Long-term monitoring of ground beetles (Coleoptera, Carabidae) in a Hungarian wetland area

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Abstract

A 10- year study of ground beetles was carried out in the protected area of Kis-Balaton, Western Hungary. Pitfall-traps (15) were placed along a transect and were operating continuously. The traps caught 10,332 individuals, belonging to 127 species. Both the number of species and cumulative number of species increased continuously with no sign of saturation over the 10-year period. The dominant species showed large changes in numbers from year to year. We suggest that fluctuations in abundance, and the year to year changes in the dominant species are caused mainly by the unstable wetland habitat, and only partially by species biology.

Key words: Carabids, wetland, Hungary

Introduction

The study area was formerly the western bay of the Lake Balaton, Hungary. The area was drained in the early 1900s, which led to the eutrophication of the lake and a deterioration of the water quality. In the 1980es, restoration was attempted by using a wetland to clear the most important water supplier of the lake, the River Zala. In 1992, the water level was raised on 16 km^2 of the so-called Kis-Balaton, a protected RAMSAR area. At the instigation of the Hungarian Ministry of the Environment, a monitoring system was established to observe the biological changes during and after the project. Part of this monitoring included ground beetles (Carabidae). This research started in 1993, and aimed to examine the effect of the artificially raised water level on ground living arthropods, particularly ground beetles.

Previous faunistical studies (Kondorosy *et al.,* 1996) found 87 carabid species in the protected area.

Materials and methods

The sampling area was on a natural land bridge (WGS 84 coordinates: 46°41’20” N, 17°16’37” E) in the northern part of the Kis-Balaton area by the Lake Balaton in Western Hungary. This area is protected, and is a wetland of international importance, belonging to the so-called "RAMSAR" network. The pitfall traps were placed along a transect beginning at the edge of the water and continuing 50 m inland. Three vegetation units could be distinguished along the transect: 1) close to the water there was an association of reeds (*Phragmites australis* and sedges *Carex riparia*, *C. acutiformis*); 2) on higher ground, a homogeneous strip of *Solidago gigantea*, giving way to a 3) a *Solidago gigantea* and *Calamagrostis epigeios* association. *S. gigantea,* an invasive weed, causes severe problems in Hungary, since its monoculture spreads aggressively and it almost fully supplants other herbs. The presence of *C. epigeios* indicates disturbance in an area (Mihály & Botta-Dukát, 2004). Fifteen pitfall traps were placed at a distance of 5 m from each other. They were emptied weekly throughout the year, apart from the snowy period. Thus, the pitfall traps were operating continuously for ten years.

To ease the operation of the pitfall traps, an iron pipe (84 mm diameter, length 140 mm) was driven into the ground with its upper rim at 5 mm below the ground level. The reclining rim of the 200 ml plastic cup (88 mm outer and 82 mm inner diameter), serving as the removable part of the trap, rested on the pipe. With the help of three bent aluminium hooks, glass plates were placed over the cups to protect the catch from rain and scavenging. A modified version of the Barber-solution (Barber, 1931) was used as killing and preserving agent, the composition of which was: 1 part alcohol, 5 parts distilled water, ¼ part acetic acid and 1/3 part glycerine. The collected samples were stored in 70% alcohol until processing, when the samples were separated under a microscope and the carabids were identified, using standard classification keys by Freude (1976), Hurka (1996), and Csiki (1905). Distributional data of carabid beetles in Hungary were taken from Kádár & Szél (1989), Kondorosy *et al*. (1996), Kutasi & Szél (2000), Szél (1996). The nomenclature followed Hurka (1996).

