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# DOES DIFFERENT PREY TYPE INFLUENCE FEEDING PREFERENCE IN LIZARDS?

**Abstract -** L. Di Vozzo, G. Montesanto, M.A.L. Zuffi, *Does different prey type influence feeding preference in lizards?*

The feeding spectrum of Lacertids has been widely studied in different geographical areas, continental, insular and microinsular. Data are particularly informative and show a trophic spectrum mainly characterized by arthropods, mainly insects, but also by other taxa. Even if lesser represented, terrestrial Isopods, (Crustacea, Isopoda, Oniscidea) have been recorded. *Armadillo officinalis* has a stridulatory apparatus and it is able to produce micro-vibrations, whose meaning and/or the biological functions are still not understood (decrease of predation?). Other species of terrestrial isopods do not produce vibrations. In *Podarcis* species diet Isopods remains have been recorded, although the taxonomic identity has not yet been determined. We considered two lizards species, *Podarcis muralis* and *P. siculus*, as potential predators. We randomly offered three prey types, i) *Tenebrio molitor* larvae, or ii) *Armadillidium granulatum* adults or iii) *Armadillo officinalis* adults. Soft and smaller preys were mainly predated while hard and large preys were mainly discarded. From our results, it is not still possible to infer that vibration per se has evolved to limit or avoid predation.

**Key words -** diet, Isopods, *Armadillo officinalis*, lizards, opportunistic behaviours

**Riassunto -** L. Di Vozzo, G. Montesanto, M.A.L. Zuffi, *Differenti tipi di preda possono influenzare le preferenze alimentari nelle lucertole?*

Lo spettro alimentare dei Lacertidi è stato ampiamente studiato in diverse aree geografiche, continentali, insulari and microinsulari. I dati sono particolarmente informativi e mostrano uno spettro trofico caratterizzato da artropodi, soprattutto da insetti, ma anche da altri taxa. Anche se meno rappresentati, sono stati trovati anche isopodi terrestri (Crustacea, Isopoda, Oniscidea). *Armadillo officinalis* ha un apparato stridulatore ed è in grado di produrre micro-vibrazioni, il cui significato e funzioni biologiche sono ancora poco conosciuti (diminuzione della predazione?). Altre specie di isopodi terrestri invece non producono vibrazioni. In specie del genere *Podarcis* sono stati raccolti resti di Isopodi, sebbene non ne sia stata ancora determinata l'identità tassonomica. Noi abbiamo considerato due specie di lucertola (*Podarcis muralis* e *P. siculus*) come predatori potenziali. Abbiamo somministrato in modo casuale tre tipi di preda a) larve di *Tenebrio molitor*, o b) adulti di *Armadillidium granulatum* o c) adulti di *Armadillo officinalis.* Sono state predate principalmente le prede soffici o di piccola taglia, mentre sono state in genere scartate le prede dure e di grandi dimensioni. Dai nostri risultati, non è ancora possibile sostenere che la vibrazione per sè si sia evoluta per limitare o per evitare la predazione da parte di un predatore di piccola taglia.

**Parole chiave -** dieta, Isopodi, *Armadillo officinalis*, lucertole, comportamenti opportunistici

## Introduction

The feeding spectrum of Lacertids has been widely studied in different geographical areas, continental, insular and microinsular (Pérez-Mellado & Corti, 1993; Carretero, 2004; Cooper, 2006). Available data are particularly informative and show a trophic spectrum mainly characterized by arthropods, where Insects are the majority, but some exceptions do exist, with lizards integrating their diet with fruit, seeds, flowers and pollen (Pérez-Mellado *et al.*, 2000), and occasionally even with small vertebrates, e.g. geckoes, lizards, shrews (Capula & Aloise, 2011; Zuffi & Giannelli, 2013). Among the number of preyed animals, terrestrial isopods (Crustacea, Isopoda, Oniscidea) have been recorded (Carretero, 2004; Castilla *et al.*, 2008).

