Zootaxa 1226: 61–68 (2006)
www.mapress.com/zootaxa/

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

1226

Description of the pupa and observations on the distribution, ecology, and life history of *Quedius spelaeus spelaeus* Horn (Coleoptera: Staphylinidae) in Nova Scotia, Canada

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Abstract

The troglophilic staphylinid beetle *Quedius spelaeus spelaeus* Horn 1871, has been found in a number of porcupine dung caves in Nova Scotia where it appears to be the dominant predator on other invertebrates. In culture, late-instar larvae were observed to excavate and remain in cavities excavated in dung, and to pupate in these cavities. The pupa is described for the first time and compared with other pupae in the genus *Quedius* Stephens. The apparently disjunct distribution of the species in Nova Scotia is discussed and it is suggested that it may have colonized the province from Atlantic glacial refugia.

Key words: Coleoptera, Staphylinidae, *Quedius spelaeus*, Canada, Nova Scotia, description of pupa, life history, cavernicole, troglophile, glacial refugia

Introduction

The Staphylinidae (rove beetles) is the largest or second-largest family of beetles, with over 47,744 species in some 3,200 genera worldwide (Newton *et al*. 2000, Thayer 2005). In Canada there are at least 1,374 nominal species of rove beetles classified into some 274 genera and 23 subfamilies (Klimaszewski 2000). However, few troglobites (obligate cavernicoles) and relatively few troglophiles (facultative cavernicoles) are known from the family (Peck & Thayer 2003). The cavernicolous rove beetles include only a handful of troglobitic species. Sixty-six species of staphylinid beetles (excluding Aleocharinae and Pselaphinae) were listed from caves in the continental United States by Peck & Thayer

Accepted by P. Johnson: 10 May 2006; published: 9 Jun. 2006

(2003). Klimaszewski & Peck (1986) recorded 20 species of aleocharines collected from caves in eastern North America and Chandler (1997) recorded 43 species of pselaphines from caves on the continent.

The genus *Quedius* includes a number of troglobites and troglophiles in addition to the much more taxonomically numerous epigean forms. In North America four *Quedius* species frequently occur as troglophiles: *Q. erythrogaster* Mannerheim, *Q. fulgidus* (Fabricius), *Q. mesomelinus* (Marsham), and *Q. spelaeus* Horn (Peck & Thayer 2003). Different species of *Quedius* thus offer the opportunity to investigate a progressive series of species of increasing morphological, physiological, and behavioral adaptation to the subterranean environment.

Quedius spelaeus is a widespread Nearctic species described by Horn (1871). It has eyes and is normally pigmented, but has only been found in subterranean habitats. It is a member of the subgenus *Microsaurus* Casey (Smetana 1971). The nominate subspecies *Q. spelaeus spelaeus* has been reported, primarily from caves, in California, Colorado, Idaho, Iowa, Illinois, Indiana, Kentucky, Missouri, New Mexico, New York, Oregon, Pennsylvania, Virginia, Washington, West Virginia, and Wisconsin in the United States and Alberta, British Columbia, Nova Scotia, and Saskatchewan in Canada by Smetana (1971) to which Peck & Thayer (2003) added records from Maryland, Minnesota, and Utah. Blatchley (1910, 370) observed that *Q. s. spelaeus*, "Occurs in decaying organic matter, usually the excrement of raccoons and other cave visiting vertebrates, or beneath stones in the vicinity thereof." The larva was described by Blatchley & Wickham (1896) and then Voris (1939). The subspecies *Q. spelaeus aplodontiae* Smetana is known only from the burrows of mountain beaver, *Aplodontia rufa* (Rafinesque) (Smetana 1971).

Quedius s. spelaeus was first reported from Nova Scotia by Calder & Bleakney (1967) who found adults in a small porcupine-inhabited cave known as Frenchman's Cave. Little detailed information has been provided about its bionomics and its pupa has not been described. In view of its almost exclusively subterranean occurrence, information on its ecology, behaviour, and life history are of value in understanding the way in which *Quedius* beetles have been able to colonize and adapt to the cave environment and evolve as cavernicoles.

