Testing the predatory behaviour of Podarcis sicula (Reptilia: Lacertidae) towards aposematic and non-aposematic preys

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Testing the predatory behaviour of *Podarcis sicula* (Reptilia: Lacertidae) towards aposematic and non-aposematic preys

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Abstract. Food preferences and the effects of prey chemical repellents in the dietary behaviour of *Podarcis sicula* were tested using four species of Carabid beetles as prey models. The goal of the study was to assess (i) the ability of *P. sicula* to recognize insect preys provided with chemical repellents and aposematic colorations under laboratory conditions, and (ii) the importance of chemical signals used by the prey model as antipredatory strategy. Preys used in this study were *Brachinus sclopeta* and *Anchomenus dorsalis* (aposematic species) and *Amara anthobia* and *A. aenea* (non-aposematic species). Aposematic species are characterized by warning color pattern and by production of chemical repellents, while non-aposematic ones do not. *Amara anthobia* and *A. aenea* were attacked with high frequency by *P. sicula*, *Brachinus sclopeta* and *Anchomenus dorsalis* with low frequency. Non-aposematic species were preyed more often than the aposematic ones. *Brachinus sclopeta* was preyed after low latency, while *Amara anthobia* and *A. aenea* after long latency. Non-aposematic species were captured and eaten without difficulty, while when *B. sclopeta* or *A. dorsalis* were captured, lizards always tossed their head and then rub the snout on the soil, probably because of the unpalatability of aposematic preys.

Keywords: aposematism, Calabria (southern Italy), Carabid beetles, food preference, *Podarcis sicula*.

Most lizards are generalist predators and prey upon insects and small vertebrates (Cooper and Al-johany, 2002). Lizards are able to identify food using both visual and chemical cues, but little is known about the nature of chemicals to which they respond and the chemical senses that mediate these responses (Cooper et al., 2002). Behavioural responses to certain types of food chemicals by lizards were studied by Cooper and Pérez-Mellado (2001a,b). Many lizards can identify some chemicals in the prey by tongue-flicking (Halpern, 1992; Cooper, 1994a,b). The occurrence of innate responses to prey chemicals by lizards is well known in the members of at least three families: Varanidae, Anguidae, Scincidae (Burghardt, 1973; Von Achen and Rakestraw, 1984; Garrett and Card, 1993). The senses that mediate food chemical discrimination by lizards are poorly know, but the major candidates are vomerolfaction and gustation. In particular, the vomerolfactory system responds to large, non-volatile molecules sampled by tongue-flicking (Halpern, 1992). In general, active foragers lizards rely more on chemical senses in detecting the prey than ambush foragers do (Evans, 1961; Enders, 1975; Regal, 1978; Huey and Pianka, 1981; Simon, 1983). Positive responses by lizards to food supply were obtained towards proteins, lipids and carbohydrates (Wang et al., 1988). As an example, the lacertid lizards *Podarcis lilfordi* and *Lacerta perspicillata* positively responded to sugar and sucrose supply (Cooper and Pérez-Mellado, 2001a; Cooper et al., 2002), while the supply of a mixture of lipids, pork fat and sucrose elicited strong negative feeding responses in both species. These lizards are able to discriminate between odorous and odourless control substances and surface chemicals of preys and plants given as food by lingually sampling them (Cooper and Pérez-Mellado, 2001b). Prey chemical discrimination was also pointed out by Cooper and Hartdegen (2000) in *Scincella lateralis* and *Mabuya macularia* (Scincidae).

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Podarcis sicula is a diurnal lacertid lizard occurring in Italy (mainland and islands), Sicily, Sardinia, Corsica, in the coastal regions of Slovenia and Croatia and in some parts of Montenegro (Corti and Lo Cascio, 2002). This lizard can be considered as an active forager and a generalist predator (Capula et al., 1993; Pérez-Mellado and Corti, 1993). It preys on a wide variety of invertebrates, mainly on arthropods (Arachnidae, Insect larvae, Diptera, Coleoptera, Heteroptera, Hymenoptera, Orthoptera, Gastropoda), but occasionally small vertebrates can also be preyed (Sorci, 1990; Capula et al., 1993; Rugiero, 1994; Sicilia et al., 2001). In this study the food preferences and the effects of prey chemical repellents in the dietary behaviour of *P. sicula* were tested using four species of Carabid beetles (Insecta) as aposematic and chemical protected and non-aposematic and unprotected prey models. The goal of the study was to assess the importance of chemical signals used by the prey model as antipredatory strategy, and the ability of *P. sicula* to recognize insect preys provided with chemical repellents and aposematic colorations.

