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## **Ecological and evolution strategies of necrophagous beetles (Coleoptera)**

Thesis extended summary

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## 1.1 General introduction

How beetles cope with the environment and competition provoked scientists for generations. Ultimately, studies on ecological and evolutionary strategies become a very broad topic with various impacts on our lives and it is important to see that general understanding of direct and indirect interactions in nature is highly important for applied and theoretical fields of science (Begon *et al.*, 2006; Galante & Angeles, 2008).

Beetles are very diverse order with about 300,000 – 400,000 described species (Stork, 2009), so in this thesis I narrowed my focus down only to some selected species of necrophagous beetles of Central Europe. I would like to provide a new insight at how the ecological and evolutionary strategies could be used for answering pressing issues in forensic entomology and nature protection.

My selected species came from two particular groups of beetles, family Silphidae (carrion beetles) and subfamily Cholevinae of the family Leiodidae (small carrion beetles). More specifically, I targeted necrophagous, Central European species of family Silphidae and one particular species of subfamily Cholevinae (Leiodidae), *Sciodrepoides watsoni* (Spence, 1813). All those taxa are connected by the fact that they develop and feed on carrions, which is also very interesting ecological and evolutionary strategy itself (Szymczakowski, 1961; Šustek, 1981).

Only one species in the group I selected, *Necrodes littoralis* (Linnaeus, 1758), was earlier recognized as potential bio-indicator species for forensic entomology (Matuszewski, 2011; Fratzak & Matuszewski, 2014). This disinterest of forensic entomology in beetles is global phenomenon (Midgley *et al.*, 2010). Beetles were for a long time perceived as not as good as flies (Diptera), because they usually arrived latter at the scene, but this image is crumbling.

The first crack in this picture was made when it was proven that African carrion beetle, *Thanatophilus micans* (Fabricius, 1794), is able to locate and start to breed on corpse in the first 24 hours (Midgley & Villet, 2009a). However, beetles in the Middle Europe are not that fast, probably due to lower ambient temperatures (H. Šuláková 2014, pers. comm.), although there are other benefits for forensic entomology they could offer.

First of all, beetles tend to have longer development than flies (Midgley & Villet, 2009a; Richards *et al.*, 2009; Velásquez & Vilorio, 2009; Ridgeway *et al.*, 2014); therefore they stay on the body for longer period, and we can use them as evidence not only in early stages of decomposition. Second of all, they also do not need to form a maggot ball and individual rearing is less difficult (Midgley *et al.*, 2010), so they are easier to handle in laboratory conditions. But we think that the biggest advantage is possibility to cross validate the estimates between species and groups like flies and mites. This is important mainly in times when one of these groups or species could have been affected by external factors (restricted access to body, too high or low temperature, etc.) and give biased estimation (H. Šuláková, 2014 pers. comm).

Only few beetle species were studied specifically for further use in forensic entomology, so in this thesis I would like to look closely on developmental biology of *Sciodrepoides watsoni* and find the thermal summation model for this species, which will enable to estimate the post mortem interval. Further, I would like to find a new character for instar determination and propose a new methodology for estimation of size-based larval characters (section B).

Some species of burying beetles that we studied could not only be useful bio-indicators. They are also listed in the Red List of endangered species (Růžička, 2005), but their protection is lacking behind of other groups and nothing happened except the statement that they are indeed endangered.

In comparison, American burying beetle (*Nicrophorus americanus* (Oliver, 1790)) (Silphidae) was recognized as federally endangered in the USA in 1989. In 1991, just two years after, the recovery plan was prepared and this plan is still running

(Jurzenski *et al.*, 2014). What is maybe even more important than the recovery plan is a fact, that this unfortunate fait put this beetle in a spot light of a scientific world. On the Web of Science you can find 38 articles for a topic query: "Nicrophorus americanus", but nothing on "Nicrophorus antennatus" or "Nicrophorus vestigator" (accessed 27.8.2015).

Because we are currently few decades behind on this task, it is necessary to address very basic questions, which will allow us to proceed further. One of those, which I will cover in this thesis, is current geographical distribution of necrophagous carrion beetles (section **C**) and what are the ecological requirements of the European carrion beetles (section **A**).

