus binotatus (Fabricius, 1787)	SP			3	0.30			3	23.08				
Asaphidion flavipes (Linnaeus, 1761)	SP			19	1.98	3	3.15	6	46.15				
Badister dilatatus Chaudoir, 1837	SP							1	7.69				
Badister lacertosus Sturm, 1825	SP			2	0.20			1	7.69				
Badister peltatus (Panzer, 1797)	SP	2	0.16										
Bembidion biguttatum (Fabricius, 1779)	SP			2	0.20			2	15.38				
Bembidion dentellum (Hunberg, 1787)	SP			2	0.20			1	7.69				
Bembidion guttula (Fabricius, 1792)	SP	1	0.08										
Bembidion lampros (Herbst, 1784)	SP	2	0.16	55	5.73	1	1.05	8	61.54	18	0.54	1	0.01
Bembidion properans (Stephens, 1828)	SP			4	0.42			3	23.08			7	0.09
Bembidion quadrimaculatum (Linnaeus, 1761)	SP	3	0.24										
Bembidion tetracolum Say, 1823	SP			2	0.20			1	7.69				
Bradycelus caucasicus (Chaudoir, 1846)	SP			1	0.10			1	7.69				
Bradycelus harpalinus (Audinet-Serville, 1821)	SP											1	0.01
Brachynus crepitans (Linnaeus, 1758)	SP									29	0.87		
Brachynus ganglbaueri Apfelbeck, 1904	SP									84	2.51		
Brachynus explodens Duftschmidt, 1812	SP			5	0.52	1	1.05	3	23.08	219	6.54	11	0.16
Calathus ambiguus (Paykull, 1790)	AU	20	1.60							1	0.03		
Calathus cinctus Motschulsky, 1850)	AU	33	2.64										
Calathus erratus Sahlberg, 1827)	AU			1	0.10			1	7.69			9	0.12
Calathus fuscipes (Goeze, 1777)	AU			10	1.04	6	6.31	2	15.38	4	0.12	481	6.32
Calathus melanocephalus (Linnaeus, 1758)	AU	52	4.16	5	0.52			3	23.08			7	0.09
Calosoma auropunctatum (Herbst, 1784)	AU									7	0.21	2	0.02
Carabus granulatus Linnaeus, 1758	SP									1	0.03	1	0.01
Carabus intricatus Linnaeus, 1761	SP			14	1.46			1	7.69				
Carabus scheidleri Panzer, 1799	SP									1	0.03		
Carabus ullrichi Germar, 1824	SP									2	0.06		
Carabus violaceus Linnaeus, 1758	AU									2	0.06		
Chlaenius spoliatus (Rossi, 1790)	SP	2	0.16										
Chlaenius tristis (Schaller, 1783)	SP	3	0.24										
Cicindela germanica Linnaeus, 1758	SP	1	0.08									1	0.01
Clivina fossor (Linnaeus, 1758)	SP	17	1.36	12	1.25	3	3.15	3	23.08	1	0.03		
Demetrias atricapilus (Linnaeus, 1758)	PL	1	0.08										
Dolichus halensis (Schaller, 1783)	AU	42	3.41	4	0.42			2	15.38			1370	18.06
Elaphrus uliginosus Fabricius, 1792	SP					1	1.05	1	7.69				
Europhilus fuliginosus (Panzer, 1800)	SP					1	1.05	1	7.69				

Table 1. (continued)

