Predatory behaviour of *Discoelius zonalis* (Hymenoptera: Eumenidae)

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Abstract: *Discoelius zonalis* was observed in captivity with respect to hatching, mating, nesting behaviour and stinging behaviour. The wasps accepted larvae of *Corcyra cephalonica* Stainton as prey. In contrast to other eumenid wasps, hitherto described, *D. zonalis* displayed a complete stinging pattern. The sequence of stinging was: throat, first, second and third thoracic segments and, subsequently, in an antiparallel position, the sixth, fifth, fourth and third abdominal segments. In a few cases other abdominal segments were stung.

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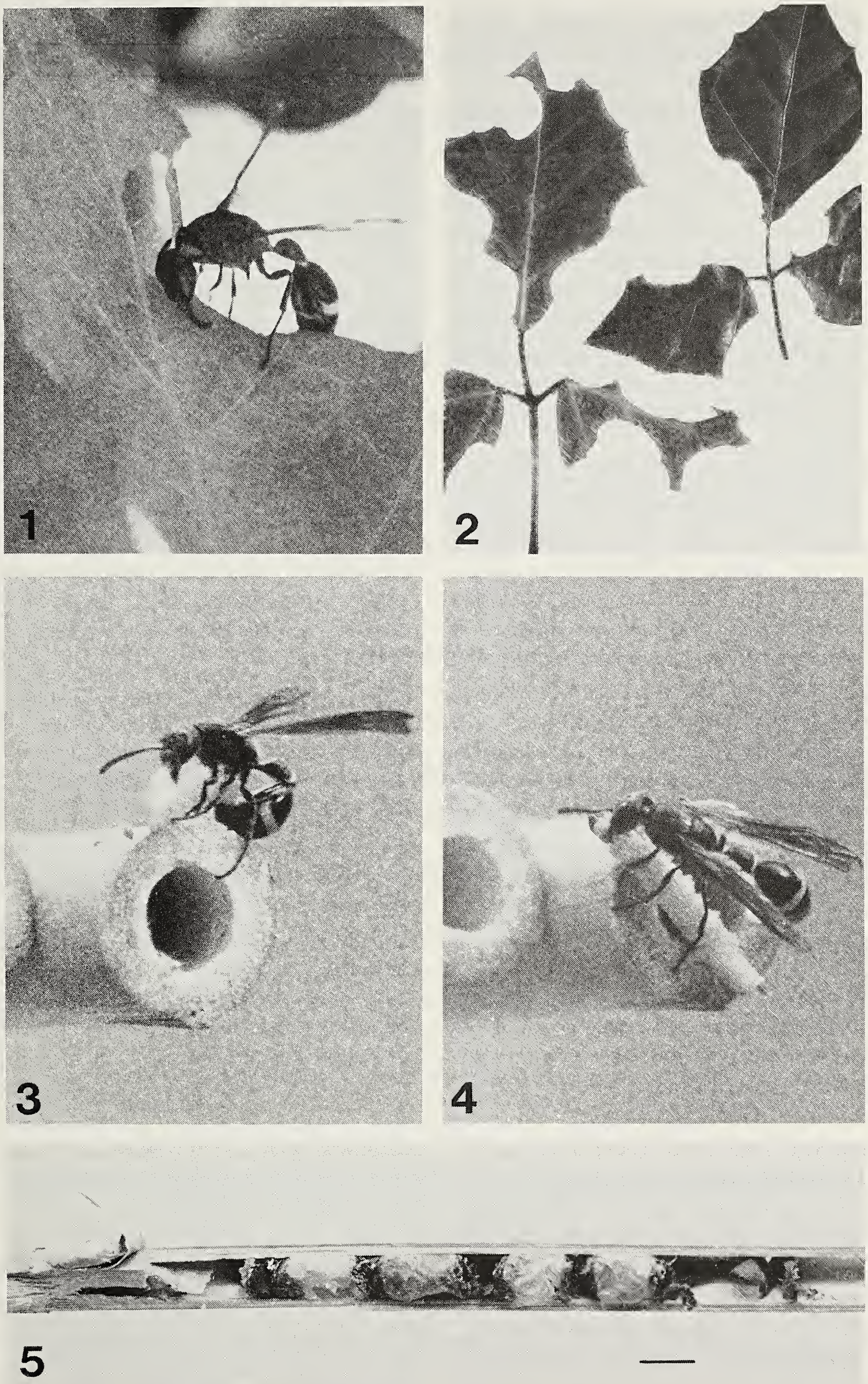
Introduction