## 1.2 Aim of the Thesis

Aim of the thesis is to study the ecological and evolutionary strategies of necrophagous beetles from family Silphidae and subfamily Cholevinae. Thesis is dealing with their habitat preferences, geographical distribution and effect of temperature on the rate of their development. Possible applications in forensic entomology and nature protection are discussed in each article and the chapter General conclusions.

### **Specific goals:**

**a) Is the type of soil an important factor determining the local abundance of carrion beetles (Coleoptera: Silphidae)?**

The main goal of this article is to determine the habitat preferences of European open-landscape carrion beetles, especially those on the local Red list (*Nicrophorus antennatus*, *N. germanicus* and *N. sepultor*), and to discuss the effect of intra- and interspecific competition on their abundances.

**b) Thermal summation model and instar determination of all developmental stages of necrophagous beetle, *Sciodrepoides watsoni* (Spence) (Coleoptera: Leiodidae: Cholevinae)**

To allow future utilization of *S. watsoni* in forensic entomology, the article will offer the parameter estimates of the thermal summation model. Also, a new size-based character for accurate larval instar determination will be provided together with new methodology of establishing such characters.

**c) Distribution of open landscape carrion beetles (Coleoptera: Silphidae) in selected lowlands of the Czech Republic**

This article will publish large dataset with key information about spatial and temporal distribution and abundance of open-landscape carrion beetles in the Czech Republic. Information about population trends and ecology of those beetles will be also included.



**A** Is the type of soil an important factor determining the local abundance of carrion beetles (Coleoptera: Silphidae)?

**Abstract.** Carrion beetles (Coleoptera: Silphidae) provide a valuable ecosystem service by promoting nutrient cycling and controlling pests like noxious flies (Diptera: Calliphoridae and Sarcophagidae). Our main goal was to examine the relationship between the occurrence of carrion beetles and soil type. We used pitfall traps to collect 43,856 specimens of 15 species of carrion beetles in the Czech Republic during 2009. We found that the abundance of seven of the carrion beetles – *Nicrophorus antennatus* (Reitter), *N. germanicus* (Linnaeus), *N. humator* (Gleditsch), *N. interruptus* (Stephens), *N. sepultor* (Charpentier), *Silpha obscura obscura* (Herbst) and *T. sinuatus* (Fabricius) – was significantly higher either in areas with chernozem or fluvisol soils. These findings support our hypothesis that soil type could be an important factor determining the occurrence of necrophagous European carrion beetles. Our findings could be helpful when selecting important nature conservation sites (particularly inasmuch as *N. antennatus*, *N. germanicus* and *N. sepultor* are listed as endangered species on the Czech Red List of Invertebrates) as in this respect localities where there are chernozem soils are potentially valuable.

**Citation:** *Is the type of soil an important factor determining the local abundance of carrion beetles (Coleoptera: Silphidae)? European Journal of Entomology, 112: accepted.*

**Authorship:** Pavel JAKUBEC & Jan RŮŽIČKA

**Key words:** Ecology, Nicrophorinae, Silphinae, burying beetles, soil type, chernozems, fluvisols, diversity

## B Thermal summation model and instar determination of all developmental stages of *Sciodrepoides watsoni* (Coleoptera: Cholevinae)

**Abstract.** Necrophagous beetles are underrepresented in forensic entomology studies despite their undeniable utility for the field. In our article we would like to address this problem and provide information regarding developmental biology and instar determination of *Sciodrepoides watsoni* (Spence, 1813), which is very common species occurring across the Holarctic region. We collected adult specimens from several localities across the Czech Republic to establish a laboratory culture with constant temperature regime and long day photoperiod. These adults were divided between five treatments that differed only in temperature (15, 18, 21, 25 and 28°C). Emerging larvae were separated and their individual development was photographically documented every day until adulthood. Parameters of thermal summation models and their standard errors were calculated for each developmental stage. We also propose head width as a new character for larval instar determination together with a new methodology for future studies of size based characters.