Species	Breeding type	Catches on light A	Catches on light D	Pitfall traps in centre of Bratislava 1981–1982 A	1981–1982 D	1988 A	1988 D	SN	P	Fields wheat A	wheat D	maize A	maize D
Europhilus micans (Nicolai, 1822)	SP			1	0.10			1	7.69				
Harpalus affinis (Schrank, 1781)	AU	6	0.48	59	6.14	28	29.47	7	53.84	1	0.03	2	0.02
Harpalus atratus Latreille, 1804	SP			6	0.62			1	7.69				
Harpalus distinguendus (Duftschmidt, 1812)	SP	4	0.32	11	1.15			4	30.77	4	0.12	101	1.32
Harpalus latus (Linnaeus, 1758)	SP	5	0.40					1	7.69				
Harpalus signaticornis) (Duftschmidt, 1812)	AU							1	7.69				
Harpalus tardus (Panzer, 1797)	AU	8	0.64	5	0.52			2	15.38				
Harpalus tenebrosus Dejean, 1929	AU	3	0.24										
Harpalus zabroides Dejean, 1829)	AU	7	0.56										
Lasiotrechus discus (Fabricius, 1792)	AU			1	0.10			1	7.69				
Leistus ferrugineus (Linnaeus, 1758)	AU											12	0.16
Loricera pilicornis (Fabricius, 1775)	SP	1	0.08	1	0.10			1	7.69				
Microlestes maurus (Sturm, 1827)	PL			1	0.10			1	7.69			4	0.05
Microlestes plagiatus (Guftschmidt, 1812)	PL			1	0.10			1	7.69			5	0.06
Nebria brevicollis (Fabricius, 1792)	AU			3	0.30			3	23.07				
Notiophilus palustris (Duftschmidt, 1812)	SP											1	0.01
Notiophilus rufipes Curtis, 1829	SP	1	0.08	2	0.20			2	15.38				
Ophonus azureus (Fabricius, 1775)	AU	2	0.16							8	0.24		
Ophonus diffinis (Dejean, 1829)	AU	1	0.08										
Ophonus puncticeps Stephens, 1828)	AU	43	3.44										
Ophonus schaubergerianus Puel, 1937	AU	6	0.48	4	0.42			3	23.07			3	0.04
Ophonus subsinuatus Rey, 1886	AU			22	2.29			1	7.69				
Oxypselaphus obscurus (Herbst, 1784)	SP			1	0.10			1	7.69				
Paradromius linearis (Linnaeus, 1758)	SP	2	0.16	2	0.20			2	15.38				
Poecilus cupreus (Linnaeus, 1758)	SP									1931	57.67	19	0.25
Poecilus sericeus Fischer von Waldheim, 1823	SP											32	0.42
Polystichus connexus (Fourcroy, 1785)	AU	1	0.08										
Pseudoophonus calceatus (Duftschmidt, 1812)	AU	113	9.07									2	0.02
Pseudoophonus griseus (Panzer, 1797)	AU	14	1.12	7	0.73			3	23.07			773	10.16
Pseudoophonus rufipes (De Geer, 1774)	AU	207	16.58	386	40.21	8	8.42	8	61.54	239	7.14	4414	57.99
Pterostichus macer (Marsham, 1802)	SP	1	0.08	1	0.10			1	7.69	7	0.21		
Pterostichus melanarius (Illiger, 1798)	PL	2	0.16	192	20.00	20	21.05	7	53.84	65	1.94	166	2.18
Pterostichus niger (Schaller, 1783)	PL	1	0.08	45	4.69	2	2.1	2	15.38				
Stomis pumicatus (Panzer, 1796)	SP									1	0.03	1	0.01
Syntomus obscuroguttatus (Duftschmidt, 1812)	PL									3	0.09		
Syntomus pallipes (Dejean, 1825)	PL			1	0.10	1	1.05	2	15.38				
Synuchus vivalis (Illiger, 1798)	AU									1	0.03	1	0.01
Trechoblemus micros (Herbst, 1784)	AU			1	0.10			1	7.69				
Zabrus tenebrionides (Goeze, 1777)	SP											3	0.04
Trechus quadristriatus (Schrank, 1781)	AU	459	36.73	4	0.42			5	38.46	26	0.77	66	0.87
Zabrus tenebrionides (Goeze, 1777)	SP											3	0.04
Number of individuals		1251		960		2083				3348		7614	
Number of species		40		44		16				29		35	

Key: SP – spring, AU – autumnal, PL – plastic, A – abundance, D – dominance in %, SN – number of pitfall trapping sites, where a species was found, P – presence in %.