The lizards used in this study were 11 adult males *Podarcis sicula*. They were collected by hand in the field (Cosenza, southern Italy). Lizards were reared in laboratory conditions under a regime of natural daylight. They were maintained in plastic cages (55 cm length, 34 cm width, 33 cm heigth) with opaque sides. After the experiment, lizards were released at the same location where they were captured. Preys used in this study were four species of Carabid beetles (Insecta, Coleoptera), two aposematic ones: *Brachinus sclopeta* (N = 11), *Anchomenus dorsalis* (N = 11); and two non-aposematic ones: *Amara anthobia* (N = 11), *Amara aenea* (N = 11). The Carabid beetles were collected by hand in the Crati Valley, province of Cosenza, southern Italy (latitude: 39°35′56″N, longitude: 16°15′48″E; elevation: 60 m a.s.l.). We chose these carabids as "prey models" because they are very abundant in the field, could be potential preys of *Podarcis sicula*, and have different antipredatory patterns: *Brachinus sclopeta* and *Anchomenus dorsalis* are characterized by a bright orange-red dorsal coloration with blue or green elytra and produce repellent chemicals products (Zetto et al., 2006); *Amara anthobia* and *Amara aenea* are characterized by uniform dark coloration (fig. 1) and do not produce repellent chemicals products. The chemicals produced by the aposematic species are: quinones and water at 100°C for *Brachinus sclopeta*, and methylsalicilate for *Anchomenus dorsalis* (Schildknecht and Holoubek, 1961; Schildknecht et al., 1968; Schildknecht, 1970, 1975; Dazzini Valcurone and Pavan, 1980).

Lizards were tested individually in an open arena (size: 28 cm length, 18 cm width, 16 cm heigth) with a lamp and a white plaster substratum. During the experiment the temperature was maintained within the range of 24-26°C. The tests were performed from June to July 2006. Each lizard was tested once by offering the four preys (*B. sclopeta*, N = 1; *A. dorsalis*, N = 1; *A. aenea*, N = 1; *A. anthobia*, N = 1). Each carabid beetle was tested once. Before the beginning of the test, each lizard was not fed for two days. The lizard to be tested was kept in the arena for 10 minutes before starting the test. The trial began when the prey (all species at the same time) was put in the arena and lasted when the prey was ingested. If no predation occurred, the trial lasted 30 minutes after the prey was put in the arena. The preys were placed manually (N = 1 individual of each specie in each trial) in the arena using a glass container. The behaviour of each lizard during the test was recorded using a digital camcorder (Sony HDV 1080i). The latency of attack and whether the Carabid beetles were killed or refused were also recorded. The difference between prey attack occurrence was estimated using Chi-square test. The latencies of attack were estimated using Mann-Whitney test and Kruskal-Wallis test by SPSS v.12.0 statistical package.

When comparing the number of attacks towards aposematic and non-aposematic preys, there was a statistically significant preference towards non-aposematic preys. *Amara anthobia* and *A. aenea* were attacked with high frequency, while *Brachinus sclopeta* and *Anchomenus dorsalis* with low frequency ($X^2 = 23.758$, df = 3, $p = 0.0001$). There was no statistically significant difference in the attacking frequencies between the two non-aposematic species ($X^2 = 1.227$, df = 1, $p = 0.268$). The attack latency was different between the two prey types ($X^2 = 810.015$, df = 78, $p = 0.001$). Statistically significant differences were found comparing the latencies of attack of the four species: the latency of attack towards *Brachinus sclopeta* was low, while *Amara anthobia* and *A. aenea* were preyed after long latency (*B. sclopeta* vs *A. anthobia*: U = 344; Z = −2.614; $p = 0.009$; *B. sclopeta* vs *A. aenea*: U = 307; Z = −3.104; $p = 0.002$). Non-aposematic preys were captured and eaten without difficulty, while when *Brachinus sclopeta* or *Anchomenus dorsalis* were captured, lizards always tossed their head and then rub the snout on the soil. This is probably because of the unpalatability of the aposematic preys.

