The predatory behaviour of some Central European rove beetles (Coleoptera: Staphylinidae: Staphylininae, Paederinae)

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Zusammenfassung: Trotz ihrer Häufigkeit und weltweiten Verbreitung ist über das Beutefangverhalten von Kurzflügelkäfern (Coleoptera: Staphylinidae) innerhalb der beiden eng verwandten und artenreichen Unterfamilien Staphylininae und Paederinae nur wenig bekannt. Viele ihrer Vertreter leben in Dung und anderen organischen Ablagerungen, worin sie Jagd auf Arthropoden von geringerer Körpergröße machen. Von derartigen Mikrohabitaten wurden Kurzflügelkäfer der genannten Taxa in Tübingen (Süddeutschland, Baden-Württemberg) gesammelt, wovon in diesem Artikel die Arten *Rugilus rufipes* (Paederinae), *Philonthus marginatus*, *Philonthus varians* und *Bisnius sordidus* (Staphylininae) berücksichtigt werden. Mit einer Highspeed-Kamera mit angeschlossenem Makroobjektiv wurde deren Jagdverhalten aufgezeichnet. In Gegenüberstellung mit potenziellen Beutetieren konnten unterschiedliche Beutefangmethoden beobachtet werden: (1) Direktes Ergreifen mit den Mandibeln, (2) Zuschlag mit dem vorderen Beinpaar, (3) Zerr-Verhalten, d.h. Ergreifen mit den Mandibeln, gefolgt von einem Anheben und Rückwärtsziehen der Beute und (4) Formieren eines Fangkorbs, d.h. Schieben der Beute (mit dem Kopf, den Mandibeln und/oder den Vorderbeinen) unter den Thorax und zwischen die Innenseiten der Beine, um eine käfigartige Struktur zu bilden, welche die Beute umgibt und an der Flucht hindert. Diese Fangtechniken können unterschiedlich miteinander kombiniert werden, was auf verhaltenstechnische Korrekturmöglichkeiten innerhalb der jeweiligen spezifischen Beutefangsituation hindeutet. Wenn beispielsweise die Ergreifung der Beute mit Verhalten (1) oder (2) nicht zur optimalen Fixierung der Beute führt, kann zusätzlich Verhalten (4) eingeleitet werden. Die komplexeren Verhaltensweisen sind vermutlich beutetyp- und wahrscheinlich auch taxonspezifisch, wozu jedoch noch weitere Untersuchungen ausstehen.

Keywords: *Bisnius*, hunting behaviour, *Philonthus*, predation, *Rugilus*

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Introduction

Despite their common occurrence and worldwide distribution, little is known about the predatory behaviour of beetles of the two closely related and species-rich subfamilies of rove beetles, namely the Staphylininae and Paederinae. Many representatives of these two subfamilies can be found in dung and debris, where most of them hunt for smaller sized arthropods that feed on decaying materials. The hunting methods and related morphological adaptations and specializations that are involved therein have remained largely undescribed so far. Our investigation of four selected species provides a preliminary attempt to address this subject.

Materials and Methods

Beetles of the two subfamilies Staphylininae and Paederinae were collected with a beetle sieve and by hand from piles of dung and garden waste, horse dung on pastures and litter in the woods around Tübingen (Southern Germany, Baden-Württemberg) from October to December 2017. Among these were representatives of the species *Philonthus varians* (Paykull, 1789)*, Philonthus marginatus* (O. Müller, 1764)*, Bisnius sordidus* (Gravenhorst, 1802) (all belonging to the subfamily Staphylininae) and *Rugilus rufipes* (Germar, 1836) (Paederinae). The beetles were kept in small pots in a climate cabinet and fed every three days with larvae and crushed adults of *Drosophila melanogaster* (Meigen, 1830), beetle jelly and

Folsomia candida (Willem, 1902) and *Heteromurus nitidus* (Templeton, 1835) springtails. Each beetle was recorded with a highspeed-camera (PhotronFastcam; 500fps, Pfullingen, Germany) equipped with a macro lens while being successively confronted with three different types of potential prey, i. e. hard-shelled and slow *Archegozetes longisetosus* (Aoki, 1865) mites (Oribatida: Trhypochthoniidae), soft and elusive *Heteromurus nitidus* springtails (Collembola: Entomobryidae) and soft and slow *Drosophila melanogaster* larvae (Diptera: Drosophilidae). A time frame of at least 10 minutes was given to each beetle in each confrontation trial to allow them to interact with the potential prey. As the *Drosophila* larvae were the largest possible prey, they were always given last to prevent any decline in hunting motivation due to beetle repletion. The springtails and mites were presented in an arbitrary sequence. The three confrontation trials were repeated twice per beetle so as not to miss any chances of activity. Before each confrontation round, the beetles were starved for three days to ensure sufficient prey-capture motivation. After the recordings, the beetles were killed in a refrigerator and transferred to 70% alcohol for detailed identification (Assing & Schülke 2011).