In this suborder, the genus *Armadillo* is able to produce vibrations via a stridulatory apparatus (Caruso & Costa, 1976; Schmalfuss, 1996; Taiti *et al.*, 1998; Montesanto, 2018). *Armadillo officinalis* is the only species belonging to this genus in Italy. Despite the interest of this behaviour, the meaning and/or the biological function of the stridulatory apparatus of *A. officinalis* are still not completely known and under current investigation (Montesanto & Cividini, 2017, 2018; Montesanto, 2018; Cividini & Montesanto, 2018a, 2018b, 2018c, 2020; Cividini *et al.*, 2020). Indeed, while many arthropods (especially Insects), scorpions, and spiders are able to produce micro-vibrations (Cocroft & Rodríguez, 2005; Cividini & Montesanto, 2020), terrestrial crustaceans lack this ability, *A. officinalis* being the only exception as far as we are aware.

Isopods are known to be a component of *Podarcis* species diet, however which species these lizards can prey upon (Capula *et al.*, 1993) is still unknown. Consequently, we question if the *A. officinalis* micro-vibrations may avoid or reduce predation by lizards (*P. siculus* and *P. muralis*). Our preliminary experimental research has been aimed at verifying if lizards can select and discriminate preys characterized by different body hardness associated to vibrating or not vibrating

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properties. Another goal is to verify if *A. officinalis* uses the stridulation as defensive strategy in terms of vibrational aposematism.

## MATERIALS AND METHODS

The Italian wall lizard, *Podarcis siculus*, and the wall lizard, *Podarcis muralis*, are two medium size lizards, maximum snout to vent length, SVL, of 120 and 88 mm respectively (Biaggini *et al.*, 2011; Corti *et al.*, 2011), with evident sexual dimorphism, sharing a wide Italian distribution. In 2018 (from mid April to the end of May), we captured lizards in the surroundings of the Natural History Museum of Pisa, in Calci (Pisa), northwestern Italy, (43.721366 N, 10.521775 E). Lizards have been captured with noosing, measured (svl, snout to vent length, to the nearest mm), weighted (to the nearest gram), and photographed in laboratory, for individual recognition. Body size was analyzed for normality (Kolmogorov-Smirnov test) and then processed with Student-t test for independent samples. Each lizard was housed in an individual cage (40×30×25 cm) for 24 hours fasting, with a bowl of water and a shelter. All cages were placed in a room with large windows and natural light, therefore providing them a natural photoperiod. After fasting period, we randomly gave each lizard one of the three types of prey: meal worms, *Tenebrio molitor*, and the two woodlice, *Armadillidium granulatum* and *Armadillo officinalis*. The insect larva is the common food provided to captive/housed lizards; *A. granulatum* is a species of terrestrial isopod, belonging to the family Armadillidiidae which does not bear a stridulatory apparatus (Messina *et al.*, 2011, 2012, 2014; see also Zecchini & Montesanto, 2019, for further details on sampling and rearing); *A. officinalis* is a species of terrestrial isopod that can produce stridulations when rolled-up into a ball (Caruso & Costa, 1976; Cividini & Montesanto, 2018a, 2018b; Montesanto, 2018). We used similar size *A. granulatum* adults (12 mm) and similar size *A. officinalis* adults (16 mm).

We performed two experiments. In the first one we tested only males of both lizard species (33 *Podarcis muralis*; 9 *Podarcis siculus*) [males have larger heads and jaws and can prey larger and harder preys than females do (Herrel *et al.*, 1995; Carretero, 2004)] fed with all prey types, to verify any selection and discrimination among preys. Each individual lizard was tested once only. We analyzed results with $\chi^2$ test on the original frequencies. Then, we applied a General Linear Model with feeding (i.e.: male lizards feed or do not feed upon a given prey) as dependent variable, prey species (i.e.: the randomly offered preys) as factor and lizard size, i.e.: snout to vent length), as covariate. We ran separate analysis for each species, *Podarcis muralis* and *P. siculus*.