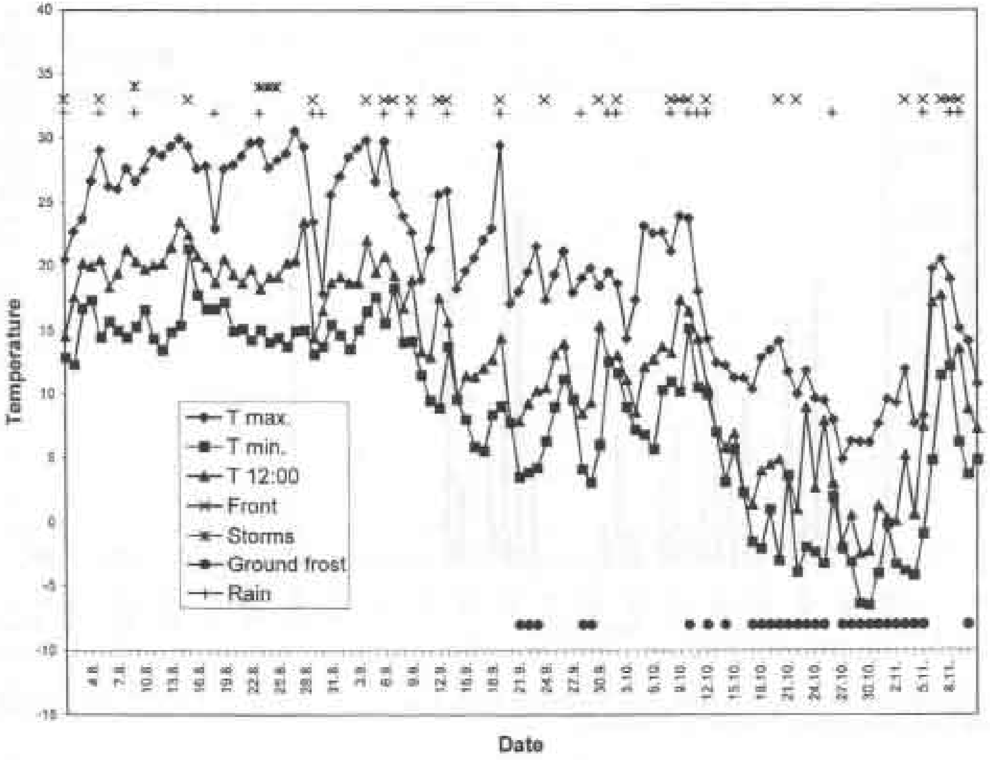

Fig. 4. Temperature (maximum, minimum and at 9.00 p.m.), passing of the fronts, occurrence of storms, rain and ground frosts registered in the meteorological station Bratislava airport from 1 August to 9 November, 1997.

A remarkable discovery was the presence of a *Polystichus connexus* female on 6 August, 1997 (another female was found at the same site just one year later, on 4 August, 1998 (Šustek, pers. obs.). According to available information, *P. connexus* was found in Slovakia, for the last time, in vicinity of Banská Bystrica (48°43'38'' N, 19°9'10'' E) in 1961 (Holecová & Rychlík, in verb). Rather contradictory data exist in the literature on its autecology. Some authors suggest that it inhabits dry open habitats (e. g. Roubal, 1930; Burakowski et al., 1974; Hůrka, 1996), while others (e. g. Lindroth, 1974) consider it to inhabit water sides. My personal observations from the floodplain forests along the Danube at the Romanian-Bulgarian border and the recently published data on its distribution in Bulgaria (Gueorguiev & Gueorguiev, 1995) support the former opinion.

Temporal changes of the beetle activity

Three distinct periods in the flight activity of Carabids can be distinguished according to the catch size and its structure (Figs 6, 7). The first period lasted from 7 August (beginning of regular observations) to 22 August, the second one from 23 August to 4 September and the third one from 5 September to 6 November.

The first period was characterised by the occurrence of 6–16 species (12 ± 3.04; mean ± SD) recorded each day, by a number of individuals fluctuating in very wide range of 9–134 (50.42 ± 32.69) and by the predominance of the species of the genera *Harpalus*, *Ophonus* and *Amara* and occurrence of *Dolichus halensis* and *Calathus* spp. In the first half of this period *Harpalus zabroides* and *H. tenebrosus* were also observed. In comparison, *Trechus quadristiatus* was absent or at most 1–2 individuals occurred only accidentally at the end of this period. The end of this period coincided with a