*Citation:* Thermal summation model and instar determination of all developmental stages of *Sciodrepoides watsoni* (Coleoptera: Cholevinae). *PeerJ*, submitted.

*Authorship:* Pavel JAKUBEC

*Key words:* Coleoptera, Leiodidae, Cholevinae, development, thermal summation model, forensic entomology, instar determination, Holarctic region

## C Distribution of open landscape carrion beetles (Coleoptera: Silphidae) in selected lowlands of the Czech Republic

**Abstract.** Beetles of the family Silphidae are an important but imperfectly understood part of Palaearctic ecosystems. Our team studied the ecology of open-landscape silphids around Louny, Kutná Hora, Zábřeh and Židlochovice in 2008 and 2009. We used 420 baited pitfall traps and, at 84 localities, we collected 71 234 specimens of 15 silphid species. Distribution data for all species are provided here. We found three endangered carrion beetle species listed on the Czech Red List of Invertebrates. Two are vulnerable thermophilic species of open landscapes, *Nicrophorus antennatus* (Reitter, 1884) (collected around Louny and Židlochovice) and *Nicrophorus germanicus* (Linnaeus, 1758) (Louny, Zábřeh and Židlochovice). The third is the near threatened species, *Nicrophorus sepultor* Charpentier, 1825 (collected around Louny, Kutná Hora, Zábřeh and Židlochovice), which also prefers open landscapes

**Citation:** *Distribution of open landscape carrion beetles (Coleoptera: Silphidae) in selected lowlands of the Czech Republic. Klapalekiana, 48: 169–189.*

**Authorship:** Pavel JAKUBEC & Jan RŮŽIČKA

**Key words:** Coleoptera, Silphidae, distribution, open habitats, Bohemia, Moravia, Czech Republic, Palaearctic region

## 5.1 Principal conclusions of the thesis

European necrophagous species are overlooked, but they deserve much more attention, because they play major role in nutrient cycling, and information about their ecology and evolution can have great impact on applied fields of science like forensic entomology and nature protection (Lomolino *et al.*, 1995; Lomolino & Creighton, 1996; Ratcliffe, 1996; Begon *et al.*, 2006; Looney *et al.*, 2009; Crawford & Hoagland, 2010; Midgley *et al.*, 2010; Jurzenski *et al.*, 2014; Houston *et al.*, 2015).

During the field work on article **A** and **C**, we captured and identified 15 species of Central European carrion beetles. Three of which are currently considered as rare and are on the Czech Red List of Invertebrates as Endangered (*Nicrophorus antennatus* and *N. germanicus*) or Nearly Endangered (*N. sepultor*) (Růžička, 2005). The last ecological studies of these species in Europe were done almost 50 years ago when they were probably much more common (Novák, 1966; Petruška, 1968).

The most frequently observed species was *Thanatophilus sinuatus*, whose dominance was overshadowed by *N. vespillo* and *T. rugosus*, but only in autumn. All these species seem to be very common in open landscape habitats and our findings confirm the earlier observations of Novák, (1962, 1965, 1966) and Petruška (1964). Both species of genus *Thanatophilus* are therefore fairly common in the Czech Republic and they visit regularly the carcasses of large animals.

*T. sinuatus* and *T. rugosus* are considered to be co-occurring species without spatially or temporally differentiated niches (Novák, 1966). The higher abundance of *T. rugosus* in autumn samples could indicate a temporal niche differentiation.

All these traits could be used in forensic entomology, but larval identification, instar determination and thermal summation models are not established for them yet. In contrast, successful case report of estimation of PMI based on closely related

African species of genus *Thanatophilus* (*T. mutilatus* and *T. micans*) was published last year (Ridgeway *et al.*, 2014). These species were only recently studied and proposed thermal summation models made them available for use in forensic entomology (Midgley & Villet, 2009a; Ridgeway *et al.*, 2014). *T. sinuatus* and *T. rugosus* are showing similar qualities and options for future research looks very promising.