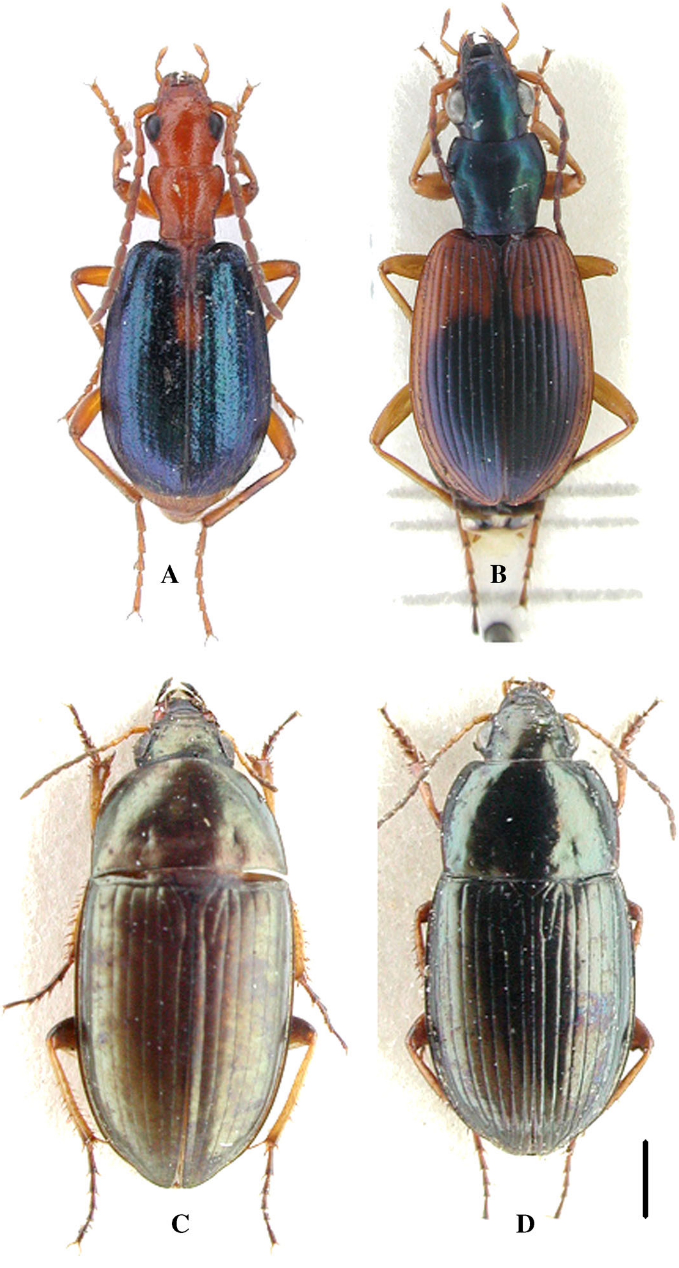

Figure 1. *Brachinus sclopeta* (A), *Anchomenus dorsalis* (B), *Amara aenea* (C), *Amara anthobia* (D). Note in A and B the bright orange-red dorsal coloration with blue or green elytra. Scale bar = 2 mm.

Our data indicate that *Podarcis sicula* detects and responds adaptively to chemical cues from some species of Carabid beetles. Our findings support the hypothesis that *P. sicula* prefers to attack species of Carabid beetles without chemical defences, probably through the ability to discriminate between prey chemicals by lingually sampling the preys (see Cooper, 1995, 1997, 2000). This would suggest that *P. sicula* has evolved the ability to detect the chemicals secreted by dangerous preys, such as those present in the pigidial and cuticle glands of

Brachinus sclopeta and *Anchomenus dorsalis*. In this case the quinones excreted by *Brachinus sclopeta* and the methylsalicilate produced by *Anchomenus dorsalis* would act as aversive signals towards predators. In this regard it must be stressed that the chemicals produced by *Brachinus sclopeta* and *Anchomenus dorsalis* act as effective antipredatory repellents towards as different predatos as *Crocidura leucodon* (Mammalia, Insectivora, Soricidae) and *Ocypus olens* (Insecta, Coleoptera, Staphylinidae) (Bonacci et al., 2004, 2006)

Moreover, it may well be that the aposematic species used in this experiment can synthesise other unknown repellent chemicals and/or warning odours. The warning odours (Pyrazines) are a group of odours commonly associated with warning coloration of many insects (Rothschild, 1961; Woolfson and Rothschild, 1990; Rowe and Guilford, 1998), and therefore are assumed to have a function which is closely related to the coloration warning signals (Rowe and Guilford, 1998). Although our data show that preys with no chemical defence were attacked more frequently than chemically defended ones, at present we cannot say anything about the chemicals involved in prey discrimination by *P. sicula*. Further studies are thus needed to investigate on (i) the ability of *P. sicula* to discriminate repellent chemicals and/or warning odours produced by several kinds of prey, (ii) the senses that mediate this ability, and (iii) the factors (multimodal signals) that could be responsible for the differences found in latency of attack between aposematic species.