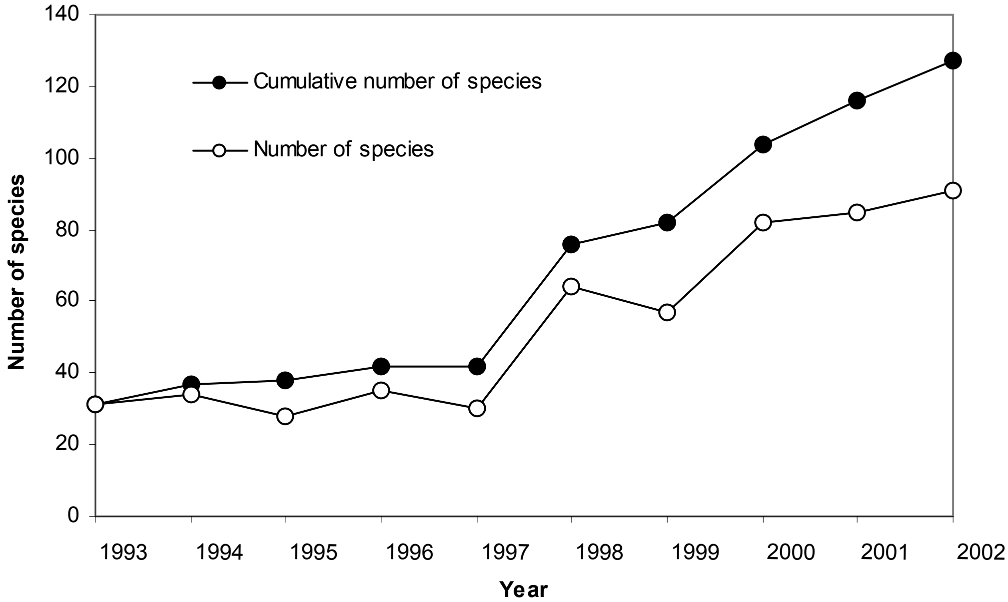

Figure 1. The number of carabid species and the cumulative number of carabid species collected by pitfall traps in the Kis-Balaton, Hungary, between 1993-2002.

Species that were responsible for at least 10% of the samples in at least one year were classified dominant species. The annual cumulative number of species was calculated.

Results

Between 1993-2002, a total of 10,332 individuals were captured, belonging to 127 species (Table 1). This is 25% of the Hungarian carabid fauna, which numbers about 500 species (Horvatovich, 1993). Numerous rare, or very rare carabid species were captured. These include *Trechus austriacus, T. obtusus, Benbidion doris, B. gilvipes, Pterostichus rhaeticus, Amara cursitans, A. municipalis, A. lunicollis,* and *Trichocellus placidus*.

Fig. 1 shows the changes in the number of species each year and the trend in cumulative number of species. Both values increased continuously over the years. The increase was steeper in the second than in the first five-year period (Fig. 1). The number of species caught per year ranged from 28 (1995) to 91 (2002). Fourteen of the 127 species were caught every year, 11 of which were hygrophilous (Table 1).

The total number of individuals collected varied from 416 (1995) to 2009 (2002) with no obvious trend over time.

Table 1. Total yearly catches of ground beetles at the Kis-Balaton Nature Reserve, Western Hungary, in the period 1993-2002. Species sequence follows Hurka (1996). Species captured in every year are in bold.

