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Light Trapping as a Valuable Rapid Assessment Method for Ground Beetles (Carabidae) in a Bulgarian Wetland

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Abstract: The collection of insects with ultraviolet light is a common method in entomology but rarely used in ground beetle surveys. We collected ground beetles with light trap at the Srebarna Wetland Nature Reserve, Bulgaria, in the summer of 2010, and compared the results with existing species lists based on standardised pitfall trap surveys. A total of 116 species was recorded, with 11 new records for the Srebarna Reserve: *Agonum* (*Agonum*) *sexpunctatum* (Linnaeus, 1758), *Amara* (*Amathitis*) *parvicollis* Gebler, 1833, *Anthracus insignis* Reitter, 1884, *Badister* (*Badister*) *bullatus* (Schrank, 1798), *Badister* (*Baudia*) *dilatatus* (Chaudoir, 1837), *Bembidion* (*Philochthus*) *guttula* (Fabricius, 1792), *Bembidion* (*Pseudolimnaeum*) *doderoi* Ganglbauer, 1892, *Bembidion* (*Synechostictus*) *millerianum* Heyden, 1883, *Limnastis galilaeus* Brulerie, 1875, *Parophonus* (*Ophonomimus*) *hirsutulus* (Dejean, 1829), *Pterostichus* (*Bothriopterus*) *quadrifoveolatus* Letzner, 1852, and one new record for Bulgaria (*Anthracus insignis*). This study demonstrated that light trapping could be a valuable complementary survey method to standardised pitfall trapping for studying ground beetles, especially in wetland regions.

Key words: Carabidae, light trapping, collecting methods, Srebarna Reserve

Introduction

Ground beetles (Coleoptera, Carabidae) are a well-studied group of beetles commonly used as bioindicators for habitat type and quality. They have a cosmopolitan distribution and are one of the most taxonomically diverse beetle families. There are many species playing an import role in ecosystem functioning, and thus are commonly studied (e.g. Kotze *et al.* 2011). Additionally, many ground beetles are predators of weed seeds, insects, and slugs, including several pest species (Kromp 1999). Their agronomic significance together with the high diversity and well-defined ecological niches, explain the common use of ground beetles as indicator species in ecological analyses, habitat quality evaluation and studies of ecosystem succession (e.g. Desender *et al.* 1994, Luff 1996, Rainio & Niemelä 2003, Pearsall 2007) or anthropogenic impact (Avgin & Luff 2010). Carabids are excellent model organisms for ecological and conservation research.

There is a great variety of assessment methods, but most standardised ground beetle surveys apply exclusively pitfall trapping. Pitfall traps provide quantitative estimates of community assemblages, associated with specific microhabitats, and an insight in seasonal activity (Lövei & Sunderland 1996). Many studies deal with the efficiency of pitfall traps (see Luff 1975, Spence & Niemela 1994).

Ground beetles can be found in high numbers in wetlands, littoral regions and locations with fluctuating water table. The use of pitfall traps in a these habitats is not easy because they can float or inundate with changing water level, rendering them ineffective. In particular, if the aim of the study is to compose an overview of carabid species of a diverse region, pitfall trapping alone may fail to collect "trap-shy" species (Benest 1989), such as some myrmecophilous, endogeic and litter dwelling species, predominantly small and highly agile species dispersing through flight. Additional techniques are often applied to complete the species composition overview and evaluate the rarity of species (Lövei 2008, Timm *et al.* 2008, Makarov & Matalin 2009). In this way, efficient evaluation of the taxonomical diversity of carabids in wetlands requires using complementary methods.

Light trapping is a common method in entomologic research, but it is rarely used for ground beetle surveys despite the common presence of these beetles at light traps. Collection of carabids at light traps is mentioned in studies in Hungary (Kádár & Szél 1989, 1992), Japan (Yahiro & Yano 1997), Malaysia (Abdullah *et al.* 2008, Abdullah & Shamsulaman 2010) and Slovenia (Vrezec & Kapla 2007). Overall, little information is available on the value of light trapping as a survey method for carabid surveys and only limited data from light trap collections have been presented (Frost 1958, Vanhercke *et al.* 1981, Ishitani 1996).

We present an overview of ground beetles collected using light trapping in Srebarna Reserve, Bulgaria. The species recorded were compared with published checklists of Carabidae from Srebarna (Kodzhabashev & Penev 1998, 2006) that were based on pitfall trapping. The importance of light trapping for rapid biodiversity assessments in wetlands is discussed.