The stinging behaviour of solitary wasps has recently been reviewed by Steiner (1986), who concluded that although the wide spectrum of stinging methods cannot easily be summarized in a single simple formula, the locomotor ganglia hypothesis of stinging seems to be the best-fitting one for a number of aculeate wasps, which use large and powerful prey. For example, a number of sphecid wasps, which prey on crickets and grasshoppers, give basically four successive stings to the third, second and first thoracic segment, and finally to the throat (Steiner, 1962, 1971, 1981). In other sphecid wasps, such as the Palearctic *Podalonia hirsuta* Scopoli, and the Nearctic *P. luctuosa* (Smith), which prey on very large and strong cutworms, the above mentioned four-sting pattern is supplemented by a certain number of abdominal stings, up to a maximum of six (Fulcrand, 1966; Gervet & Fulcrand, 1970; Steiner, 1983a). In sharp contrast, many eumenid wasps sting small and frail caterpillars often less than four times. This might be the case for caterpillars stung by *Odynerus* spp, which delivers a sting to each thoracic segment (Janvier, 1930). Cooper (1953), who observed sting-wounds, described the stinging pattern of the eumenid wasp *Ancistrocerus antilope* (Panzer) to be reduced to the throat and the third thoracic segment. Steiner (1983b) described a similar stinging behaviour of *Euodynerus foraminatus* (Saussure), but the complete four-sting pattern was also observed. In all cases described above, eumenid wasps show a stinging pattern, which is more or less reduced, compared to that of sphecid wasps of the genus *Podalonia* using a comparable prey. The present paper describes the stinging pattern of the eumenid wasps *Discoelius zonalis* (Panzer, 1801) which is not reduced.

Material and methods

Discoelius zonalis (figs. 1, 3, 4) is a rare species in Europe (Bouwman, 1910; Haverhorst, 1924; Berland, 1928; Verhoeff, 1943). However, Simon Thomas & Wiering (1976) reared 14 females and two males of this species from three artificial nests (with openings of 0.5 cm), in East Flevoland (Netherlands) during the summer of 1975.

After collection of the nests at the end of the summer, they were kept at 4 °C during three months, in order to mimic winter con-



Figs 1-5. Nesting and stinging behaviour of *Discoelius zonatus*. 1, A female bites sickle-shaped pieces of leaves of *Rhoicissus rhomboidea;* 2, the leaves obtain an appearance as if they are damaged by caterpillars; 3, female stings a rice-moth larva ventrally in the thoracic segments; 4. the paralysed larva is taken between the mandibles at the central part of the head region, and brought into the nest; 5, the bottom of every cell in the bamboo nest consists of a 3-8 mm thick layer of leaf pieces (Bar = 1 cm at 5).

ditions, and subsequently warmed up to 22 °C, at a regime of 16 h light and 8 h dark. In the winter of 1976 14 females and two males hatched. After mating, four females were introduced into a cage (80×80×70 cm) with a plexiglass front, a closed bottom, and four walls made of small mesh wire-netting (2×2 mm). The cage was placed in a warm greenhouse. Artificial nests were prepared of bamboo *Pseudosasa japonica* (Sieb. et Zucc. ex Steud.) Mak. and, moreover, a few wooden nests with a plexiglass wall were provided for observations. Water was available from wet tissues and the wasps were fed with honey.

D. zonata covers the internal wall of the nest with leaves (Bouwman, 1910), and according to Iwata (1976: 253) wasps of this genus prefer leaves of Rosaceae such as *Prunus* or *Rosa*. From the plants tested, *Begonia rex* Putzeys, *Ligustrum ovalifolium* Hassk. and *Rhoicissus rhomboidea* Planch. the latter one was accepted by the wasps. Prey was offered on a small table in the centre of the cage. Larvae of the rice-moth *Corcyra cephalonica* Stainton were used since they were accepted by the wasp. The rice-moths were reared using a semi-artificial diet (Veenendaal, 1986).

Results

Directly after hatching, the wasps were transferred to an experimental cage. The first mating was observed within one hour. Four females were used for the study of the predatory behaviour. The wasps started their nesting behaviour two days after hatching by biting sickle-shaped pieces of the leaves of *Rhoicissus rhomboidea* (fig. 1) The damage to the leaves looked like caused by caterpillars (fig. 2). The bottoms of the bamboo nests were covered with a 3-8 mm thick layer of leaf pieces, and afterwards comparable layers were constructed between the different cells (fig. 5). Subsequently paralysed caterpillars were carried into the nest (see Provisioning of the Nest).