Species	Year										Total
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	
Leistus ferrugineus (L., 1758)	4		2	6	4	9		26	33	6	90
Nebria brevicollis (Fabricius, 1792)										2	2
Notiophilus palustris (Duftschmid, 1812)						3		14	6	11	34
Carabus cancellatus sopronensis Dejean, 1826	86	50	41	105	150	9	7	4	4	10	466
Carabus clatratus auraniensis Müller, 1902	52	67	62	55	100	21	9	3	14	16	399
Carabus coriaceus coriaceus L., 1758						1				1	2
Carabus ullrichi sokolari Born, 1904								2			2
Carabus granulatus granulatus L., 1758	102	68	91	157	90	129	43	41	172	99	992
Cicindela germanica L., 1758						1		2			3
Cicindela campestris L., 1758							1				1
Elaphrus cupreus Duftschmid, 1812										2	2
Elaphrus uliginosus Fabricius, 1792		1						2	8	10	21
Loricera pilicornis Latreille, 1802							1			1	2
Clivina collaris (Herbst, 1784)									1		1
Clivina fossor (L., 1758)	5	3	1	3	5	4	1	4	5	2	33
Dyschirius aeneus (Dejean, 1825)								2			2
Dyschirius globosus (Herbst, 1784)						26	38	53	91	60	268
Brachinus crepitans (L., 1758)										3	3
Brachinus explodens Duftschmid, 1812							1			2	3
Brachinus ganglbaueri advena Schauberger, 1921										1	1
Epaphius secalis (Paykull, 1790)								5	11	6	22
Trechus austriacus Dejean, 1831									1	3	4
Trechus obtusus Erichson, 1837									1	9	10
Trechus quadristriatus (Schrank, 1781)				29	15	33	58	199	166	56	556
Paratachys bistriatus (Duftschmid, 1812)								1	1		2
Tachita nana (Gyllenhal, 1810)								1			1
Asaphidion flavipes (L., 1761)						1	1	3	4	2	11
Bembidion articulatum (Panzer, 1796)								1			1
Bembidion assimile Gyllenhal,1810	6	2				4	1	11	12	3	39
Bembidion biguttatum (Fabricius, 1779)										3	3
Bembidion fumigatum (Duftschmid, 1812)						1					1
Bembidion inoptatum Schaum, 1857									2		2
Bembidion guttula (Fabricius, 1792)							2	6	20	11	39
Bembidion mannerheimi (Sahlberg,1827)						4	11	20	59	152	246
Bembidion doris (Panzer, 1797)								6	1		7
Bembidion gilvipes Sturm, 1825									1		1
Bembidion lampros (Herbst, 1784)								1			1
Bembidion properans (Stephens, 1828)						8	5	15	3	1	32
Bembidion octomaculatum (Goeze, 1777)								1			1
Bembidion quadrimaculatum (L., 1761)						1		3			4
Bembidion tenellum Erichson, 1837									1		1

Species	Year										Total
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	
Stomis pumicatus (Panzer, 1796)						4	6	6	4	24	44
Poecilus cupreus (L., 1758)	77	59	35	93	56	2	20	8	4	11	365
Poecilus versicolor (Sturm, 1824)	8	6		2		17	1		4	12	50
Pterostichus anthracinus (Illiger, 1798)	36	17	5	9	43	35	6	7	10	15	183
Pterostichus aterrimus (Herbst, 1784)	27	16	9	22	7	3	2	26	11	4	127
Pterostichus cursor (Dejean, 1828)	2	1		1					2	2	8
Pterostichus diligens (Sturm, 1824)	8	22	5	28	2	12	8	11	40	21	157
Pterostichus elongatus (Duftschmid, 1812)									1	1	2
Pterostichus gracilis (Dejean, 1828)								1	1		2
Pterostichus melanarius (Illiger, 1798)	83	68	42	84	76	74	2	17	11	70	527
Pterostichus minor (Gyllenhal, 1827)			2	3	6	3		17	27	42	100
Pterostichus niger (Schaller, 1783)	5	38		6		72	22	24	57	33	257
Pterostichus nigrita (Fabricius, 1792)		2	3	19	4	4		10	19	44	105
Pterostichus oblogopunctatus (Fabricius,1787)				1	5						6
Pterostichus rhaeticus Heer, 1837								1			1
Pterostichus strenuus (Panzer, 1797)						25	28	39	25	41	158
Pterostichus vernalis (Panzer, 1796)	51	35	12	37	36	8	7	26	104	151	467
Calathus erratus (Sahlberg, 1827)	1					3					4
Calathus fuscipes (Goeze, 1777)		16	5	11	10	5		2	1	5	55
Calathus melanocephalus (L., 1758)	42	22	9	18	23	14	27	13	23	5	196
Synuchus vivalis (Illiger, 1798)						1	20	28	13	2	64
Oxypselaphus obscurus (HERBST, 1784)							1		2	17	20
Platynus assimilis (Paykull, 1790)	2		1	6	1	1					11
Platynus krynickii (Sperk, 1835)						3	13	7	28	122	173
Agonum lugens (Duftschmid, 1812)	17	9	10	7	31	8		33	9	4	128
Agonum atratum (Duftschmid, 1812)										1	1
Agonum moestum (Duftschmid, 1812)*	*37*	*48*	*7*	*9*	*280*	*75*	*19*	*97*	*176*	*352*	*1100*
Agonum duftschmidi Schmidt, 1994								41	43	47	131
Agonum afrum (Duftschmid, 1812)								17	24	17	58
Agonum permoestum Puel, 1931								39	109	288	436
Agonum sexpunctatum (L., 1758)	1			1	4		2				8
Agonum viduum (Panzer, 1797)		2			5						7
Europhilus fuliginosus (Panzer, 1809)						1	3				4
Europhilus thoreyi (Dejean, 1828)						1		1	8	2	12
Amara aenea (De Geer, 1774)						1	19	8	14	10	52
Amara anthobia A. et G.B. Villa,1833	4	1	1	2	3				3	1	15
Amara bifrons (Gyllenhal, 1810)	3	6	3	3	2	1	3	6		2	29
Amara communis (Panzer, 1797)	62	35	23	56	34	60	53	117	174	45	659
Amara convexior Stephens, 1828						9	7	22	44	23	105
Amara cursitans (Zimmermann, 1831)						1	1	1		1	4
Amara familiaris (Duftschmid, 1812)									10	18	28
Amara fulva (O.F. Müller, 1776)										1	1
Amara lucida (Duftschmid, 1812)										1	1
Amara lunicollis Schiodte, 1837							1				1
Amara municipalis (Duftschmid, 1812)									1	1	2
Amara similata (Gyllenhal, 1810)								2	3	5	10