Material and Methods

Carabidae were collected during 11 evenings (5, 6, 8, 9, 11–17 June 2010) of light trapping in the summer of 2010 at Srebarna Wetland Nature Reserve in Bulgaria. Light trapping was started at the predicted time of sunset, around 9:30 p.m. and continued for three hours. A 125W mercury vapour lamp was mounted on the flat roof of a garage (44°05'37.66''N, 27°04'04.71''E) in a village at the edge of Srebarna Reserve, North-eastern Bulgaria. The roof of the garage was at about three meters above the ground. The bulb was strung at 1 meter above the ground, above a white sheet spread out on the ground. All ground beetles were collected by hand.

Specimens were identified following Kryzhanovskij (unpublished data), Arndt *et al.* (2011), Lindroth (1974), Hůrka (1996), Reitter (2006), Trautner, Geigenmüller (1987).

A VANTAGE VUE weather station was mounted at the collecting site to measure temperature (°C, low, high) every 15 min. Influence of air temperature on dispersing ground beetle abundance and richness was tested with a simple correlation. The temperature values collected every 15 minutes were averaged over the duration of the light trapping session and correlated with richness and abundance of carabid beetles. Correlation and graphs were performed in R (R Development Core Team 2014 version 3.0.3) using the package GGPLOT2 and MASS (cor and cor.test, version 7.3-44).

Results

A total of 1728 specimens of ground beetles were collected comprising 116 species (Table 1) of 38 genera and three subfamilies (Cicindelinae, Carabinae and Brachininae). They represented 15% of the species and 32% of the genera currently recorded in Bulgaria (Guéorguiev & Guéorguiev 1995) and 33% and 45%, respectively, of the species and the genera described for the region of South Dobrudzha (Kodzhabashev & Penev 2006). They were over the half (54%) of the 238 ground beetle species recorded from the Srebarna Reserve (Kodzhabashev & Penev 1998, 2006).

Eleven carabid species (*Agonum sexpunctatum*, *Amara parvicollis*, *Anthracus insignis, Badister bullatus*, *Badister dilatatus*, *Bembidion doderoi*, *Bembidion guttula*, *Bembidion millerianum*, *Limnastis galilaeus*, *Parophonus hirsutulus* and *Pterostichus quadrifoveolatus*) were new for Srebarna Nature Reserve, including one new record for Bulgaria (*Anthracus insignis*).

Weather conditions recorded during the light trapping events were correlated with the number of species and abundance of ground beetles observed. The abundance and the richness of ground beetles were positively associated with the higher temperatures ($R = 0.83$, $t = 4.43$, $df = 9$, $p\text{-value} = 0.001$; Fig. 1). We found that it was not the highest temperature during the night that was related to a high dispersal of ground beetles, but the highest minimum temperature.

Discussion

This study shows how light trapping can be a valuable complementary method and a contribution to the biodiversity surveys of the carabid fauna. With ten species added to the published list of Srebarna nature

Table 1. Species list of Carabidae collected at the light trap in Srebarna Nature Reserve, Bulgaria. Species marked with "*" represent new observations for Srebarna Nature Reserve, "**" represent a new observation for Bulgaria