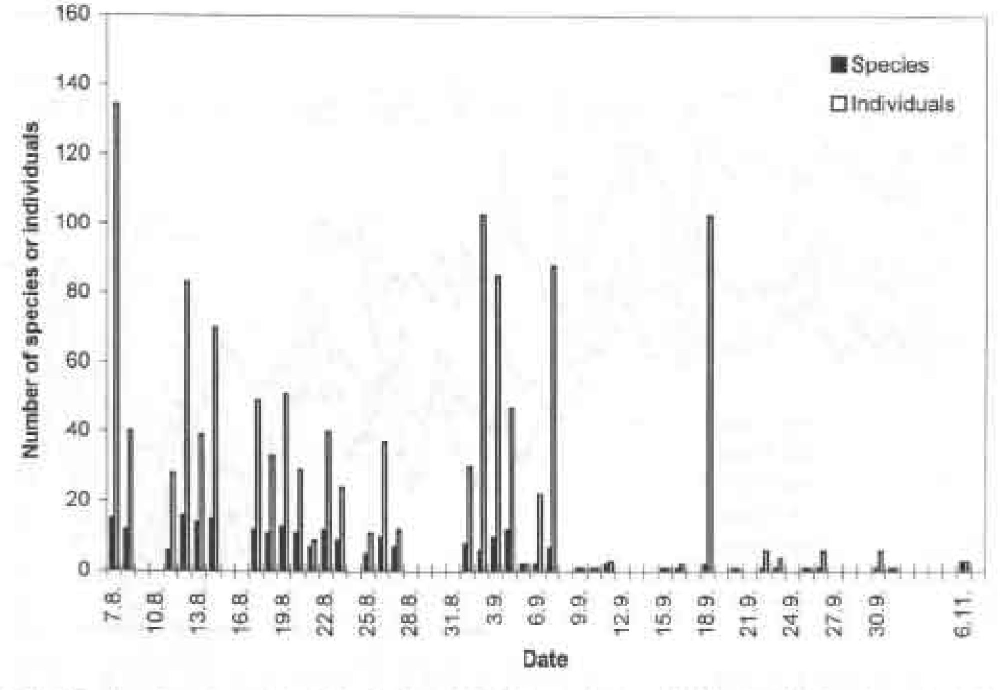

Fig. 5. Number of species and individuals of carabids flying to the strongly illuminated advertisements in the Suché Mýto street from 7 August to 6 November 1997.

sudden decrease of abundance of *Pseudophonus rufipes* (from 12.4 ± 13.22 individuals to 2.25 ± 1.67 individuals) and the absence of *Calathus ambiguus* and *D. halensis*. This period was characterised by minimal temperatures often exceeding 15 °C, maximal temperature close to 27–29 °C and the temperatures at 9.00 p.m. around 20 °C. This period ended with a series of storms beginning on 22 August (Fig. 5).

The second period was characterised by the presence of 5–12 (8.35 ± 2.32) species recorded daily, by a very variable number of individuals (range 11–103, 43.62 ± 33.65) and, above all, by a high predominance of *T. quadristriatus*, which represented the only abundant species in that period. Among other species only low numbers of *Pseudophonus rufipes*, *P. calceatus* and *Amara consularis* were observed more regularly. *D. halensis* and *Clathus ambiguus* did not occur in this period. This period was characterized by a very slight decline in temperature (ca. by 1 °C) after some storms and rains (Fig. 4) resulting in a decrease in the flight activity of the carabids. This period was stopped by a series of frontal systems passing in the first decade of September (Fig. 4).

The third period was characterised by presence of very low number of species (1–3, 1.32 ± 1.49), by a very low number of individuals (range 0–103, 11.41 ± 27.71) and by the almost exclusive occurrence of *T. quadristriatus*. During this period a strong drop of temperature was recorded: the minimum temperature often fell under 5 °C, the maximum moved around 20 °C and the temperature at 9.00 p.m. varied between 8–15 °C (Fig. 4). On 21 September the first ground frosts were also recorded. The activity of beetles surviving in the galleries definitely stopped when the minimal temperature fell under 0 °C, but a short increase of temperature on 6 and 7 November together with passing of three frontal systems was sufficiently strong to stimulate the beetles activity again for one day.

In agreement with the observations of Kádár & Szentkirályi (1992), the passing of a cold or warm front (Fig. 4) coincided with the increased flight activity of carabids. In the first period it was on 7 and 14 August (the second postfrontal and first prefrontal day, respectively), when increased flight activity was observed simultaneously in several species. In the second and third periods it was on 2 and 3 September (two prefrontal days), on 7 September (cumulative effect of the fronts passing on 6, 7 and 9 September), on 18 September (first prefrontal day) and on 30 September (frontal day). In these days a strongly increased flight activity was observed only in *T. quadristriatus* (Fig. 6). The single occurrence of one individual of *B. lampros*, *H. affinis* and *N. rufipes* on 6 November (not presented in the diagram) coincided with three fronts passing on 4, 7 and 8 November.