In the second experiment we tested males (6 *P. muralis*, 2 *P. siculus*) and females (5 *P. muralis*, 2 *P. siculus*) of both lizard species offering them only juvenile *A. officinalis* individuals, therefore limiting the constrain factor of large size of adult Isopods coupled with the rounded shape they assume when touched, disturbed or attacked (Caruso & Costa, 1976; Cividini & Montesanto, 2018a, 2018b; Montesanto, 2018). Size and shape of adults *A. officinalis* could in fact be considered a discriminating factor against predation of lizards, other than the production of micro-vibrations.

## RESULTS

As expected, *Podarcis muralis* is smaller in size than *Podarcis siculus* (Student $t_{svl} = -4.096$; 51 df; $P < 0.0001$; Student $t_{bmass} = -4.194$; 44 df; $P < 0.0001$), with males larger than females (Student t test, $bmass_{Pmuralis} = 3.995$, df 47, $P < 0.0001$; $svl_{Pmuralis} = 2.713$, df 54, $P = 0.009$). *P. siculus* differences were not provided, due to the limited female sample.

*Experiment 1.* All tested lizards (10 *P. muralis*, 4 *P. siculus*) preyed *T. molitor*; 10 lizards (*P. muralis*) out of 14 (13 *P. muralis*, 1 *P. siculus*) preyed *A. granulatum* (71.43%), 2 lizards (1 *P. muralis*, 1 *P. siculus*) out of 14 (10 *P. muralis*, 4 *P. siculus*) preyed *A. officinalis* (14.28%) ($\chi2 = 22.615$; 2 df; $P < 0.0001$). General Linear Model analysis for *Podarcis muralis* showed a significant effect of prey type ($F = 38.896$, 2 df; $P < 0.0001$), and significant covariation of SVL ($F = 18.260$, 1 df; $P < 0.0001$). General Linear Model analyses for *Podarcis siculus* showed no significant effect of prey type ($F = 4.150$, 2 df; $P < 0.087$), and no covariation of SVL ($F = 0.143$, 1 df; $P = 0.721$). On the contrary, there is a strong effect of the prey type×lizard size interaction ($P < 0.0001$), where the vibrating Isopod is on average discarded by all *P. muralis* and preyed just two times by *P. siculus*.

*Experiment 2.* All male lizards preyed all juvenile *A. officinalis*, while all female lizards did not prey the juvenile *A. officinalis*.

## DISCUSSION

This research, despite highly preliminary, has highlighted that, at least in our sampling area, larger (longer and heavier) lizards (of both species) have success in eating the available preys. Specifically, in experiment 1, soft (*Tenebrio* larvae) and smaller woodlice have been easily handled and eaten, while only some of larger and harder woodlice have been eaten by very large and heavy *Podarcis* (*P. siculus*). In experiment 2, when controlling for size of *A. officinalis*, all possible constrains recorded in experiment 1 were avoided and we did not observe any rejection by males of both species, suggesting that vibration *per se*, at least in this short experiment, has no actual effect on palatability in lizards. In addition, the inability of females in preying also these small preys may be attributable to the low bite force that female lizards possess (Herrel *et al*., 1995). Our preliminary results could mean that the stridulatory apparatus of *A. officinalis*, despite not evidently limiting the predation activity of an adult, large, male lizard, does not allow us to exclude *a priori* its supposed function of defence by predators, at least not in our tested lizards. In case of females, one can argue that vibration could avoid predation or, simply, that female head and bite force (see Herrel *et al*., 1995) are not strong enough to handle, crush and swallow such a prey. However, as alternative scenario, we can hypothesize, that the stridulatory apparatus of juveniles of *A. officinalis* is not functional (see also Montesanto, 2018) or, if functional, it is not properly used due to the early age of the animals, thus allowing predation also by small lizards. However, we should verify in the future if the partial exclusion of the vibrating species is actually a simple effect of the larger size of *A. officinalis* with respect to *A. granulatum*, or a direct consequence of the vibrating feature of the Crustacean. Infact, more data shall be necessary and other experiments needed in order to clarify these aspects, testing other predators such as spiders, centipedes, mice and birds. Biotremology is still a new field of research for zoologists (and isopodologists) and the stridulatory behaviour known for this species also needs to be better understood in terms of vibrational aposematism.