	Genus	Species	Author			Genus	Species	Author	
1	*Acupalpus*	*dubius*	Schilsky, 1888		59	*Demetrias*	*atricapillus*	(Linneaus, 1758)	
2	*Acupalpus*	*elegans*	(Dejean, 1829)		60	*Demetrias*	*imperialis*	(Gemar 1824)	
3	*Acupalpus*	*exiguus*	(Dejean, 1829)		61	*Dyschirius*	*cylindricus*	Dejean, 1825	
4	*Acupalpus*	*luteatus*	(Duftschmid, 1812)		62	*Dyschirius*	*strumosus*	(Erichson, 1837)	
5	*Acupalpus*	*maculatus*	Schaum, 1860		63	Dyschirius	sp.		
6	*Acupalpus*	*meridianus*	(Linneaus, 1767)		64	*Elaphropus*	*haemorrhoidalis*	(Ponza, 1850)	
7	*Acupalpus*	*paludicola*	Reitter, 1900		65	*Harpalus*	*affinis*	(Schrank, 1781)	
8	*Acupalpus*	*suturalis*	(Dejean, 1829)		66	*Harpalus*	*attenuatus*	Stephens, 1828	
9	*Agonum*	*marginatum*	(Linnaeus, 1758)		67	*Harpalus*	*froelichi*	Sturm, 1818	
10	*Agonum*	*sexpunctatum*	(Linnaeus, 1758)	*	68	*Harpalus*	*smaragdinus*	(Duftschmid, 1812)	
11	*Agonum*	*thoreyi*	(Dejean, 1828)		69	*Harpalus*	*tenebrosus*	Dejean, 1829	
12	*Agonum*	*vuduum*	(Panzer, 1797)		70	*Harpalus*	*zabroides*	Dejean, 1829	
13	*Agonum*	*viridicupreum*	(Goeze, 1777)		71	*Lebia*	*cyanocephala*	(Linneaus, 1758)	
14	*Amara*	*apricaria*	(Paykull, 1790)		72	*Lebia*	*humeralis*	Dejean, 1825	
15	*Amara*	*consularis*	(Duftschmid, 1812)		73	*Lebia*	*scapularis*	(Fourcroy, 1785)	
16	*Amara*	*parvicollis*	Gebler, 1833	*	74	*Limnastis*	*galilaeus*	Brulerie, 1875	*
17	*Amblystomus*	*metallescens*	(Dejean, 1829)		75	*Microlestes*	*corticalis*	(Dufour, 1820)	
18	*Anisodactylus*	*signatus*	(Panzer, 1797)		76	*Microlestes*	*plagiatus*	(Dufour, 1812)	
19	*Anisodactylus*	*poeciloides*	(Stephens, 1828)		77	*Ophonus*	*azureus*	(Fabricius, 1775)	
20	*Anthracus*	*consputus*	(Duftschmid, 1812)		78	*Ophonus*	*cordatus*	(Duftschmid, 1812)	
21	*Anthracus*	*insignis*	(Schrank, 1798)	**	79	*Ophonus*	*cordicollis*	(Dejean, 1829)	
22	*Anthracus*	*longicornis*	(Schaum, 1857)		80	*Ophonus*	*gabrieleae*	Wrase, 1987	
23	*Badister*	*bullatus*	(Schrank, 1798)	*	81	*Ophonus*	*melleti*	(Heer, 1837)	
24	*Badister*	*collaris*	Motschulsky, 1844		82	*Ophonus*	*nitidulus*	Stephens, 1828	
25	*Badister*	*dilatatus*	Chaudoir, 1837	*	83	*Ophonus*	*puncticeps*	(Stephens, 1828)	
26	*Badister*	*lacertosus*	Sturm, 1815		84	*Ophonus*	*puncticollis*	(Paykull, 1798)	
27	*Badister*	*unipustulatus*	Bonelli, 1813		85	*Ophonus*	*rufibarbis*	(Fabricius, 1792)	
28	*Bembidion*	*semipunctatum*	(Donovan, 1806)		86	*Ophonus*	*rupicola*	(Sturm, 1818)	
29	*Bembidion*	*assimile*	Gyllenhal, 1810		87	*Ophonus*	*subsinuatus*	(Rey, 1886)	
30	*Bembidion*	*castaneipenne*	Jacquelin-Duval, 1851		88	*Ophonus*	*sabulicola*	(Panzer, 1796)	
31	*Bembidion*	*cordicole*	Duval, 1851		89	*Panageus*	*cruxmajor*	(Linnaeus, 1758)	
32	*Bembidion*	*dalmatinum*	Dejean, 1831		90	*Parophonus*	*hirsutulus*	(Dejean, 1829)	*
33	*Bembidion*	*dentellum*	(Thunberg, 1787)		91	*Parophonus*	*maulicornis*	(Duftschmid, 1812)	
34	*Bembidion*	*doderoi*	Ganglbauer, 1892	*	92	*Parophonus*	*planicollis*	(Dejean, 1829)	
35	*Bembidion*	*guttula*	(Fabricius, 1792)	*	93	*Poecilus*	*cupreus*	(Linnaeus, 1758)	
36	*Bembidion*	*inoptatum*	Schaum, 1857		94	*Perigona*	*nigriceps*	(Dejean, 1831)	
37	*Bembidion*	*latiplaga*	Chaudoir, 1850		95	*Polyderis*	*cardioderus*	(Chaudoir, 1846)	
38	*Bembidion*	*millerianum*	Heyden, 1883	*	96	*Polystichus*	*connexus*	(Fourcroy, 1785)	
39	*Bembidion*	*octomaculatum*	(Goeze, 1777)		97	*Pseudophonus*	*rufipes*	(Degeer, 1774)	
40	*Bembidion*	*praeustum*	Dejean, 1831		98	*Pterostichus*	*anthracinus*	(Illiger, 1798)	
41	*Bembidion*	*properans*	(Stephens, 1828)		99	*Pterostichus*	*cursor*	(Dejean, 1828)	
42	*Bembidion*	*quadripustulatum*	(Serville, 1821)		100	*Pterostichus*	*elongatus*	(Duftschmid, 1812)	
43	*Bembidion*	*striatum*	(Fabricius, 1792)		101	*Pterostichus*	*longicollis*	(Duftschmid, 1812)	
44	*Bembidion*	*varium*	(Olivier, 1795)		102	*Pterostichus*	*nigrita*	(Paykull, 1790)	
45	*Brachinus*	*crepitans*	(Linnaeus, 1758)		103	*Pterostichus*	*strenuus*	(Panzer, 1797)	
46	*Brachinus*	*plagiatus*	Reiche, 1868		104	*Pterostichus*	*quadrifoveolatus*	Letzner, 1852	*
47	*Brachinus*	*psophia*	Audinet-Serville, 1821		105	*Pterostichus*	*vernalis*	(Panzer, 1796)	