Comparison of light catches of carabids with the pitfall trap catches in the centre of Bratislava and in the agrarian landscape of South Slovakia

The structure of the light attracted carabids in the centre of Bratislava differs strongly from the pitfall-trapped assemblages from the centre of Bratislava (Šustek, unpublished) and the surrounding fields in Bratislava (Tab. 1). Seven open landscape species, viz. *C. ambiguus*, *C. cinctus*, *P. calceatus*, *H. tenebrosus*, *H. zabroides*, *O. diffinis*, *O. puncticeps* (cumulative dominance in the light catches 17.60%) and four hygrophilous species, viz. *B. peltatus*, *B. guttula*, *Ch. spoliatus*, *Ch. tristis* (cumulative dominance 0.64%) were not recorded at all in the city centre by means of pitfall traps. The species *A. apricaria*, *A. consularis* and *D. halensis* (cumulative dominance in the light catches 15.80%) were much rarer in pitfall traps (cumulative dominance 0.51% in 1981–1982 and 7.37 in 1988). In comparison six species, viz. *Anchomenus dorsale*, *Harpalus affinis*, *H. distinguendus*, *Bembidion lampros*, *Amara aenea*, *A. familiaris*, having been found regularly in the traps installed in the city centre (cumulative dominance 14.18% in 1981–1982, 35.78% in 1988) were much rarer among the light attracted carabids (cumulative dominance 1.28%).

These differences are clearly reflected by the proportional similarity between the light catches and pooled pitfall trap samples from the Bratislava centre ranging from 12.34% (samples from 1988) to 23.02% (samples from 1981–1982) and by much higher proportional similarity of both sets of pitfall trap samples (45.51%). On the contrary, the qualitative similarity exhibits much smaller differences: 32.73% (light catches and samples from 1988), 43.33% (samples from 1981–1982 and 1988) and 50.60% (light catches and samples from 1981–1982). In addition, the lowest value of quantitative similarity (32.73%) results to a considerable degree from the different size of compared samples.

Further differences were found between light attracted carabids and their assemblages from the fields. The assemblage in wheat was characterised, like in many other cases not presented here, by the a high codominance of the spring breeding species (89.3%), especially by *Poecilus cupreus* (57.7%), *Anchomenus dorsale* (20.4%), *Brachynus explodens* (6.5%) and *B. gangelbaueri* (2.5%), while the autumn breeding species were represented much less, *Pseudoophonus rufipes* being the only abundant representative of them. By comparison, the species *P. cupreus*, *B. explodens*, and *B. gangelbaueri* were missing in the light catches and only two individuals of *A. dorsale* were caught on light.

The assemblage in maize, i. e. a crop which emerges relatively late in May and begins to form close canopies as late as in June, was dominated by the autumn breeding species (94.3%), especially by *P. rufipes*, *P. griseus*, *D. halensis* and *C. fuscipes* (cumulative dominance 92.5%). Spring breeding species and species with indefinite breeding type represented only 5.7% of the whole catch. The autumn breeders, except of *C. fuscipes*, formed 93.9% of the carabids caught on light in city centre.

Almost half of individuals belonging to autumn breeding species in the light attracted carabids was represented by *T. quadristriatus*, which flew into city centre in two relatively short, but intensive waves, the first between 1 and 7 September, and the second on 18 September. This species was relatively little represented in both field assemblages, but on some other sites (Šustek, unpublished) it formed a characteristic late autumnal aspect of the field carabid assemblages.

P. calceatus was represented by 113 individuals (9.1%) in the light catches. It was not present in the pitfall catches in city centre or it occurred rarely in the maize field.

The only common feature of all carabid assemblages compared here was the high predominance of the extremely expansive *P. rufipes*: 16.58% in light catches, 40.21% in pitfall traps in the city centre, 7.14% and 57.99% in wheat and maize fields, respectively.