We were able to show in the article **A** that the abundance of seven of the carrion beetles (*N. antennatus*, *N. germanicus*, *N. humator*, *N. interruptus*, *N. sepultor*, *Silpha obscura obscura* and *T. sinuatus*) differed significantly in areas with chernozem and fluvisol soils, and therefore soil type is an important factor in determining the occurrence of these carrion beetles. Our findings are supported by the results of the CCA analysis and Wilcoxon rank-sum tests (article **A**).

CCA analysis in article **A** also revealed that the factors that are significantly associated with the species composition are both soil types (chernozem and fluvisol) and also three crops (*Zea mays*, *Hordeum vulgare* and *Heliantus annus*). The association between the abundance of the carrion beetles and these crops is very interesting and we did not expect such a relationship. We think that it could be due to the microclimatic conditions in fields with these crops. Based on our experience, *Z. mays* provides much more humid and cooler environment than *H. vulgare* and *H. annus*. Further study is needed to reveal causality.

Association between abundance of Nicrophorinae and soil characteristics was assumed by many authors (Pukowski, 1933; Paulian, 1946; Theodorides & Heerdt, 1952; Novák, 1961, 1962). Heretofore, this phenomenon was empirically proven only for North American species (Muths, 1991; Bishop *et al.*, 2002; Looney *et al.*, 2009), where the association of beetles of the subfamily Silphinae with a particular soil was previously reported by Bishop *et al.* (2002).

However, burying beetles are good fliers and can cover long distances, they mostly choose to stay close to their original locations (e.g., *Nicrophorus americanus*), which is a relatively large and robust beetle, is capable of flying as far as 7.41 km in a single night, but more typically travels less than 1.6 km/night) (Jurzenski *et al.*,

2011). Limited mobility coupled with adaptation to local conditions could cause the observed spatial structure rather than individual habitat choice (preferential colonization). This is also in line with general local adaptation hypotheses (Alstad, 1998). It is also possible that the abundances of those species are different throughout their distribution area, as pointed out by Scott (1998).

Among other species, which were more abundant on cernozem, we also identified three endangered species (*N. antennatus*, *N. germanicus* and *N. sepultor*). Our finding can help in actions towards the conservation of these species, which is currently not a topical issue in the Czech Republic and Europe generally, but these beetles are charismatic and could become a widely accepted flagship species for stakeholders and policymakers, as indicated by the public interest in and the vast number of studies on the American burying beetle (*N. americanus*) (e.g., Anderson, 1982b; Lomolino *et al.*, 1995, 1999; Lomolino & Creighton, 1996; Bedick *et al.*, 1999, 2004; Szalanski *et al.*, 2000; Sikes & Raithel, 2002; Bishop *et al.*, 2002; Walker & Hoback, 2007; Crawford & Hoagland, 2010; Jurzenski *et al.*, 2011, 2014; Black, 2012; Hall *et al.*, 2015; Houston *et al.*, 2015).

The article **B** provides parameter estimates of thermal summation model of *Sciodrepoides watsoni* together with new character for instar determination. *S. watsoni* is very common necrophagous beetle (Růžička, 1994, 2000; GBIF, 2015), which occurs across Holarctic region (Peck & Cook, 2002; Perreau, 2004). This species was offered as possibly useful for forensic entomology by Schilthuizen *et al.* (2011). This view was recently challenged by Kilian & Mađra (2015), but unfortunately they did not show any evidence to support their claim that this species is irrelevant for forensic entomology.

The mean development time decreased with increasing temperature (article **B**, Fig. 6), except for L2 and L3 instars in the 25°C treatment. This might indicate that between 21°C and 25°C should be an optimal temperature for the development of these two stages. Optimal temperatures for lower stages are probably even higher. This agrees with findings of Engler (1981), who reported *S. watsoni* as warm season species in contrast to some species of *Choleva* and *Catops* that prefers to breed

during the winter season and their optimal temperatures for development were below 16°C.

During the breeding we observed very high levels of mortality in later stages of development (third larval instar and pupae). It is more likely that separation from other larvae and adults was the reason for this phenomenon. Peck (1975) mentioned that *Ptomaphagus hirtus* (Tellkamp, 1844) (Leiodidae: Cholevinae: Ptomaphagini) needed soil from the cave of its origin to successfully complete the development. Soil bacteria probably played some part in this process, because specimens did not develop on autoclaved soil (Peck, 1975). It is possible that adults feeding along with larvae could provide such bacteria in our case. Another explanation could be that feeding of multiple individuals is much more effective or improves the quality of the food source.