Table 1. Continued

	Genus	Species	Author			Genus	Species	Author	
48	*Calathus*	*ambiguus*	(Paykull, 1790)		106	*Scarites*	*terricola*	Bonelli, 1813	
49	*Calathus*	*cinctus*	(Motschulsky, 1850)		107	*Stenopholus*	*discophorus*	(Fischer-Waldheim, 1823)	
50	*Calathus*	*fuscipes*	(Goeze, 1777)		108	*Stenopholus*	*mixtus*	(Herbst, 1784)	
51	*Calathus*	*melanocephalus*	(Linneaus, 1758)		109	*Stenopholus*	*skrimshiranus*	Stephens, 1828	
52	*Calosoma*	*auropunctatum*	(Herbst, 1784)		**110**	*Stenopholus*	*teutonus*	(Schrank, 1781)	
53	*Carabus*	*coriaceus*	Linneaus, 1758		**111**	*Syntomus*	*obscuroguttatus*	(Duftschmid, 1812)	
54	*Cicindela*	*chiloleuca*	Fisher-Waldheim, 1820		**112**	*Synuchus*	*vivalis*	(Illiger, 1798)	
55	*Cicindela*	*germanica*	Linneaus, 1758		**113**	*Tachys*	*bistriatus*	(Duftschmid, 1812)	
56	*Clivina*	*fossor*	(Linnaeus, 1758)		**114**	*Tachys*	*scutellaris*	(Stephens, 1829)	
57	*Clivina*	*laevifrons*	Chaudoir, 1842		115	*Trechus*	*quadristriatus*	(Schrank, 1781)	
58	*Curtonotus*	*aulicus*	(Panzer, 1797)		116	*Zabrus*	*tenebrioides*	(Goeze, 1777)	