Comparison with the light trap catches in other localities

Structure of the light trap catches made by different authors (Milánder, 1972; Siroki, 1981; Honěk & Pulpán 1983; Kádár & Szentkirályi, 1984; Veselý, 1987; Kádár & Lővei, 1992; Kádár & Szél, 1995) differs considerably. Moreover, striking between-year differences were found even in the same localities (Honěk & Pulpán, 1983; Kádár & Szentkirályi, 1984; Kádár & Lővei, 1992).

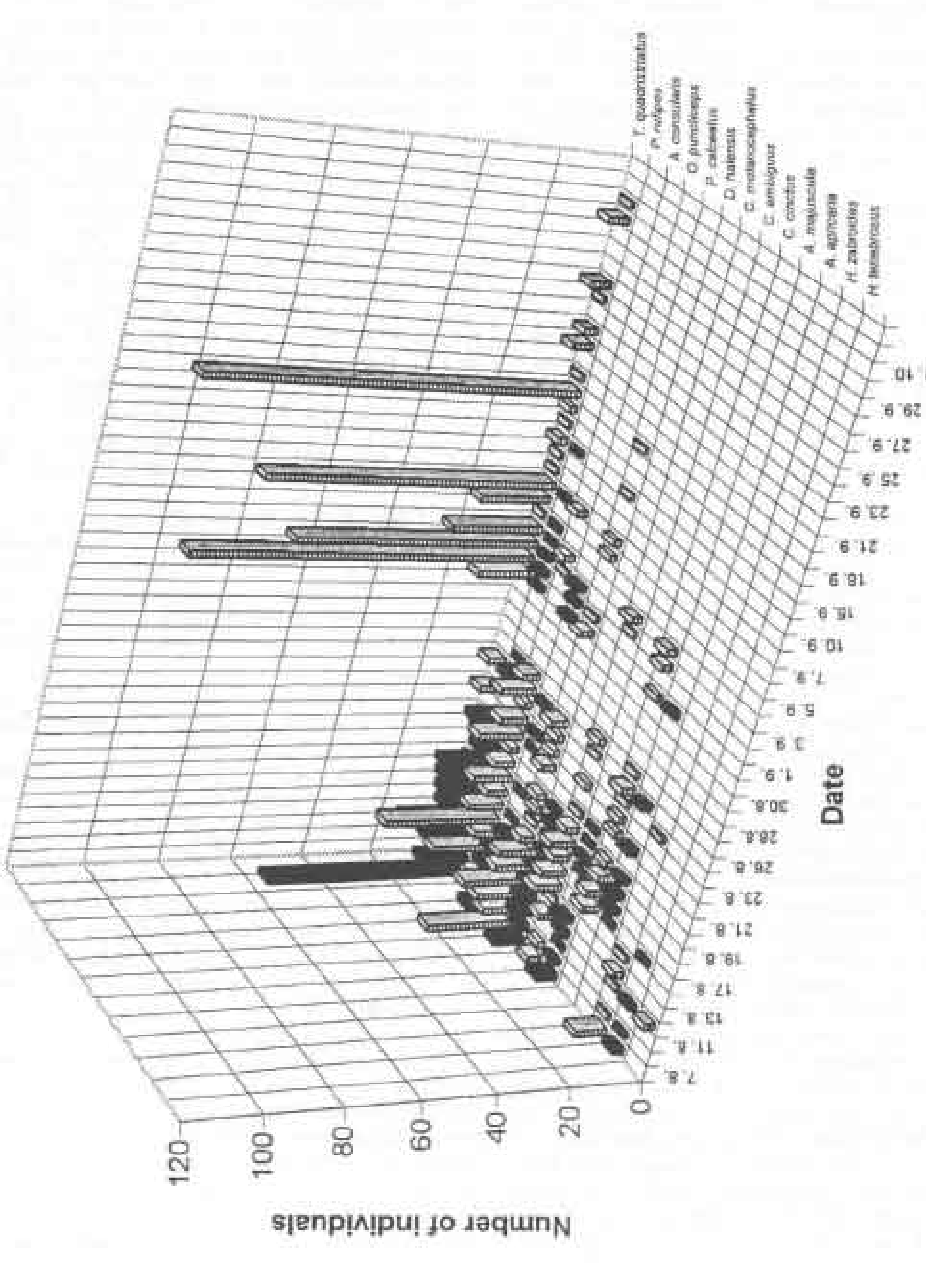

Fig. 6. Flight activity of dominant or subdominant carabid species and of the ecologically significant xerothermophilous *H. tenebrosus* and *H. zabroides* in the Suché Mýto street from 7 August to 1 October 1997.