References

Bonacci, T., Aloise, G., Brandmayr, P., Cagnin, M., Zetto Brandmayr, T. (2004): Risposte comportamentali di *Crocidura leucodon* (Hermann, 1780) (Insectivora, Soricidae) ai meccanismi antipredatori di alcuni artropodi. Hystrix It. J. Mamm. (n.s.) **15** (1): 73-76.

Bonacci, T., Massolo, A., Brandmayr, P., Zetto Brandmayr, T. (2006): Predatory behaviour on ground beetles (Coleoptera: Carabidae) by *Ocypus olens* (Müller) (Coleoptera: Staphylinidae) under laboratory conditions. Entomological News **117** (5): 545-551.

Burghardt, G.M. (1973): Chemical release of prey attack: extension to naïve newly hatched lizards, *Eumeces fasciatus*. Copeia: 171-181.

Capula, M., Luiselli, L., Rugiero, L. (1993): Comparative ecology in sympatric *Podarcis muralis* and *P. sicula* (Reptilia: Lacertidae) from the historical centre of Rome: what about competition and niche segregation in an urban habitat? Boll. Zool. **60**: 287-291.

Cooper, W.E. (1994a): Chemical discrimination by tongue-flicking in lizards: are view with hypotheses on its origin and its ecological and phylogenetic relationships. J. Chem. Ecol. **20**: 439-487.

Cooper, W.E. (1994b): Prey chemical discrimination, foraging mode and phylogeny. In: Lizard Ecology: Historical and Experimental Perspectives, p. 95-116. Vitt, L.J., Pianka, E.R., Eds, Princeton, Priceton University Press.

Cooper, W.E. (1995): Foraging mode, prey chemical discrimination, and phylogeny in lizards. Anim. Behav. **50**: 973-985.

Cooper, W.E. (1997): Correlated evolution of prey chemical discrimination with foraging, lingual morphology and vomeronasal chemoreceptor abundance in lizards. Behav. Ecol. Sociobiol. **41**: 257-265.

Cooper, W.E. (2000): An adaptive difference in the relationship between foraging mode and responses to prey chemicals in two congeneric scincid lizards. Ethology **71**: 193-206.

Cooper, W.E., Al-johany, A.M. (2002): Chemosensory responses to foods by an erbivorous acrodont lizard, *Uromastix aegyptius*. J. Ethol. **20**: 95-100.

Cooper, W.E.J., Hartdegen, R. (2000): Lingual and biting responses to prey chemicals by ingestively naive scincid lizards: discrimination from control chemicals, time course and effect of method of stimulus presentation. Chemoecology **10**: 51-58.

Cooper, W.E., Pérez-Mellado, V. (2001a): Location of fruit using only airborne odor cues by a lizard. Physiology & Behavior **74**: 339-342.

Cooper, W.E.J., Pérez-Mellado, V. (2001b): Chemosensory responses to sugar and fat by the omnivorous lizard *Callotia caesaris* with behavioral evidence suggesting a role for gustation. Physiol. Behav. **73**: 509-516.

Cooper, W.E.J., Pérez-Mellado, V., Vitt, L.J. (2002): Responses to major categories of food chemicals by the lizard *Podarcis lilfordi*. J. Chem. Ecol. **28** (4): 709-720.

Corti, C., Lo Cascio, P. (2002): The Lizards of Italy and Adjacent Areas. Frankfurt-am-Main, Chimaira Verlag, 165 pp.

Dazzini Valcurone, M., Pavan, M. (1980): Glandole pigidiali e secrezioni difensive dei Carabidae. Pubblicazioni dell'Istituto di entomologia dell'Università di Pavia, p. 1-36.