Species	Year										Total
	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	
Amara tibialis (Paykull, 1798)						2				1	3
Amara tricuspidata Dejean, 1831								1	1	1	3
Panagaeus cruxmajor (L., 1758)								1			1
Chlaenius tristis (Schaller, 1783)	1	2	1	2				3	4	1	14
Chlaenius nigricornis (Fabricius, 1787)				5			1	3	1	2	12
Chlaenius nitidulus (Schrank, 1781)		1						1	1		3
Oodes gracilis A. et G.B. Villa, 1833	2	3						2	5	1	13
Oodes helopioides (Fabricius, 1792)	71	24	33	45	88	44	25	90	80	189	689
Licinus depressus (Paykull, 1790)	1	1	1			2					5
Badister bullatus (Schrank, 1798)						3	8	3			14
Badister latercosus Sturm, 1815						2		8	3		13
Badister unipustulatus Bonelli, 1813									1		1
Badister meridionalis Puel, 1925	1	4	1	7	1	1	1	4	2		22
Badister dilatatus Chaudoir, 1837								2	4	2	8
Badister peltatus (Panzer, 1797)						4	1		6	3	14
Badister sodalis (Duftschmid, 1812)						2	1	5	5	3	16
Anisodactylus binotatus (Fabricius, 1787)	4	2	2	4		3	6		2	1	24
Anisodactylus signatus (Panzer, 1797)								2		4	6
Stenolophus mixtus (Herbst, 1784)	9	12	6	19	14		2	12	42	57	173
Stenolophus skrimshiranus Stephens,1828						2					2
Trichocellus placidus (Gyllenhal, 1827)								1	2	3	6
Bradycellus collaris (Paykull, 1798)						8	7	14	7	10	46
Bradycellus csikii Laczó, 1912						16	16	81	39	43	195
Acupalpus flavicollis (Sturm, 1825)						1		3	6	1	11
Acupalpus parvulus (Sturm, 1825)										1	1
Parophonus maculicornis (Duftschmid, 1812)						4	2	1	2	1	10
Ophonus diffinis (Dejean, 1829)										1	1
Ophonus puncticeps Stephens, 1828									1	1	2
Pseudophonus griseus (Panzer, 1797)		2					1	8	14	2	27
Pseudophonus rufipes (De Geer, 1774)	16	9	3	9	12	11	7	11	40	42	160
Harpalus distinguendus (Duftschmid, 1812)								1		1	2
Harpalus latus (L., 1758)				4	3	1	4	2	23	18	55
Harpalus luteicornis (Duftschmid, 1812)						2	9	12	6	4	33
Harpalus rubripes (Duftschmid, 1812)							3	2	6	24	35
Harpalus subcylindricus Dejean, 1829									1	1	2
Harpalus tardus (Panzer, 1797)						6	7	2	5	3	23
Drypta dentata (Rossi, 1790)								1			1
Lebia chlorocephala (Hoffmann, 1803)										1	1
Syntomus pallipes (Dejean, 1825)						10	2		6		18
Syntomus truncatellus (L., 1761)						9	9	22	26	26	92
Microlestes maurus (Sturm, 1827)						4	1	2	8		15
Yearly total	**826**	**654**	**416**	**868**	**1110**	**835**	**563**	**1256**	**1795**	**2009**	10332