Material and methods

Staphylinid adults and larvae were searched for and collected by hand in the course of a general survey of cave invertebrates in Nova Scotia (Moseley 1998). Adults and/or larvae were found in several caves (Figure 6). Most specimens were in, on, or near deposits of North American porcupine, *Erethizon dorsatum* (Linné) dung. Collection sites were as follows:

1) Frenchman's Cave, St Croix, Hants County, NS: adults and larvae, dark zone, under stones (5 June 1988); two larvae, deep threshold, in moderately composted porcupine

dung (14 October 1996).

2) Frenchman's II, St Croix, Hants County, NS: two adults, dark zone, under stones in area of well-composted porcupine dung (12 June 1988); one larva dead in stream and two adults in well-composted porcupine dung, dark zone (22 May 1996); larva, deep threshold, under stone on floor, associated with porcupine dung (30 June 1997); larvae common, dark zone, in moderately-composted porcupine dung (pH 6.0) (5 October 1997); two larvae, dark zone, dead in pool (18 October 1997); many larvae + one newly-emerged adult, dark zone, under stones in area of dung (19 October 1997).

3) Woodville Ice Cave, Woodville, Hants County, NS: one larva, deep threshold, under a rock associated with porcupine dung (19 October 1997).

4) Minasville Cave, Minasville, Hants County, NS: one larva, deep threshold, under stone in area of porcupine dung (26 October 1996).

5) Fairy Hole II, Cape Dauphin, Victoria County, NS: one adult, dark zone, on deposit of fish bones on ledge (24 October 1971).

The larvae were identified as *Q. s. spelaeus* following rearing of cave-collected specimens to adults in laboratory culture, as follows:

1) bulk samples of slightly damp, moderately-composted porcupine dung (pH 6.0) containing live staphylinid larvae together with other dung micro-arthropods and annelids were collected from a large dung pile in the dark zone of Frenchman's II cave. This site was selected because of its proximity to Halifax, predictable and reliable occurrence of larvae, and because the presence of substantial deposits of dung made sampling easy and relatively non-disruptive to the cave's ecosystem.

2) one subsample of dung was separated and extracted using a Tullgren funnel. The recovered invertebrates were preserved and identified. Further subsamples of dung, each containing staphylinid larvae, were dispersed into three 21cm x 12 cm clear styrene Mosquito Breeders (BioQuip cat. No. 1425) and placed in the dark in a refrigerator set at 7°C. No effort was made to add food as it was assumed that the developing larvae would feed on the natural fauna in the dung samples. The cultures were observed until the larvae had pupated and emerged as adults: voucher specimens (deposited with the Nova Scotia Museum) of larvae, pupae and adults were killed, preserved and retained for identification and description.

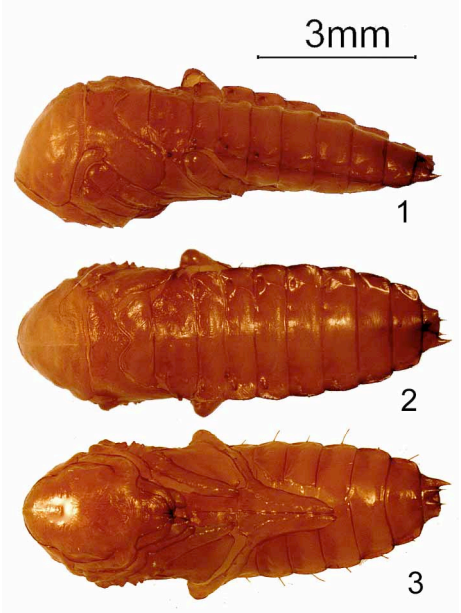
Results

Description: Pupa

Pupa obtect (Figures 1–3), with appendages adhering closely to the body. Body strongly sclerotized; length (without abdominal processes) approximately 7.3 mm; width 2.8 mm; color pale-reddish brown (alcohol preserved specimen). Head directed ventrally towards thorax; width (between eyes) 1.6 mm, length 2.9 mm. Antennae curved and extending to

approximately the apex of mesotibae. Pronotum 1.9 mm wide and 1.8 mm long; anterior margin without spines. Mesonotum broader than long; metanotum narrower than mesonotum, anterior margin deeply bisinuate with two lobes directed anteriad. Wings extending to ventral side. Tibiae directed obliquely towards middle of body. Meso- and metatibiae with several tubercle-like protuberances; metatarsi extending to mid-point of the third visible (actually fifth) abdominal sternite. Abdomen distinctly dorso-ventrally flattened with margins of tergites slightly reflexed; nine tergites and seven sternites visible, narrowed at tergite IV. Spines located at midpoint of lateral margins of abdominal segments II–VIII rather long (~ 0.15 mm). Median tergites (III–VI) 0.5 mm long. Functional spiracles, on elevated tubercles located circa 0.10 mm from the lateral margins of the tergites, visible on tergites I–IV; apparently atrophied spiracles visible on tergites V–VII. Terminal abdominal segment sexually dimorphic as in other *Quedius* pupae (Staniec 1996, 1999, 2003) with four spines on the female and two on the male.