## Author contributions

LDV sampled the lizards and carried out the experimental part of data collection; GM had the idea of these experiments, collected and managed the two species of woodlice. MALZ dealt with the study design, sample size calculation, sampling of lizards, graphical and statistical analysis of data. All the authors drafted the manuscript, carried out the bibliographic searches, read, reviewed and approved the final manuscript. LDV and GM are both first author.

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## References

Biaggini M., Bombi P., Capula M., Corti C., 2011. *Podarcis muralis* (Laurenti, 1768). In: Corti C., Capula M., Luiselli L., Razzetti E., Sindaco R., Fauna d'Italia 47. *Reptilia*: 391-401. Ministero dell'Ambiente e Tutela del Territorio, Direzione Protezione della Natura. Calderini Gruppo 24 Ore, Bologna.

Capula M., Aloise G., 2011. Extreme feeding behaviours in the Italian wall lizard, *Podarcis siculus*. *Acta Herpetologica* 6: 11-14.

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? *Bollettino di Zoologia* 60: 287-291.

Carretero M.A., 2004. From set menu to *a la carte*. Linking issues in trophic ecology of Mediterranean lacertids. *Italian Journal of Zoology* 71: 121-133.

Castilla A.M., Vanhooydonck B., Catenazzi A., 2008. Feeding behaviour of the Columbretes lizard *Podarcis atrata*, in relation to Isopoda (Crustaceae) species: *Ligia italica* and *Armadillo officinalis*. *Belgian Journal of Zoology* 138: 146-148.

Caruso D., Costa G., 1976. L'apparato stridulatore e l'emissione di suoni in *Armadillo officinalis* Duméril (Crustacea, Isopoda, Oniscoidea). *Animalia* 3: 17-27.

Cividini S., Montesanto G., 2018a. Changes in turn alternation pattern in response to substrate-borne vibrations in terrestrial isopods. *Behavioural Processes* 146: 27-33. https://doi.org/10.1016/j.beproc.2017.11.005

Cividini S., Montesanto G., 2018b. Differences in the pattern of turn alternation between juveniles and adults of *Armadillo officinalis* Dumèril, 1816 (Isopoda, Oniscidea) in response to substrate-borne vibrations. *Acta Ethologica* 21: 59-68. https://doi.org/10.1007/s10211-018-0282-y

Cividini S., Montesanto G., 2018c. Aggregative behavior and intraspecific communication mediated by substrate-borne vibrations in terrestrial arthropods: An exploratory study in two species of woodlice. *Behavioural Processes* 157: 422-430. https://doi.org/10.1016/j.beproc.2018.07.006

Cividini S., Montesanto G., 2020. Biotremology in arthropods. *Learning & Behavior* 48: 281-300. https://doi.org/10.3758/s13420-020-00428-3

Cividini S., Sfenthourakis S., Montesanto G., 2020. Are terrestrial isopods able to use stridulation and vibrational communication as forms of intra and interspecific signaling and defense strategies as insects do? A preliminary study in armadillo officinalis. *The Science of Nature* 107: 4. doi:https://doi.org/10.1007/s00114-019-1656-3

Cocroft R.B., Rodríguez R.L., 2005. The behavioral ecology of insect vibrational communication. *Bioscience* 55: 323-334.

Cooper W.E., 2006. Foraging modes as suites of coadapted movement traits. *Journal of Zoology, London* 272: 45-46.