Results

Four different prey-capture techniques were observed:

(1) Direct seizure with the mandibles

The beetles seized their prey directly with the mandibles (Figs. 1, 5), as shown in Fig. 1 in the Paederine beetle *Rugilus rufipes*. It slowly approaches the prey while opening the mandibles without being detected by the prey (Fig. 1a – c). The actual attack follows at high speed, whereby the beetle hurls its body forward and rapidly closes its mandibles to fix the prey (Fig. 1d-e). While pushing forward, it sometimes moves its antennae backwards (Fig. 1e). Finally, the beetle uses its mouthparts to seize the prey and its frontal leg pair to position the food optimally (Fig. 1f).

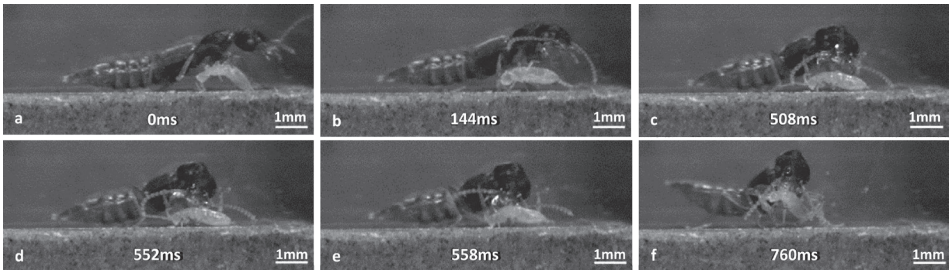

Fig. 1: *Rugilus rufipes.* Direct seizure with the mandibles (side view).

(2) Predatory strike with the front legs

The behaviour conducted with the front legs (Figs. 2, 5) could already be observed in *Philonthus marginatus* and has been previously described by Betz & Mumm (2001). Figure 2 shows a sequence of a *Philothus marginatus* beetle (Staphylininae) hunting a springtail. The front legs were regularly observed in an alert position as shown in Fig. 2a. Once the prey comes close to the beetle, the beetles move their forelegs above the prey (Fig. 2a – c) and strike them down rapidly onto the prey (Fig. 2d – e) followed by the final seizure and feeding with the mouthparts (Fig. 2f).

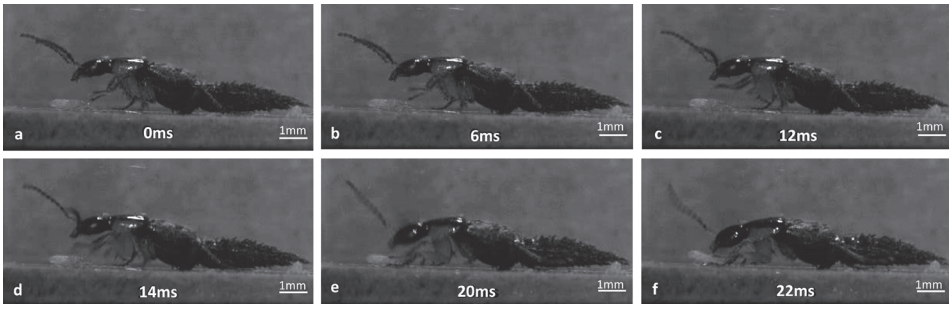

Fig. 2: *Philonthus marginatus*. Predatory strike with the front legs (side view).

(3) Pulling backwards

The third observed technique involves a pulling behaviour, i.e. direct seizure with the mandibles is followed by the lifting and dragging of the prey backwards (Figs. 3, 5). Figure 3 shows a sequence of lateral (first row) and top (second row) views of a *Philonthus varians* beetle (Staphylininae) capturing a *Drosophila* larva. The beetle approaches the prey, palpates it with the antennae (Fig. 3a), grasps it with the mandibles (Fig. 3b) and starts pulling the prey upwards (Fig. 3c). The antennae are moved backwards, while the highly movable abdomen moves upward (Fig. 3c). The beetle pushes its front body upwards with the prey continuously being grasped by its mandibles (Fig. 3d). Continuing the pulling movement, it walks backwards still holding the prey in its mandibles (Fig. 3d-g). The antennae are kept retracted during this phase. The prey is finally held up off the ground (Fig. 3g-h), seized with the mouthparts.