The pupa is similar in all essential respects to other pupae in the genus *Quedius* (*Q. (Raphirus) fumatus* (Stephens), *Q. (Raphirus) humeralis* Stephens, *Q. (Quedionuchus) plagiatus* Mannerheim, *Q. (Microsaurus) mesomelinus* (Marsham), *Q. (M.) brevicornis* (Thompson), and *Q. (Quedius) fuliginosus* (Gravenhorst)) as described by Staniec (1996, 1999, 2003). *Quedius s. spelaeus* (in the subgenus *Microsaurus*) lacks spines on the anterior margin of the pronotum, consistent with *Q. mesomelinus* and *Q. brevicornis* in *Microsaurus* and *Q. fuliginosus* in *Quedius sensu stricto* Stephens, whereas other the other species discussed (in the subgenera *Raphirus* Smetana and *Quedionuchus* Sharp) do have spines, a character state which Staniec (1999, 2003) employs in his keys to the known pupae of Polish Staphylinidae.



FIGURES 1–3. *Quedius spelaeus spelaeus* pupa. 1, lateral view; 2, dorsal view; 3, ventral view.

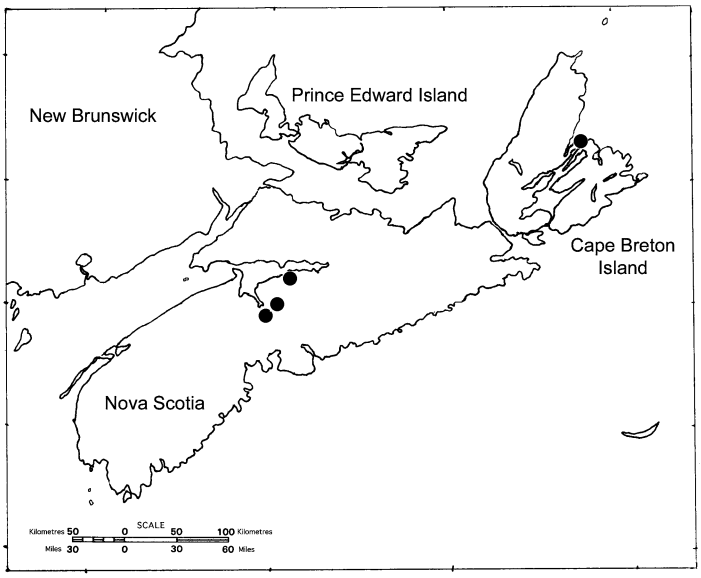


FIGURE 4. Distribution of *Quedius s. spelaeus* in Nova Scotia, Canada.

Observations

Arthropods found to be present in the porcupine dung samples were: Sciaridae (Diptera) larvae and emergent adults (abundant); *Trichocera maculipennis* Meigen (Diptera: Trichoceridae) larvae (frequent); Psychodidae (Diptera) adults (occasional); *Protaphorura armata* (Collembola: Onychiuridae) and *Folsomia* sp. (Collembola: Isotomidae), as well as Parasitidae and other Acari, and *Acrotrichis castanea* (Mathews) adults (Coleoptera: Ptiliidae) (abundant). A second instar *Meta ovalis* (Gertsch) spiderling was also recorded. Undetermined Enchytraeidae (Annelida) worms were present.

Twenty-four hours after establishing the cultures, larvae were observed to have excavated cavities within the dung. Most of these cavities were next to the clear walls of the rearing jars, fortuitously making it possible to directly observe the growing larvae. The excavated "cells" were smooth-surfaced and somewhat irregular in shape, often egg-shaped or sub-triangular, 0.6–0.8cm x 1.0–1.5cm in dimension. Once created, the larvae were never observed to leave their cells, remaining in them in a semi-curled "C" or "J" position through to pupation: the adults left the cells shortly after eclosion.