Methodology of measuring the size of the instars of *S. watsoni* was based on continual observation of individuals from egg until pupation. This approach differs from other studies with similar goals (see Velásquez & Vilorio, 2010; Fratzak & Matuszewski, 2014), where authors tried to estimate the stage of development based on the size of selected characters without prior knowledge of the true stage of the specimen. This approach is from my point of view a little bit problematic, because those measured characters are correlated, therefore bigger larvae could be misidentified as higher instar than they really are. This bias would probably not affect the obtained mean values, but it would give distorted picture about variation.

I found an overlap in the head width between of all instars. This is especially true for the first and second instar, but measuring more, probably correlated, characters would not solve the problem. The first instar larva has only primary setae on its body, but after molt to the second instar a secondary set of setae will emerge and they are present unchanged also in the third instar. Thus chaetotaxy can be used for the discrimination of the first and second instar larvae. For additional differential diagnosis of those morphological characters, see Kilian & Mađra (2015).

The article **B** established developmental parameters for *Sciodrepoides watsoni* together with the new and reliable character for instar determination. This species is so far the smallest necrophagous beetle with known thermal summation model. The developmental characteristics provided in this study will help to estimate the PMI<sub>min</sub> in cases where it was not possible before. The instar determination is the integral part of the PMI<sub>min</sub> estimation, because without accurate determination, we could not reach the right conclusion. We strongly encourage other authors to adopt our methodology for establishing the size-based instar characteristics, because it provides correct picture about its variability.

Altogether, these three articles aim to contribute to growth of our knowledge about ecological and evolutionary strategies of necrophagous beetles and I hope that I bring some of them to attention of professional public.



## 5.2 Souhrn (Summary in Czech)

Nekrofágní brouci (Coleoptera) jsou zajímavou a velmi diversifikovanou ekologickou skupinou, s velkým dopadem na přirozený cyklus živin. Jejich hlavní složkou potravy, a zároveň místem rozmnožování, jsou mršiny obratlovců, člověka nevyjímaje. Tento vztah je často různě využíván ve forenzní entomologii, ale jeho potenciál není zdaleka využit, protože znalost biologie a ekologie těchto brouků je velmi kusá.

V této disertační práci chci prozkoumat geografické rozšíření, ekologické nároky a vývojovou biologii několika středoevropských druhů nekrofágních brouků, tedy výsledek jejich ekologických a evolučních strategií. Za tímto účelem jsem si položil tři široce formulované otázky. Které faktory jsou určující pro lokální abundanci mrchožroutovitých brouků (Coleoptera: Silphidae)? Jaké je současné geografické rozšíření mrchožroutů otevřené krajiny v České republice? Jak ovlivňuje teplota vývoj druhu *Sciodrepoides watsoni* (Spence, 1813)?

Zjistili jsme, že půdní typ má statisticky významný vliv na početnost mrchožroutů. Šest druhů preferovalo černoze – *Nicrophorus antennatus* (Reitter), *N. germanicus* (Linnaeus), *N. interruptus* (Stephens), *N. sepultor* (Charpentier), *Silpha obscura obscura* (Herbst), *T. sinuatus* (Fabricius), a jeden fluvizemě – *N. humator* (Gleditsch). Tyto závěry podporují naši hypotézu, že půdní typ by mohl být jedním z určujících faktorů pro výskyt nekrofágních evropských mrchožroutů.

Za účelem zjištění geografického rozšíření mrchožroutů jsme položili 420 vnazených padacích pastí na 84 lokalitách a takto jsme získali 71 234 kusů 15 druhů těchto brouků. Mezi nimi byly i tři druhy hrobaříků, kteří jsou na Červeném seznamu bezobratlých. Dva z nich jsou zranitelné, teplomilné druhy otevřené krajiny *Nicrophorus antennatus* (Reitter, 1884) (nalezen okolo Loun a Židlochovic) a *Nicrophorus germanicus* (Linnaeus, 1758) (Louny, Zábřeh a Židlochovice). Třetí je téměř ohrožený druh *Nicrophorus sepultor* Charpentier, 1825 (nalezen okolo Loun, Kutné Hory, Zábřeha a Židlochovic), který taktéž preferuje otevřenou krajinu.