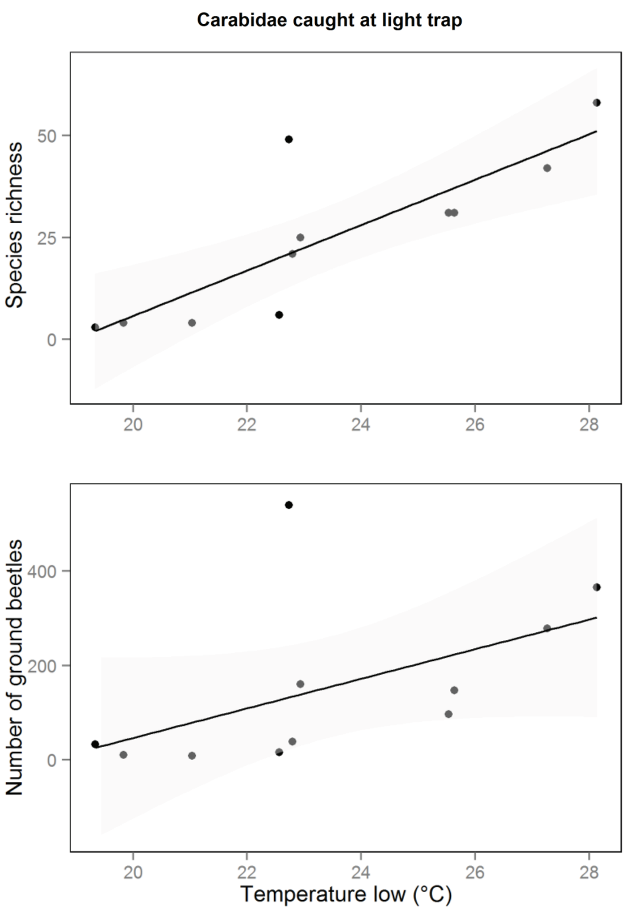

Fig. 1. Correlation of the species richness and number of ground beetles with the lowest temperature recorded during light trapping evenings in Srebarna Nature Reserve

reserve and one new species for Bulgaria, in as little as eleven trapping nights, light trapping proved to be an effective addition to other survey methods, especially pitfall traps.

The overall contribution of light trapping to ground beetle surveys varies. Ishitani (1996) collected 14% of the captured carabids by a light trap; Yahiro & Yano (1997) established 26% (77 species) of the known carabid fauna of the region they studied and Abdullah & Shamsulaman (2010) obtained 84%.

The variation in contribution is obviously related with the survey time effort and also with the habitat type. Light trapping is particularly useful to collect ground beetles in regions where it is difficult to set pitfall traps due to a high risk of flooding or moist terrain, such as wetlands, swamps and marches. In some situations light trapping can even be more effective than Malaise trap, pitfall or net sweeping (Abdullah *et al*. 2008).

One of the major advantages of light trapping is the easy logistics, working from a single or a small number of places, and the short time needed to collect a large number of observations. In this study data were collected on eleven light trapping nights only. This contrasts strongly with pitfall trapping surveys often including large numbers operated over a substantial time. The ease of use and short time needed to gain insight in ground beetle communities of multiple habitats from a whole region is a valuable factor to be considered in surveys, especially initial surveys of a region such as rapid biodiversity assessments.

The advantage to easily collect ground beetles from several habitats in the same time is also a drawback. Carabid beetles collected at the light traps are dispersing animals, so it is not possible to know where exactly they come from, and whether they actually have established communities in the region. At least their presence indicates the possibility for them to occur there.

All elements affecting dispersal by flight will play an important role in using light trapping as a survey method. Flight of ground beetles is greatly influenced by temperature, rain and wind (Thiele 1977, van Huizen 1979, Lövei & Sunderland 1996). We observed a positive relationship between the number of ground beetles (both abundance and richness) and the minimal temperature during the night.

Seasonal timing of the survey determining presence and development of flight muscles in carabid beetles may affect observations and limit the possibilities for community ecological research (Desender 2000). Larger carabids without flight muscles, i.e., most of the *Carabus* species will be missed with this method. On the other hand, terrestrial traps are good for large and more mobile species (Luff 1975, Thiele 1977), but most of the small beetles (Notiophilini, Clivinini, Dyschiriini, Apotomini, Trechini, Tachyni, Bembidiini, Lebiini) are often missed. These small beetles can easily be collected by manual collection but this method in turn is less efficient at collecting nocturnal or more seclusive species (Kodzhabashev, unpublished data).

The light trap set up in this study was at the edge of Srebarna Nature Reserve. It would therefore be possible that the newly recorded species are more associated with the neighbouring village environment than with the wetland. For all newly recorded species except for *Parophonus hirsutulus*, which is mesoxerophilous and typically associated with mesic or dry meadows, life history indicates a clear association with wetlands. Mesohygrophylous species are: *Agonum sexpunctatum* (inhabitant of humid open habitats – swamps, humid meadows), *Badister bullatus* (canopy banks, swamp forests), *Badister dilatatus* (humid open habitats), *Pterostichus quadrifoveolatus* (mesophytic forests, swamps, banks), *Amara parvicollis* (halobiont). Hygrophilous species are *Bembidion doderoi* and *Bembidion millerianum* (inhabitants of river and lake banks), *Bembidion guttula* (banks, swamps, swamp forests), *Limnastis galilaeusis* (found mostly in swamps). Only the ecology of *Anthracus insignis* is still not studied.

This study shows how light trapping is most valuable to detect highly vagile species inhabiting littoral regions and peatlands, such as *Agonum sexpunctatum*. Additionally, species with highly fragmented distributions (e.g. *Pterosticus quadrifoveolatus*) or edging at their distribution range (e.g. *Amara parvicollis*) are more easily detected with light trapping.

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