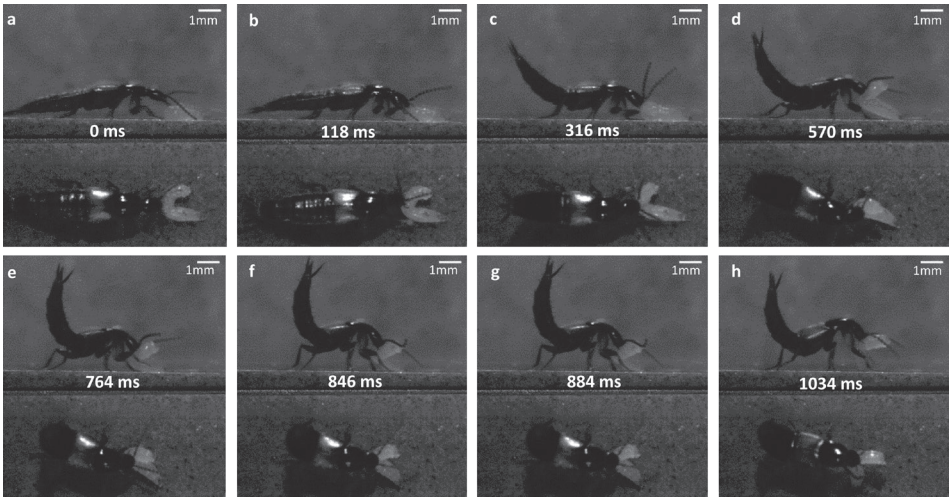

Fig. 3: *Philonthus varians.* Direct seizure with the mandibles followed by lifting and dragging the prey backwards (upper parts: side view, lower parts: top view).

(4) Formation of a catching basket

The fourth and most complex technique observed involves the formation of a catching basket, whereby the prey is manoeuvred (by means of the head, the mandibles and/or the front legs) beneath the thorax and the inner sides of the forelegs that together form a cage-like structure enclosing the prey (Figs. 4, 5). This is shown in Figure 4, in which a sequence of lateral (first row) and top (second row) views of a *Bisnius sordidus* beetle preying upon a springtail is presented. The beetle approaches the prey by shifting its body cautiously above the prey (Fig. 4a–b), bending down the head and manoeuvring the prey beneath the thorax, resulting in the springtail finally being enclosed by the legs and body of the beetle (Fig. 4c). Other beetles that belong to the investigated species from the subfamily Staphylininae and use the same hunting technique have been observed to perform first a grip either with the mandibles or, in *Philonthus marginatus*, with their front legs in order to manoeuvre the prey under their body. All pairs of legs are finally involved in enclosing and fixating the prey, while the beetle continues to bite it with its mandibles (Fig. 4d-e). At some point, the beetle stops enclosing the prey with all pairs of legs and returns towards its initial position, still seizing the prey with its mouthparts and readjusting its position with the frontal pair of legs (Fig. 4f).