Studium vývoje běžného holarktického druhu *Sciodrepoides watsoni* probíhalo v laboratoři za několika konstantních teplot (15, 18, 21, 25 a 28°C). Na základě pozorování délky vývoje jsme vypočítaly parametry termálně sumačního modelu s jejich standardní chybou pro každé stádium vývoje (vajíčko, tři larvální instary a kukla). Zároveň jsme zjistili, že šířka hlavové kapsule je u tohoto druhu dobrým nástrojem pro určení stupně larválního instaru. Popisná statistika tohoto znaku a nová metodika jak studovat velikostně definované znaky je přiložena k práci.

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## 7.1 Curriculum vitae

### ING. PAVEL JAKUBEC

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#### Personal information:

Date of birth: 28th October, 1982

Place of birth: Kutná Hora

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#### Education:

- |                        |   |
|------------------------|---|
| <b>2011 – till now</b> | <b>Ph.D.;</b> Faculty of Environmental Sciences, Czech University of Life Sciences Prague, PhD study program: <b>Ecology.</b>                           |
| <b>2013 – 2014</b>     | <b>MSc.;</b> Wageningen University (Netherlands), Msc study program: <b>Plant Sciences</b> , specializace: Plant Pathology and Entomology (incomplete). |
| <b>2009 – 2011</b>     | <b>Ing.;</b> Faculty of Environmental Sciences, Czech University of Life Sciences Prague, MSc. study program: <b>Nature conservation.</b>               |

- 2006 – 2009** Bc.; Faculty of Environmental Sciences, Czech University of Life Sciences Prague, Bachelor study program: **Applied ecology**.
- 2001 – 2004** SZeŠ Čáslav, study program: **Tourism**.

**Employment:**

- 09/2015 – till now** Researcher; Department of Ecology, Faculty of Environmental Sciences, Czech University of Life Sciences Prague

**Language knowledge:**

**Czech** (native), **English** (B2), **German** (A2)

**Graduate students:**

- 2015** Bc. Petra Hlaváčová – Rychlost vývoje u hmyzu
- 2015** Bc. Tereza Račáková – Rychlost vývoje u vybraných zástupců podčeledi Cholevinae

**Participation on projects:**

- 2015 BV MVČR VI20152018027** Využití nekrofágických brouků (Coleoptera) ve forenzní entomologii: determinace a vývojové modely.
- 2015 NF EHP-CZ02-OV-1-027-2015** Zmírnění důsledků fragmentace biotopů v různých typech krajiny České republiky.
- 2015 IGA 20154221** Larvální morfologie práchnivců rodu Choleva (Coleoptera: Leiodidae)

<b>2014 IGA</b> 20144228	Vývojové a růstové modely preimaginálních stádií <i>Thanatophilus sinuatus</i> (Coleoptera: Silphidae).
<b>2013 IGA</b> 20134269	Variabilita rychlosti vývoje u brouků z podčeledi Cholevinae (Coleoptera: Leiodidae).
<b>2012 IGA</b> 20124253	Vliv teploty na preimaginální vývoj práchnivců (Coleoptera: Leiodidae: Cholevinae).
<b>2009 IGA</b> 200942110012	Ekologie mrchožroutovitých brouků (Coleoptera: Silphidae) v polních biotopech ČR

## 7.2 Publication activity

Peer-review papers in journals with impact factor:

**Jakubec P. & Růžička J., 2015:** Is the type of soil an important factor determining the local abundance of carrion beetles (Coleoptera: Silphidae)? *European Journal of Entomology*, **112**: accepted.

**Jakubec P., 2015:** Thermal summation model and instar determination of all developmental stages of necrophagous beetle, *Sciodrepoides watsoni* (Spence) (Coleoptera: Leiodidae: Cholevinae). *PeerJ*, submitted.