* *Agonum duftschmidi, A. afrum, A. permoestum* together

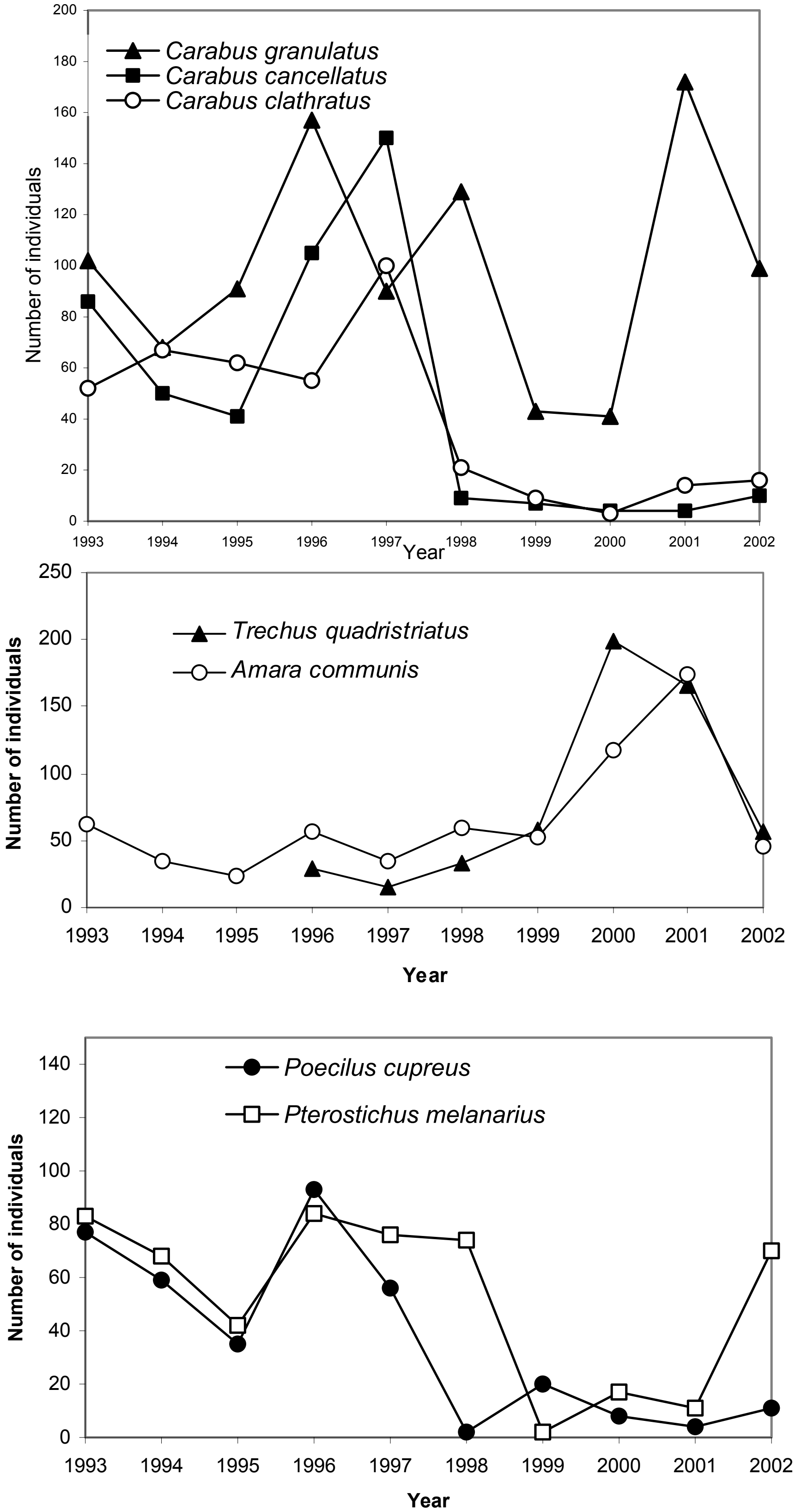

Figure 2A. Year-to-year fluctuations in the yearly total number of individuals captured in the Kis-Balaton, Hungary, between 1993-2002. a) Species common over most of the years: *Carabus granulatus, C. cancellatus, C. clatratus*; b) species common in a short period only: *Trechus quadristriatus, Amara communis;* c) initially common species: *P. cupreus, P. melanarius.*

Between 1993-2002, seven species had relative abundance > 10% in at least one year: these species were considered dominants in the habitat. However, their cumulative relative abundance was < 10%. This list included: *C. granulatus* 8.0%, *Amara communis* 5.4%, *Trechus quadristriatus* 5.4%, *C. cancellatus* 3.2%, *Pterostichus melanarius* 3.2%, *C. clatratus* 2.7% and *Poecilus cupreus* 2.2%. The changes in these populations during the 10 years are shown in Fig. 2. The populations of *C. clatratus* and *C. cancellatus* fluctuated between relatively high values during the first five years, after which (in 1997-1998) their populations drastically fell and stabilised around low values (Fig. 2A). The third species, *C. granulatus*, had relatively high population values. The changes in the population numbers of *A. communis* and *T. quadristriatus* (Fig. 2B) were mostly at low abundances over the whole period, except in 2000 and 2001, when they produced a peak. By 2002, they were back to the former low values. *P. cupreus* and *P. melanarius* (Fig. 2C), fluctuated around high values in the first five years after flooding, and became rare in the second five years.

Conclusions

Common sense would suggest that, with the advance of time, fewer and fewer new species are discovered. Such saturation curves are produced in many species inventories (Magurran, 2003). A small number of new species appears each year because the probability of collecting rare species is small. We witnessed the appearance of new species from year to year and the pace of appearance did not indicate saturation. The results possibly indicated an unstable habitat for carabids, probably due to the year to year changes in the water level. In the case of common species, the population numbers could fall to a fraction of the former value or show a large increase within a few years. In the case of low-population-species the population size can easily slip under the detection threshold and the species would not be detected for years. In the ten years cycle, 28 species (35%) were trapped in just one year. These species could be tourists, or can survive at such low levels that their detection was not possible in most years. Only 14 species (11%) were caught in all years.