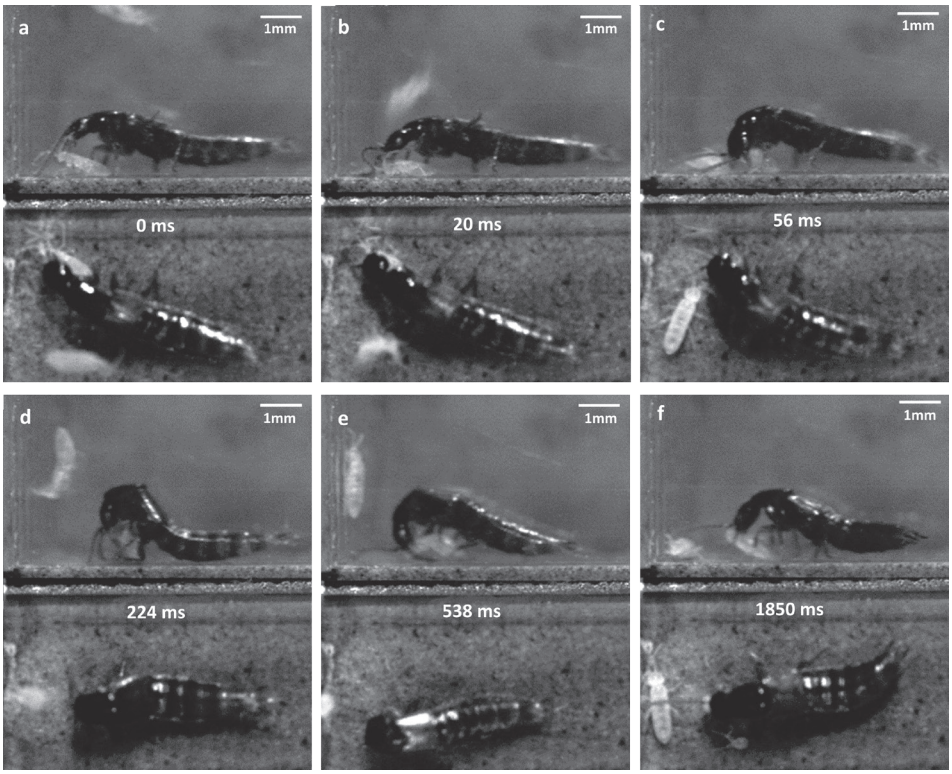

Fig. 4: *Bisnius sordidus.* Maneuvering the prey beneath the thorax and between the inner sides of the fore legs to form a cage-like structure that encloses the prey (upper parts: side view, lower parts: top view).

In representatives of both subfamilies, in the feeding procedure that follows successful prey-capture events, the front pair of legs was often observed to position the prey (as shown in Fig. 3e and 4f).

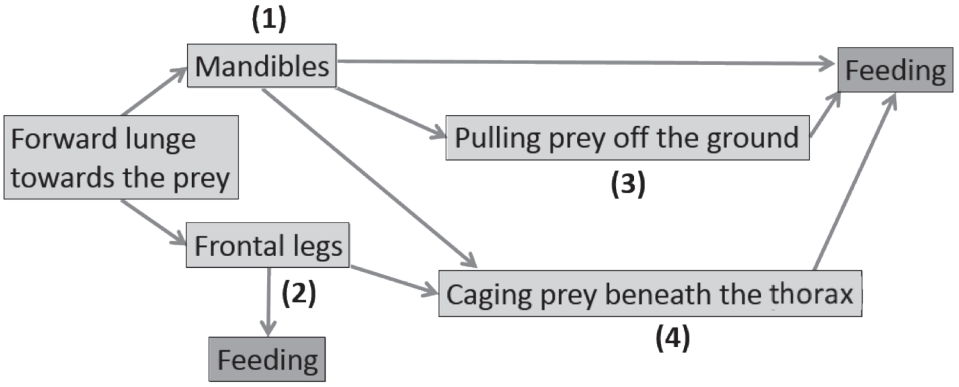

Fig. 5: Observed prey-capture patterns with their possible combinations and sequences.

Discussion

In this contribution, we present our observations of the feeding behaviour of beetles of the species *Philonthus marginatus, Philonthus varians, Bisnius sordidus* (all belonging to the subfamily Staphylininae) and *Rugilus rufipes* (Paederinae) and classify these observations in context with potential prey types. We assume that some of the observed behaviours follow others in a regular order. The assumed typical behavioural sequences during prey-capture are shown in a flow diagram (Fig. 5) that suggests that the pulling of the prey backwards (Fig. 5: 3) regularly follows the direct seizure of the prey with the mandibles (Fig. 5: 1), whereas the formation of a catching basket (Fig. 5: 4) is initiated by gripping the prey with the mandibles (Fig. 5: 1), with the legs (Fig. 5: 2), or by manoeuvring the prey with the head beneath the body. The variable combination of behaviours described above suggests a certain amount of flexibility and behavioural adjustability with respect to the specific prey-capture situation. For example, if the gripping performed in behaviour (1) or (2) does not lead to the proper fixation of the prey, behaviour (4) can be employed. The more complex behaviours might have evolved in the context of specialization on a specific prey type. Some of the behavioural patterns might be clade-specific and involve evolutionarily relevant morphological adaptations. For example, *Philonthus marginatus* is the only recorded species, in which the beetles used their front legs for the predatory strike (cf. Betz & Mumm 2001). The pulling backwards behaviour seems to be an adaptation to the seizure of prey that is attached to or digging into the ground, as the beetle raises its front body with the prey attached as far from the ground as possible and walks backwards in order to keep it detached from the substrate. The retraction of the antennae might be indicative of the beetle's intention to avoid potential injury by the prey. The caging behaviour seems to be used especially towards elusive prey which is not easy to grip since, in this case, the prey does not need to be seized precisely by the mouthparts. With the prey located underneath the pronotum, the beetle has a better chance to bring it into a position by using all pairs of legs from where the prey can be finally seized with the mandibles. Indeed, the pulling backwards behaviour has been mainly observed towards the (worm-like) *Drosophila* larvae, whereas the caging behaviour seems to be used mostly for catching elusive springtails. Further studies are needed to obtain stronger evidence for this observed tendency.

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