Fig. 7. A *P. rufipes* entering into the gallery built in a wall base (in left), a *P. rufipes* just after living a gallery with a died individual laying on its left (in centre of the picture), and an other individual's antenna sticking out from the gallery in the picture right side (Bratislava, Suché Mýto street).

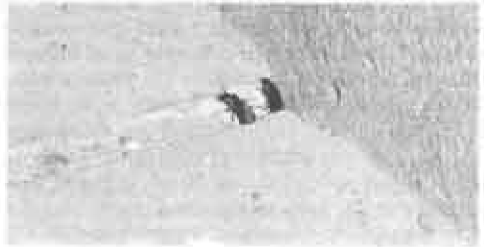

Fig. 8. Activity of two *P. rufipes* (one entering, other living) around mouth of a gallery built between flagstones at a wall base (Bratislava, Primaciálne námestie).

In spite of this, all these light trap catches differ from the pitfall trap catches by some common features. First, there is a general tendency for a considerably increase in dominance of representatives of the subgenera *Bradytus* Stephens, 1828, *Celia* Zimmermann, 1832 and *Curtonotus* Stephens, 1828 belonging to the genus *Amara* Bonelli, 1810, as well as the species *Ophonus puncticeps* and *Agonum gracilipes*. Second, a high abundance of *P. calceatus* and sometimes a considerably high representation of *H. tenebrosus* and *H. zabroides* seems to be a characteristic feature of the light trap catches made in the Carpathian basin and SE Europe (Siroki, 1981; Kádár & Lövei, 1992) in spite of the fact that *P. calceatus* is not abundant everywhere in the pitfall traps and *H. tenebrosus* and *H. zabroides* can be even considered to be rare in this area. Both these features are also characteristic of the light catches in the centre of Bratislava. In comparison, these catches strongly differ from those made by Siroki (1981) in Debrecen in E Hungary, where a considerable number of ripicolous species, mostly represented by high number of individuals, occurred. This was, however, caused by situating of the sampling site close to a brook.

Survival of larger carabids on the streets

At all three study sites in the centre of Bratislava, a considerable portion of the larger carabids (first of all *P. rufipes, P. calceatus, D. halensis*) attracted by the light did not try to leave the illuminated sites and to search for a more favourable habitat (e. g. a grassy plot in the vicinity), and remained at the base of the walls and dug relatively deep galleries in the sand or loose debris accumulated between pavement and wall basis or used various cracks in wall bases, ventilation windows and cleaning mouths of gutter pipes to hide there (Figs 7–9). Sometimes they used the galleries of ants as shelter. In some galleries two or three individuals were hiding simultaneously. About 15–20 min before nightfall the beetles appeared at the gallery opening. Some of them remain there with the posterior part of their body hidden in the gallery and waited for the surprisingly abundant prey (running ants, little cicadas and flies fallen from the illuminated wall or shopwindows). Other individuals ran along the base of the walls and searched actively for the prey. Most did not leave the very narrow strip (about 5 cm) along the wall and ran within this strip up to the distance 3–4 m from their gallery. A few individuals occasionally moved up to the distance of 1.5–2 m from the wall to the pavement middle but usually

Fig. 9. A *D. halensis* attacking from the back a *P. rufipes* in a common microhabitat around a gutter pipe and its cleaning opening (Bratislava, Primaciálne Námestie square).

they returned to the wall within 2–3 min. On the busier sites such beetles were often trampled by the pedestrians. Trampling was the most frequent cause of mortality of beetles. In the evening, some individuals ascended the wall surface to the height of 1–3 m and remained motionless for a long time.