Enders, F. (1975): The influence of prey size, particularly in spiders with long attack distances (Araneidae, Linyphiidae, and Salticidae). Am. Nat. **109**: 737-763.

Evans, L.T. (1961): Structure as related to behaviour in the organization of populations of reptiles. In: Vertebrate Speciation, p. 148-178. Blair, W.F., Ed., Houston, University of Texas Press.

Garrett, C.M., Card, W.C. (1993): Chemical discrimination of prey by naïve neonate gould's monitors *Varanus rouldii*. J. Chem. Ecol. **19**: 2599-2604.

Halpern, M. (1992): Nasal chemical senses in reptiles: structure and function. In: Hormones, Brain and Behaviour, Biology of the Reptilia, Vol. 18, Physiology E., p. 423-523. Gans C., Crews, D., Eds, Chicago, University of Chicago Press.

Huey, R.B., Pianka, E. (1981): Ecological consequences of foraging mode. Ecology **62**: 991-999.

Pérez-Mellado, V., Corti, C. (1993): Dietary adaptations and herbivory in lacertid lizards of the genus *Podarcis* from western Mediterranean islands (Reptilia: Sauria). Bonn. Zool. Beitr. **44**: 193-220.

Regal, P.J. (1978): Behavioural differences between reptiles and mammals: an analysis of activity and mental capabilities. In: Behavior and Neurology of Lizards, p. 183-202. Greenberg, N., MacLean, P.D., Eds, Rochville, Maryland, National Institute of Mental Health.

Rothschild, M. (1961): Defensive odours and Müllerian mimicry among insects. Trans. R. Ent. Soc. Lond. **113**: 101-121.

Rowe, C., Guilford, T. (1999): Novelty effects in a multimodal warning signal. Animal Behaviour **57** (2): 341-346.

Rugiero, L. (1994): Food habitus on the Ruin Lizard, *Podarcis sicula* (Rafinesque-Schmaltz, 1810) from a costal dune in Central Italy. Herpetozoa **7** (1/2): 71-73.

Schildknecht, H. (1970): Die Wehrchemie von Land- und Wasserkäfern. Angew. Chem. **87**: 16-25.

Schildknecht, H. (1975): Experimente zur Explosionschemie der Bombardierkäfer. Chem. Exp. Didakt. **1**: 43-44.

Schildknecht, H., Holoubek, K. (1961): Die Bombardierkäfer und ihre Explosionschemie. Angew. Chem. **73**: 1-7.

Schildknecht, H., Winkler, H., Maschwits, U. (1968): Vergleichend chemische Untersuchungen der Inhaltsstoffe der Pygidialwehrblasen von Carabiden. Z. Naturforsch. **23**: 637-644.

Sicilia, A., Violani, C., Zava, B. (2001): Predazione di *Podarcis sicula* su *Discoglossus pictus*. Pianura- Scienze e storia dell'ambiente padano N.13/2001.

Simon, C.A. (1983): A review of lizard chemoreception. In: Lizard Ecology: Studies of a Model Organism, p. 119-133. Huey, R.B., Pianka, E.R., Schoener, T.W., Eds, Cambridge, Massachusetts, Harvard University Press.

Sorci, G. (1990): Nicchia trofica di quattro specie di Lacertidae in Sicilia. Nat. Sicil. **4** (suppl.): 3-93.

Von Achen, P.H., Rakestraw, J.L. (1984): The role of chemoreception in the prey selection on neonate reptiles. In: Vertebrate Ecology and Systematics: A Tribute to Henry S. Fitch, p. 163-172. Seigel, R.A., Hunt, L.E., Knight, J.L., Malaret, L., Zuschlag, N.L., Eds, Lawrence, University of Kansas Press.

Wang, D., Chen, P., Jiang, X.C., Halpern, M. (1988): Isolation from earthworms of a proteinaceous chemoattractant to garter snakes. Arch. Biochem. Biophys. **267**: 459-456.

Woolfson, A., Rothschild, M. (1990): Speculating about Pyrazines. Proc. R. Soc. Lond. **242**: 113-119.

Zetto Brandmayr, T., Bonacci, T., Massolo, A., Brandmayr, P. (2006): What is going on between aposematic carabid beetles? The case of *Anchomenus dorsalis* (Pontoppidan 1763) and *Brachinus sclopeta* (Fabricius 1792) (Coleoptera Carabidae). Ethology Ecology & Evolution **18**: 335-348.

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