Stinging behaviour. The wasp started the stinging behaviour with a frontal attack. It seized the victim with the mandibles about 5 mm behind the head, and also used her forelegs to take hold of the caterpillar in a more or less parallel position. Then she bent her gaster and stung the caterpillar into the throat. Subsequently the wasp seized the caterpillar a little bit more posteriorly and stung in the ventral side of the prothorax, followed by small changes in position accompanied by stings in the meso-and metathorax respectively (fig. 3). During this initial stinging act the victim regurgitated violently and the wasp proceeded cleaning and grooming herself. The caterpillar which was now partially paralysed, struggled much less than before. After the cleaning procedure was finished the wasp turned the caterpillar in an antiparallel position. Again by seizing the prey with the mandibles the wasp shifted her prey stepwise, in order to sting the leg-bearing abdominal segments ventrally, starting with the sixth segment followed by the fifth, the fourth and the third segment. This was observed for all four wasps and about 15 caterpillars. In a few cases the adjacent abdominal segements also received a sting. The last (also leg-bearing) segment has never been observed to receive a sting. This complete stinging resulted in an incomplete paralysis. The caterpillars were not capable of moving around, but smal movements of the body were observed. After having completed her stinging act the wasp kept its immobilized victim between meso- and metathoracic legs, leaving here forelegs available for cleaning herself. Then the wasp grasped the prey ventrally between the mandibles and flew to the nest (fig. 4).

Provisioning of the nest. The wasp stored a number of rice-moth larvae in the nest, in these observations varying from 3-7 larvae. The egg was suspended by a thread, as in most eumenid eggs (Iwata, 1976: 252). The wasp then closed the nest by preparing a barricade of pieces of leaf (fig. 5). The egg hatched after two days and the wasp's larva started sucking on the prey even before it was completely free from its egg shell. After a feeding period of 5-6 days and a walk through the cell the larva started spinning its cocoon in about two days.

The second generation. After the last female had died at an age of more than three months, the nests were cooled at 4 °C for three months and a half, and thereafter warmed up to 22 °C. Twelve wasps of the new generation hatched 25 days later. All of them were males, probably the females had not been inseminated during mating.

Discussion

In his *Souvenirs Entomologiques* Fabre (1879) presented the view that solitary aculeate wasps sting their victims in the central nervous system. He observed prey having a concentrated central nervous system (buprestid beetles, weevils and some beetle larvae) to be stung once, and prey with a more diffuse central nervous system to be stung more than once. Among his examples were *Sphex* spp., which sting crickets three times, once in each of the three thoracic ganglia, and *Ammophila* spp., which sting caterpillars in every segment involved in locomotion. Recently this locomotor ganglia hypothesis has been critically compared with other hypotheses by Steiner (1986), in favour of the hypothesis mentioned. He also put attention to the important sting in the throat, which was not always seen by earlier observers.

The basic four-sting pattern of sphecid wasps attacking orthopteran prey is used by Steiner (1986) as a standard of reference to describe sting reduction on the one hand and sting augmentation on the other hand.

Reduction of the number of stings may have been developed in answer to several causes. We have mentioned already the concentration of ganglia of the prey. Sting reduction has also been described for *Ampulex compressa* Fabricius, which stings cockroaches once in the thorax resulting in a transient paralysis, and then, during the few minutes of paralysis, the wasp stings carefully in the direction of the suboesophageal ganglion resulting in deactivation of the cockroach (Piek et al., 1984). In this case deactivation has replaced paralysis in order to immobilize the prey.

A third cause of reduction of the number of stings is seen in many forms which attack weak prey. This has been described for eumenid wasps preying on small caterpillars (Cooper, 1953; Steiner, 1983). However, the suggestion of Steiner (1986) that this might be a general phenomenon in Eumenidae is not in agreement with the complete, or even augmented stinging pattern described in the present paper.

It becomes evident that experimental conditions, allowing *Discoelius zonata* to prey on caterpillars which are weaker then *Corcyra cephalonica*, could provide arguments whether the sting pattern of this wasp is evolutionarily fixed or may vary according to the prey offered.

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