The cultures were established on 5 October 1997. Almost all of the larvae in the samples were similar in size. The first pupa was observed on 27 October 1997 and with one exception all other individuals had entered pupation within the following three days: a single individual had not pupated until a month later, 29 November 1997. The first emergent adult was seen on 26 November 1997, several more had emerged by the 30 November 1997. Emergent adults were present a little earlier, on 19 November 1997, at the Frenchman's II collecting site.

Discussion

In Nova Scotia *Quedius s. spelaeus* has so far only been found in caves. There is a well-established population in the St. Croix gypsum cave system (Frenchman's Cave and Frenchman's II), where it has now been observed since the mid-1960s. Larvae are seen in the field more frequently than adults. It is a guanophile, frequently associated with moderately to well-decomposed accumulations of porcupine dung: most field records of larvae are of specimens found immediately under rocks in areas of dung, whilst adults may sometimes be seen running over the surface. Both the adults and larvae appear to be dominant predators in porcupine dung communities in Nova Scotia caves. This beetle is not restricted to dung environments, with the record from Cape Breton Island being from a deposit of fish bones.

Based on observations in laboratory culture, the final instar larvae of this beetle appear to be sedentary, developing within cells excavated in dung, and presumably feeding on microarthropods or enchytraeids that find their way into or near the vicinity of the cavity. Field observations indicate that they are usually found immediately under rocks suggesting that they may utilize rock surfaces as one face of their burrow, perhaps as protection or to improve the mechanical integrity of the excavation. This is supported by behaviour observed in culture where they excavated cavities immediately adjacent to the walls of the culture jar. This would explain the frequent occurrence of larvae in areas of broken rock embedded in dung.

The synchronous development of most of the larvae in laboratory culture may be evidence of seasonality, however, it is also possible that all the collected larvae were from the same clutch of eggs.

It is worth noting that the established and apparently thriving population in the St. Croix caves makes the latter valuable sites for the study of this species. These caves are biologically the most comprehensively documented and one of the best examples of an eastern Canadian cave system. Records now extend back to the mid-1960s and this database means that these caves are of considerable speleobiological importance. For a map of this site see Moseley (1996).

Quedius s. spelaeus is distributed in a broad arc from Nova Scotia, through the central USA and western Canada, to British Columbia. It is interesting to note that the Nova Scotia population appears to be significantly disjunct, with no records from middle parts of North America. Smetana (1971) and Peck & Thayer (2003) provided no records closer than southern New York (Sullivan County), ~ 900 km to the south of where they are found in Nova Scotia. Elsewhere in Canada they have not been found east of Saskatchewan (Smetana 1971). Klimaszewski *et al.* (2006) and Majka & McCorquodale (2006) discuss the role of post-glacial land bridges and offshore continental-shelf island networks in the colonization of Nova Scotia by Coleoptera after the end of the Wisconsinan era glaciation. There are many examples of plants, Coleoptera, Acari, reptiles, and mammals which show floristic or faunistic linkages between New England and Nova Scotia populations, being

absent to varying degrees in intervening areas. Georges Bank, extending from the present Cape Cod-Connecticut-New York coastline to within ~ 75 km of the present Nova Scotia shoreline, was emergent land during the last glaciation. Following deglaciation (which began 21,000 years BP) most of the network of offshore banks on the continental shelf of Nova Scotia were also emergent and stayed so for a period of several thousand years (King 1996). *Quedius s. spelaeus* is a potential candidate for one of the species which colonized Nova Scotia in this way.

Acknowledgements

Thanks are due to the Allen family of St. Croix for permission to visit and collect samples from Frenchman's Cave and Frenchman's II, and to Kenny Proctor and Margaret Hamilton for assistance in the field. We also thank G. Pelletier (Laurentian Forestry Centre) for providing colour images of *Q. s. spelaeus*, Mikael Sörensson (University of Lund) for the determination of the *Acrotrichis* specimens, Calum Ewing and Andrew Hebda of the Nova Scotia Museum, Paul J. Johnson (South Dakota State University), and Rafal Ruta (Zoological Institute, Wroclaw, Poland) for their assistance and encouragement. Margaret Thayer (Field Museum of Natural History) read an earlier draft of this manuscript and made many constructive suggestions. The work was supported by research grants from the Nova Scotia Museum.

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