Similar investigations were carried out in Germany in an ancient woodland (Gunther & Assmann, 2004). In this research the trapping period was nine years, and the authors found that the catching rates for some species (e.g. *Carabus problematicus* and *Abax parallelepipedus*) fluctuated only slightly, whereas those of other species (e.g. *C. violaceus* and *C. auronitens*) varied as much as ten-fold. Gunther & Assmann (2004) concluded that the amplitude of fluctuations in abundance was a feature of each species rather than a special attribute of their habitats.

In our investigations we found different dominant species and a rising species number each year. Some of the initially dominant species populations eventually stabilised around low values (*C. clatratus*, *C. cancellatus*). We suggest that fluctuations in abundance, and the year-to-year changes in the dominant species were caused mainly by the unstable wetland habitat, and only partly by the species biology, a situation opposite to that in ancient woodlands (Gunther & Assmann, 2004).

Acknowledgements

We wish to express our thanks to Dr. Győző Szél, Imre Retezár and Csaba Kutasi, who helped us with identification.

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Development of the ground-beetle parasitoids, *Brachinus explodens* and *B. crepitans* (Coleoptera: Carabidae): effect of temperature

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Abstract

Establishing the thermal requirements of insects is useful for understanding when they will be present during a season and predicting the period of their maximum abundance. Here the thermal requirements for the development of all stages and certain phases within larval instars of *Brachinus explodens* Duftschmid and *B. crepitans* (Linnaeus) were established at three constant temperatures between 17.7 – 27.4°C. The lower development threshold (LDT) for eggs is 9.4°C for *B. explodens* and 7.2°C for *B. crepitans*, respectively; the sums of effective temperatures (SET) are 154.4 and 180.7 day degrees, respectively. LDT for the total postembryonic development (except the searching phase) is 12.3°C in *B. explodens* and 10.5°C in *B. crepitans*, respectively, and SET are 209.2 and 289.5 day degrees, respectively. Thermal constants for the searching phase of the first instar larva were not calculated because its duration is independent of temperature.