**Růžička J. & Jakubec P., 2015:** Description of developmental stages of two species from genus *Choleva* Latreille. *Zookeys*, in prep.

**Kolář J., Kučerová A. & Jakubec P., 2015:** The Influence of seed burial on germination of threatened *Littorella uniflora* (L.) Asch. *Folia Geobotanica*, submitted.

Peer-review papers in other scientific journals:

**Jakubec P. & Růžička J., 2012:** Distribution of open landscape carrion beetles (Coleoptera: Silphidae) in selected lowlands of the Czech Republic. *Klapalekiana*, **48**: 169–189.

Conference proceedings in SCOPUS and WoS:

**Jakubec P., 2015:** Endangered Species of genus *Nicrophorus* (Coleoptera: Nicrophorinae) in the Czech Republic. *15th SGEM GeoConference on Ecology, Economic, Education and Legislation*. SGEM2014 Conference Proceedings, Sofia, pp. 253-258.

**Jakubíková L. & Jakubec P., 2015:** The impact of landscape heterogeneity on the diversity of Russia's Far East butterflies: A pilot study. *15th SGEM GeoConference on Ecology, Economic, Education and Legislation*. SGEM2014 Conference Proceedings, Sofia, pp. 907-912.

**Jakubec P., 2014:** Impact of Droughts on Insect Populations: A Review. *14th SGEM GeoConference on Ecology, Economic, Education and Legislation*. SGEM2014 Conference Proceedings, Sofia, p. 369–374a.

**Jakubec P., 2013:** Modelling the Rate of Development for *Sciodrepoides watsoni* Larvae. *13th SGEM GeoConference on Ecology, Economic, Education and Legislation*. International Multidisciplinary Scientific GeoConference SGEM, Sofia, p. 709–714.

Other conference proceedings:

**Knapp M., Knappová, J, Jakubec P., Vonička P. & Moravec P., 2015:** How many carabid species are ignored during biological surveys employing pitfall traps? In: Bryja J., Řehák Z. & Zukal J. (Eds.): *Zoologické dny Brno 2015. Sborník abstraktů z konference 12.-13. února 2015*. Ústav biologie obratlovců AV ČR, Brno, p. 112.

**Jakubec P. & Růžička J., 2015:** Larval morphology of beetles from genus *Choleva* (Coleoptera: Leiodidae). In: Bryja J., Řehák Z. & Zukal J. (Eds.): *Zoologické*

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**Jakubec P. & Růžička J., 2013:** Rozšíření ohrožených hrobaříků (Coleoptera: Silphidae: Nicrophorinae) otevřené krajiny ve vybraných nížinných oblastech České republiky. In: Bryja J., Řehák Z. & Zukal J. (Eds.): *Zoologické dny Brno 2013. Sborník abstraktů z konference 7. – 8. února 2013. Ústav biologie obratlovců AV ČR, Brno*, p. 92.

**Jakubec P., 2012:** Rychlost vývoje u *Sciodrepoides watsoni* (Spence, 1815) a poznámky k jeho chovu v laboratoři. In: Harabiš F. & Solský M. (Eds.): *Kosteletské inspirování, sborník abstraktů 4. ročníku konference 29. – 30. listopadu 2012. Česká zemědělská univerzita v Praze, Praha*, p. 68.

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**Jakubec P., 2012:** Typ půdy, jako ekologický faktor limitující výskyt mrchožroutovitých brouků (Coleoptera: Silphidae). In Solský M. (Ed.): *Biodiverzita 2012, sborník abstraktů konference 25. – 26. února 2012. Česká zemědělská univerzita v Praze, Praha*, p. 9.

**Jakubec P., Chlumecká L., Šifrová H. & Štefúnová K., 2010:** Ekologie mrchožroutovitých brouků (Coleoptera: Silphidae) v polních biotopech ČR. In: Bryja J. & Zasadil P. (Eds.): *Zoologické dny Praha 2010. Sborník abstraktů z konference 11. – 12. února 2010. Ústav biologie obratlovců AV ČR, Brno*, p. 277.