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Feeding behaviour of the Columbretes lizard *Podarcis atrata*, in relation to *Isopoda* (*Crustaceae*) species: *Ligia italica* and *Armadillo officinalis*

Aurora M. Castilla[1,2*], Bieke Vanhooydonck[3] & Alessandro Catenazzi[4]

[1] **Estación Biológica de Sanaüja, Museo Nacional de Ciencias Naturales (CSIC). Ap. Correos nº 35, E-25280 Solsona, Lleida, España. e-mail: aurora@mncn.csic.es**

[2] **Dept. Biodiversity and Evolutionary Biology, National Museum of Natural Sciences (CSIC), C/ José Gutiérrez Abascal 2, E-28006 Madrid, Spain. e-mail: aurora@mncn.csic.es**

[3] **Laboratory of Functional Morphology, Department of Biology, University of Antwerp, Campus Drie Eiken, B-2610 Antwerp, Belgium e-mail: bieke.vanhooydonck@ua.ac.be**

[4] **Integrative Biology, University of California Berkeley, 3060 Valley Life Sciences Bldg #3140, Berkeley CA 94720, USA e-mail: acatenazzi@gmail.com**

Corresponding author : * Aurora M. Castilla. Estación Biológica de Sanaüja, Museo Nacional de Ciencias Naturales (CSIC). Ap. Correos nº 35, E-25280 Solsona, Lleida, España. e-mail: aurora@mncn.csic.es

ABSTRACT. The lizard *Podarcis atrata*, endemic to the Columbretes archipelago (Mediterranean, Spain) occupies very small islands characterized by extreme aridity and a reduced availability of potential insect prey. The results of an experimental study have shown that adult lizards offered individuals of *Ligia italica* and *Armadillo officinalis* (marine and terrestrial isopods, respectively) consumed at high frequencies; with males consuming them at significantly higher frequencies than females. The results are discussed in light of the importance of the inclusion of marine prey into the diet in arid insular ecosystems.

KEY WORDS : island, intertidal trophic resources, endemic lizard, arid zones

INTRODUCTION

The endemic lizard *Podarcis atrata* from the Columbretes archipelago (Mediterranean, Castellón, Spain), inhabits very small islands ranging from 0.5 to 13 hectares. The islands are characterized by extreme aridity and by the scarcity of terrestrial insects (see CASTILLA & BAUWENS, 1991). Adult lizards have been observed near shore feeding on seabird regurgitates, and scavenging on carcasses and gull eggs on several islands of the archipelago (CASTILLA et al., 1987). Lizards from arid coastal areas across the world are important consumers of marine and intertidal trophic resources (amphipods, crabs, shells, flies, etc) (Table 1). It is generally assumed that the inclusion of marine resources into the diet is promoted by the lack of other food resources (POLIS & HURD, 1996; BARRET el al., 2005; CATENAZZI et al., 2005; CATENAZZI & DONNELLY, 2007).

The isopod *Ligia italica* is very abundant on Columbretes, and inhabits rocky substrates from 0 to 12 meters above sea level. In some areas, lizards and isopods utilize the same rocks, thus facilitating predator-prey interactions. However, observations of the consumption of *L. italica* by *P. atrata* individuals under natural conditions are difficult because both species are very wary on exposed rocks without vegetation cover and a high abundance of bird predators. Moreover, lizards are very difficult to capture on vertical, eroded cliffs. Consequently, no data are available on stomach contents for animals living near shore. We decided to use an experimental approach similar to that employed in a previous study to examine the cannibalistic propensities of lizards on the same island (CASTILLA & VAN DAMME, 1996). We measured the willingness of *P. atrata* individuals to consume the marine isopod *Ligia italica* and the terrestrial one *Armadillo officinalis*, which is morphologically similar and has been found in the stomach contents of *P. atrata* (CASTILLA et al., 1987).

MATERIALS AND METHODS

The study was conducted on the island Columbrete Grande during the fist week of June 2006. We captured adult isopods of *L. italica* at the sea shore and offered them to free ranging adults of *P. atrata* living in vegetated areas of the island near human habitation where the lizards are abundant and used to human presence. Observations were conducted between 0900-1200 hours, with ambient temperature ranging from 20–22ºC, and relative humidity from 72-84%.

To be sure lizards were hungry at the time of the experiment we first offered them a mealworm (a preferred prey) attached to a noose. If the reaction of the lizard to the mealworm was positive (e.g. direct attack), we removed the mealworm from the noose and replaced it with an individual of *L. italica* (length x width ca. 15 x 6mm; 0.15g). We tested only adult lizards (svl=60-70mm, mass=5-9g) of both sexes. After each presentation we observed the reaction of the lizard and registered its behaviour (Table 2). We also recorded the handling time, as the time from the moment the lizard captured its prey to the moment the lizard completed ingestion. After three days we repeated the same experiment using terrestrial isopods, *A. officinalis* (length x width ca. 10x5mm; 0.05g) that were captured under rocks near human habitation.

TABLE 1

Insular and coastal lizards that include marine input in their diet. Note that there are only data for one species from the Mediterranean (present study).