Key words: *Amara*, egg, larva, pupa, thermal constants

Introduction

Precise synchronisation of egg hatching in a parasitoid with the presence of a suitable stage of its host is a prerequisite for the survival of parasitoids with actively searching larvae. There are several ways of synchronising species in time. In the absence of dormancy, this is achieved by the host and parasitoid having similar temperature requirements for development. A useful way of establishing such a relationship is to determine the thermal constants of development, lower development threshold (LDT) and sum of effective temperatures (SET). A linear relationship between development rate and temperature is assumed in order to calculate LDT and SET. Even when there is a positive departure from linearity in the rate/temperature relationship at low temperatures (Charnov & Gillooly, 2003), thermal constants are useful for predicting the duration of development (Jarošík *et al*., 2002). Thermal constants enable the prediction of the duration of development under ecologically relevant conditions. Although thermal constants for a large number of insects are known (reviewed by Honek & Kocourek, 1990; Honek, 1996; Kiritani, 1997) data for Carabidae are scarce (see Saska & Honek, 2003 for review).

In this study the thermal requirements for two ground-beetle ectoparasitoid species, *Brachinus explodens* Duftschmid and *B. crepitans* (Linnaeus) were established. Their ectoparasitoid mode of life was first predicted by Jeannel (1942) based on the fact that North-American species of *Brachinus* are parasitoids of pupae of water beetles (Wickham, 1893). However, the hosts of European species remained unknown until recently, when Saska & Honěk (2004) demonstrated that they develop on the pupae of the carabid genus *Amara* and described their life cycle. There are three larval instars, as in most carabid species, but the first and third instars have two distinct developmental phases, distinguished by behaviour (Saska & Honěk, 2004). Newly hatched first instar larvae immediately search for a host (the first phase). On finding a host pupa a larva crawls over it. When the pupa is young and undamaged the larva starts feeding (the second phase), mostly on the host's antennae or legs. Larvae usually moult to the second instar without moving away from the host pupa. The second instar larva begins to feed immediately. The mode of feeding is as in the first instar: the larva punctures the host cuticle at several places (mostly at intersegmental membranes) and sucks up the exuding haemolymph, and is attached to the host by its ventral surface. Larvae also moult to the third instar on its host. After moulting, the larva adopts a new feeding position: it now attaches itself to the host by its dorsal surface, with the head and thorax bent backwards through 180°. In contrast to the first and second instars, larvae of the third instar chew the tissues of the hosts using their mandibles. Only a few fragments of host cuticle remain on the dorsum of a larva when feeding is finished. Larvae that have consumed a pupa remain and pupate close by. Total larval development lasts 8-12 days at 25°C.

Material and methods

Rearing

The method of rearing *Amara* species is described in Saska & Honek (2003). Adult *Amara aenea* (DeGeer) and *A. similata* (Gyllenhal) were collected in pitfall traps at Praha – Ruzyně (50^{o} 06' N, 14^{o} 15' E) in early May 2002 and 2003. They were kept in pairs in plastic Petri dishes (10 cm in diameter, 2 cm high) filled to a depth of 1 cm with a layer of sieved garden soil at a temperature of 18±0.5°C and under a long day (17L:7D) photoperiod. The beetles were fed a mixed diet of pieces of *Tenebrio molitor* (Linnaeus) larvae and seeds of *Capsella bursa-pastoris* (Linnaeus) Medicus twice a week. Their larvae were kept individually in glass Petri dishes (6 cm in diameter, 1.5 cm high, with a 1 cm layer of sieved soil), in the same conditions as the adults. Twice a week the larvae were fed seeds of *C. bursa-pastoris*. Newly pupated individuals (0-48 h old) were used as hosts for the *Brachinus* larvae.