Corti C., Biaggini M., Capula M. 2011. *Podarcis siculus*, Rafinesque-Schmaltz, 1810). In: Corti C., Capula M., Luiselli L., Razzetti E., Sindaco R., Fauna d'Italia 47. *Reptilia*: 407-417. Ministero dell'Ambiente e Tutela del Territorio, Direzione Protezione della Natura. Calderini Gruppo 24 Ore, Bologna.

Herrel A., Van Damme R., De Vree F., 1995. Sexual dimorphism of head size in *Podarcis hispanica atrata*: testing the dietary divergence hypothesis by bite force analysis. *Netherland Journal of Zoology* 46: 253-262.

MESSINA G., MONTESANTO G., PEZZINO E., CARUSO D., LOMBARDO B.M., 2011. Diversity of terrestrial isopods in a protected area characterized by salty coastal ponds (Vendicari, Sicily). *Journal of Natural History* 45: 2145-2158.

MESSINA G., PEZZINO E., MONTESANTO G., CARUSO D., LOMBARDO B.M., 2012. The diversity of terrestrial isopods in the natural reserve "Saline di Trapani e Paceco" (Crustacea, Isopoda, Oniscidea) in northwestern Sicily. *Zookeys* 176: 215-230.

MESSINA G., MONTESANTO G., PEZZINO E., SCIANDRELLO S., CARUSO D., LOMBARDO B.M., 2014. Plant communities preferences of terrestrial crustaceans (Isopoda: Oniscidea) in a protected coastal area of southeastern Sicily (Italy). *Biologia* 69: 354-362.

MONTESANTO G., 2018. Presence of a stridulatory apparatus in the manca stages of isopods (Crustacea, Isopoda, Oniscidea). *Zookeys* 801: 501-518. https://doi.org/10.3897/zookeys.801.23018

MONTESANTO G., CIVIDINI S., 2017. A crossover design to assess feeding preferences in terrestrial isopods: a case study in a Mediterranean species. *Biologia* 72: 194-203. https://doi.org/10.1515/biolog-2017-0020

MONTESANTO G., CIVIDINI S., 2018. The molt cycle of the terrestrial isopod *Armadillo officinalis* Duméril, 1816 (Crustacea: Isopoda: Oniscidea). *Acta Zoologica* 99: 263-273. https://doi.org/10.1111/azo.12210.

PERÉZ-MELLADO V., CORTI C., 1993. Dietary adaptation and herbivory in lacertid lizards of the genus *Podarcis* from Western Mediterranean islands (Reptilia: Sauria). *Bonner zoologische Beitrage* 44: 193-220.

PÉREZ-MELLADO V., ORTEGA F., MARTÍN-GARCÍA S., PERERA A., CORTÁZAR G., 2000. Pollen load and transport by the insular lizard, *Podarcis lilfordi* (Squamata, Lacertidae) in coastal islets of Menorca (Balearic islands, Spain). *Israel Journal of Zoology* 46: 193-200.

SCHMALFUSS H., 1996. The terrestrial isopod genus *Armadillo* in western Asia (Oniscidea: Armadillidae) with descriptions of five new species. *Staatliches Museum für Naturkunde* A 544: 1-43.

TAITI S., PAOLI P., FERRARA F., 1998. Morphology, biogeography, and ecology of the family Armadillidae (Crustacea, Oniscidea). *Israel Journal of Zoology* 44: 291-301. https://doi.org/10.1080/00212210.1998.10688952

ZECCHINI A., MONTESANTO G., 2019. Description of the postmarsupial manca stages of *Armadillidium granulatum* (Crustacea, Isopoda, Oniscidea). *Invertebrate Reproduction & Development* 63: 30-39. https://doi.org/10.1080/07924259.2018.1514329

ZUFFI M.A.L., GIANNELLI C., 2013. Trophic niche and feeding biology of the Italian wall lizard, *Podarcis siculus campestris* (De Betta, 1857) along western Mediterranean coast. *Acta Herpetologica* 8: 35-39.

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