Species (Reptilia: Squamata)	Zone	Reference
Amblyrhynchus cristatus	Galapagos	DUNSON, 1969
Callisaurus draconoides	Baja California	QUIJADA-MASCAREÑAS, 1992
Cryptoblepharus bautony	Madagascar	FRICKE, 1970
Leiolopisma suteri	New Zealand	TOWNS, 1975
Microlophus peruvianus	Peru	VOGT, 1939
Phyllodactilus angustidigitu	Peru	CATENAZZI & DONNELLY, 2007
Uta spp.	Gulf of California	SOULÉ, 1966
Uta antiqua	Gulf of California	BALLINGER & TINKLE, 1972
Uta encantadae	Gulf of California	GRISMER, 1994
Uta lowei	Gulf of California	GRISMER, 1994
Uta palmeri	Gulf of California	WILCOX, 1980
Uta stansburiana	Gulf of California	BARRETT et al., 2005
Uta tumidarostra	Gulf of California	GRISMER, 1994
Podarcis dugesii	Atlantic, Madeira	DAVENPORT & DELLINGER, 1995
Podarcis atrata	Mediterranean, Columbretes	present study

TABLE 2

Behavioural response of free living adult males and females of *Podarcis atrata* following presentation of individuals of two different *Isopoda (Crustacea)* prey attached to a noose. For each different lizard the first immediate reaction was recorded. The results are expressed in percentages (%), and sample size given (n).

P. atrata response	*Ligia italica*				*Armadillo officinalis*			
	Males (n=18)		Females (n=10)		Males (n=20)		Females (n=18)	
	n	%	n	%	n	%	n	%
Ignore	0	0	4	40	2	10	5	28
Observe-ignore	1	6	2	20	1	5	2	11
Observe-attack-eat	3	17	1	10	5	25	1	6
Direct attack- eat	13	72	3	30	11	55	10	56
Direct attack- not eat	1	6	0	0	1	5	0	0

Differences in response (consumption of the prey or not) towards the two different prey items (*L. italica* or *A. officinalis*) by lizards of both sexes were analysed with a binomial regression (i.e., generalized linear model) with a probit link function to examine the putative effects of prey, sex and their interaction, using the program S-Plus. We also tested for differences in handling time between prey species using an analysis of variance. Prior to performing the one way ANOVA's we logarithmically transformed (log10) handling times.

RESULTS

In all cases (n=66) males and females reacted to the mealworm by directly attacking it. After that, most males consumed the isopod *L. italica* (89%), 72% attacking the prey directly without previous observation (Table 2). Most females (60%) ignored the specimen of *L. italica* offered, and only 40% of the females actually consumed them. Most males consumed the offered individuals of *A. officinalis* (80%), 55% attacking them directly without previous observation. Some females (39%) ignored this prey while 61% consumed the terrestrial isopod (Table 2).

We did not find a significant interaction effect between sex and prey ($t=1.2909$; $P>0.05$). However, the analysis showed a significant effect of sex ($t=2.8711$; $P<0.01$): males consumed both isopods species at higher proportions (*L. italica*=89%, *A. officinalis*=80%) than did females (*L. italica*=40%, *A. officinalis*=61%).

Handling time for consumption of the isopod *L. italica* was only measured for male lizards, and ranged from 22 seconds to 1 minute (mean=40.1sec; sd=13.6; n=13). Handling time of specimens of *A.officinalis* by male lizards ranged from 12 to 38sec (mean=23.9sec; sd=7.7; n=9), and the difference was significant ($F_{1, 26}=9.38$; $p=0.005$). The mean ingestion time of specimens *A. officinalis* was longer for female lizards (mean=27.6sec; sd=14.1; n=7) than it was for males (23.9sec) but the difference was not significant ($F_{1, 14}=0.11$; $p=0.75$).

DISCUSSION

The results of our study show that, in our experimental conditions, both sexes of the lizard *P. atrata* consumed the marine isopod *L. italica* in the same proportion as the terrestrial *A. officinalis.* However, males were more inclined to consume both prey types than females. In June, 80% of the females were pregnant, and they may be more selective for food during that stage. Additional experiments outside the breeding season would help to better interpret our results.

Handling time for males was lower for specimens of *A. officinalis* (24sec) than those of *L. italica* (40sec). In addition we observed one male ingesting three specimens of

A. officinalis, one after the other. For this individual, ingestion time was variable (22.41sec; 31.91sec and 24.64sec), suggesting that a larger sample size may be needed.

A longer handling time for specimens of *L. italica* could be related to the larger size of this species (ca. 5mm larger than individuals of *A. officinalis*). However, we believe that these differences were mainly due to the fact that a specimen of *L. italica* was sometimes thrown to the ground and picked up again by both males and females. Unfortunately, we could not quantify the "rejection behaviour" shown by six individuals. Interestingly, rejection behaviours were not observed with offered individuals of *A. officinalis*. Terrestrial isopods such as *A. officinalis* are abundant species in the vegetated and humid zones of the island, and are frequently consumed by *P. atrata* (Castilla et al., 1987) and other lizards (Carretero, 2004).

To test the importance of marine prey resources in the diet of *P. atrata*, future studies should include the analysis of stomach contents of lizards living near the seashore. Alternatively, stable isotope analysis could be used (e.g., Catenazzi & Donnelly, 2007) to test for the importance of the marine subsidies into the terrestrial ecosystem at the Columbretes islands. The only other data on European lizards utilising marine resources are for *Podarcis dugesi* on Madeira Island (Atlanic, Portugal; see Davenport & Dellinger, 1995). However, as there are many islands in the Atlantic and the Mediterranean seas holding lizard populations, the use of marine trophic resources to survive or complement the diet of lizards is likely more common. Indeed, our observations suggest that marine invertebrates may be an important food source for lizards living in harsh conditions on small islands.

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