There was a difference in the moving activity of individual species hiding in the galleries during the day. *D. halensis* appeared usually 1–1.5 h after nightfall and was active approximately 1–2 h. *D. halensis* preferred to stay in or close to the gallery and undertook short quick attacks to the surroundings. The final individuals of *D. halensis* disappeared in mid September. A similar behaviour was also observed in one individual of the ripicolous *Ch. spoliatus*. The behaviour similarity of these two species which differ in their habitat preference in Central Europe seems to be surprising, but the easternmost populations of *D. halensis* in Korea occur abundantly on watersides together with *Chlaenius* species (ŠUSTEK, unpublished). Furthermore, they belong to the same life form according to the classification of SHAROVA (1981) which could lead to the development of the same hunting strategy. One individual of *Ch. spoliatus*, which was not intentionally caught, survived successfully in a gallery for at least three weeks. Both species, *D. halensis* and *Ch. spoliatus* were obviously favoured by long legs enabling them to run quickly. They also exhibited a good orientation in their territory and rapidly found their hiding places.

Activity of *P. rufipes* and *P. calceatus* started 10–15 min before the nightfall and lasted over the whole night. The beetles run relatively slowly and made more pauses in movement.

The moving activity of the beetles depended strongly on the temperature. During colder periods in September, no beetles were observed for several days. In October such periods became oftener and longer, but if the temperature rose the beetles reappeared. Their number, however, decreased rapidly. The last running beetle (*P. calceatus*) was recorded on 6 November.

Territorial behaviour of carabids on the streets
No conflicts were observed in the beetles hiding simultaneously in one gallery when they left the galleries and were sitting close to their openings. However, sometimes both inter- and intraspecific fights were registered between the beetles running in the narrow strip along the walls. After 1–2 min the fight finished without visible damage of any of the rivals. Especially *D. halensis* was successful in the fights with *P. rufipes* or *P. calceatus* being favoured by longer legs enabling quicker running and giving better stability (Fig. 9).

Trampled beetles as food source for other carabids
Often beetles running along the narrow strip near the walls were trampled by shoes of the people looking the articles in the shopwindow. Their bodies were quickly found and eaten by other carabids running along the wall. However, bodies of the beetles which had died naturally, remained intact for two-three days. This consuming of the trampled congeners or "intrafamiliar cannibalism" increased the survival chance of the beetles living at such extremely unfavourable sites.

Question of the UV Light attractiveness for insects
A high proportion of UV rays (100–380 nm) in the light spectrum of a lamp has almost universally been supposed to be the main cause of attractiveness of the light for insects. On this base some authors even suggested to use germicide lamps for the light trapping of insects (VASJURIN, 1978). However, the modern halogen lamps producers place emphasis on an extremely low portion of UV rays in the spectrum of their lamps and state this in technical catalogues. However, UV lamps produced for technical or medicinal purposes do not emit visible light. The observations show the cold blue and green rays predominating in the classical UV-lamps could be the more significant causes of their attractiveness for the insects than the UV light itself. This is in accordance with the experiments of HASSELMANN (1962 in THIELE 1977), who found the maximum light spectrum sensitivity in *Carabus auratus* Linnaeus, 1761 and *C. nemoralis* O. F. Müller, 1764 to be about 500 nm, bellow which about 1/3 of energy was emitted by the halogen discharging lamp, while above 570 nm the sensitivity of these species dropped sharply.

Conclusions

The intensive illumination of some sites in the city centre attracted, in the high summer and within a relatively short period, a surprisingly high number of carabids. This number is comparable with the species and/or individual numbers occurring anywhere in the agrarian landscape in the city surroundings and it far exceeded the number of species and individuals collected at one site in the city centre by other catching methods over a much longer period. At the same time it showed the significance of night migrations of field carabids for maintenance of biodiversity in the landscape and the high dispersal power of such species. The flight wave maxima were closely correlated with the passing of frontal systems and occurred mostly within two prefrontal or postfrontal days. This correlation was evident even in the late autumn, when the flight activity was already very low.

Some of the attracted species, first of all *P. calceatus*, *P. rufipes*, *D. halensis* and *Ch. spoliatus* exhibited a remarkable ability to survive in the asphalt desert of the city centrum and to find suitable covers and food resources. In particular, *D. halensis* and *Ch. spoliatus* exhibited behaviour patterns showing a favourable adaptation to life in such conditions.

Both these observations show that the light attraction of carabids can considerably influence the succession of their communities or temporal aggregations in the city interior. At the same time the results showed that a large city does not represent any serious barrier for dispersal of large quantities of open landscape carabids, including some rare species, and, to a large extent some ripicolous species.

The presented observations suggest the high attractiveness of the cold light for the insects to be superior to the attractiveness of UV light used in the existing light traps.

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