

Seasonal consumption of insects by the crested porcupine in Central Italy

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Abstract

Many herbivorous, granivorous and frugivorous rodents can integrate animal proteins in their diet, still for many of them no information is available on the importance of animal food sources. The crested porcupine, *Hystrix cristata*, is considered a strictly vegetarian rodent. It may integrate animal proteins through bone-gnawing, while the importance of insects in his diet is poorly known. In this study we assessed the presence of insects in the diet of this rodent in Central Italy by collecting 141 faecal samples along transects in 2016–2020. Hypogeal plant organs were the main component of the diet (absolute frequency = 50.38%; volume = 60.13%). Insects were detected only in 6.8% samples, only in February–March, at the annual birth peak for the crested porcupine. Insect consumption, although occasional, could be linked to the nutritional requirements of this rodent during lactation.

Keywords: [entomophagy](#); [Hystrix cristata](#); [lactation](#); [nutritional requirements](#)

Despite being classified as mostly herbivorous species, frugivorous and granivorous rodents are known to integrate animal proteins in their diet ([Landry 1970](#); [White 2007](#)) as a physiological response to environmental and life-cycle conditions. Several small rodents integrate animal proteins (i.e. insects, carcasses) into their diets shortly before hibernation, when they need storage substances (e.g. the garden dormouse, *Eliomys quercinus* Linnaeus, 1766; [Díaz-Ruiz et al. 2018](#)), or when seeds are not available (e.g. bush rats, *Rattus fuscipes* (Waterhouse 1839), in the dry season in Australian deserts; [Watts and Braithwaite 1978](#)). Conversely, rats *Rattus* spp. and house mice *Mus domesticus* Linnaeus, 1758 may eat insects when they are locally available, with no reference to their physiological status ([Mori et al. 2019a, 2019b](#)). Large-sized rodents, e.g. capybaras *Hydrochoerus*

hydrochaeris Linnaeus 1766, coypus *Mycocastor coypus* (Molina 1782) and porcupines (Hystricidae), are generally assumed to have a strictly herbivorous diet ([Barreto and Quintana 2013](#); [Bruno and Riccardi 1995](#); [Hafeez et al. 2011](#); [Prigioni et al. 2005](#); [Woods 1973](#)). [Landry \(1970\)](#), in a review of the literature of the feeding habits of rodents, reported that many species in all major lines of rodent evolution are, surprisingly, at least partly carnivorous, piscivorous, or insectivorous and he argued that the primitive adaptation of the rodent mandibulo-dental apparatus was for an omnivorous diet rather than a herbivorous one. Among the Hystricomorpha, the consumption of insects is present in the African brush-tailed porcupine *Atherurus africanus* Gray, 1842 who can eat crickets and in *Cryptomys* sp. who may consume beetle larvae and termites.

The crested porcupine *Hystrix cristata* L. is the largest Italian rodent; its distribution also includes North Africa and a sub-Saharan belt ranging from Senegal to Ethiopia and Tanzania ([Mori et al. 2019a, 2019b](#)). Despite this broad distribution range, scant information is available on its diet and most of the published research on this topic rely on data collected in Central Italy ([Bruno and Riccardi 1995](#); [Lovari et al. 2017](#); [Mori et al. 2017a](#), but see also [Ettiss et al. 2020](#) for Tunisian data). Underground storage organs (e.g. roots, bulbs, tubers, rhizomes) are the staple of the diet of this species in woodland and other rural environments, whereas fruits are mostly consumed in suburban areas ([Bruno and Riccardi 1995](#); [Lovari et al. 2017](#); [Mori et al. 2017a](#)). Thus, the crested porcupine is typically an herbivorous rodent which may feed on a high variety of natural and cultivated species ([Laurenzi et al. 2016](#); [Zavalloni and Castellucci 1994](#)), depending on their seasonal availability, sometimes contributing to their spread through endozoochory ([Mori et al. 2017b](#)). At birth peak (i.e. February–March in Italy: [Mori et al. 2016](#)), mostly female porcupines gnaw bones of wildlife, eggshells and sometimes limestone rocks so to increase calcium and phosphorous supply during lactation ([Kibii 2009](#); [Landry 1970](#); [Mori et al. 2018](#)). [Coppola et al. \(2020\)](#) provided crested porcupines with carcasses of pigeons, which were partly consumed in four cases, suggesting also a scavenging behavior, despite no record of animal consumption is available from scat analyses. Here we aimed at reporting the first evidence of insect consumption by the crested porcupine assessed through scat analyses, during the period of lactation. Moreover, we compared our data with those of previous studies on the diet of this species.

Our study was conducted in the northernmost part of the province of Grosseto (Central Italy, Special Conservation Area “Poggi di Prata”; altitude: 475–903 m a.s.l.; about 185 ha: [Mori et al. 2017b](#)). This rural hilly area is mostly covered by a mesophilic mixed deciduous woodland (77%) and scattered fallows (about 19%: [Mori et al. 2017b](#)). The climate is sub-montane, with median annual temperature of 13.9 °C (Q_1 – Q_3 = 7.9–19.0 °C: [Mori et al. 2017b](#)). Two periods were recognized according to ambient temperature: a warm one (April–September) and a cold one (October–March). We searched for porcupine droppings (i.e. faecal pellets) once a month between March 2016 and March 2020, along routes (total = 10.4 km/month) used by porcupines previously identified through radio-tracking ([Mori et al. 2017b](#)). Porcupine droppings are cylindrical or olive-shaped pellets varying in length from 1.5 to 2.5 cm long, thus larger than those by deer species (Cervidae) but smaller than those of coypus *Myocastor coypus* (Molina 1782). Droppings were analyzed following [Lovari et al. \(2017\)](#) by using a solution of NaOH 0.06 M to dissolve the external mucous film (10–20 min at 40 °C). Then, we washed each sample through a fine mesh sieve (1 mm²). Fragments from washed samples were visually separated according to six food categories (monocotyledonous herbs; dicotyledonous herbs; underground storage organs; fruits; vegetables; insects) and identified by eye or through a stereomicroscope (WILD M3C, Heerbrugg: 400×), by comparing them with local reference collections. Insects included Coleoptera, Hymenoptera (Formicidae) and Diptera. We then estimated volumes of each food category by water displacement ([Jackson 1980](#)), with a 7-level scale (absent, <5, 6–25, 26–50, 51–75, 76–95, >96%: [Kruuk and Parish 1981](#)). Absolute frequencies (i.e. number of occurrences of each food category, when present/total number of faecal samples × 100) and volumes of each food category were then plotted on isopleth graphs ([Kruuk 1989](#)). The Levins’ standardised index (B_{STA}) was used to calculate the trophic niche breadth through the formula $B_{STA} = (B - 1)/(B_{max} - 1)$, where B is the Levins’ index and B_{max} is the total number of prey categories; B_{STA} ranges between 0 and 1 ([Bocci et al. 2017](#)). The Pianka index (O_{jk} : [Pianka 1974](#)) was used to assess the trophic niche overlap among our study and previous study on porcupine diet ([Bruno and Riccardi 1995](#); [Lovari et al. 2017](#); [Mori et al. 2017a](#); [Ettiss et al. 2020](#)). The Pianka index was computed with the formula $O_{jk} = [\sum(p_{ij} \times p_{ik})]/[(\sum p_{ij}^2 \times \sum p_{ik}^2)^{1/2}]$, where p_{ij} and p_{ik} represents relative frequencies (i.e., number of occurrences of each food category, when present/total number of occurrences

of all food items $\times 100$) of each food category i , respectively in the study “ j ” and in the study “ k ”.

We analysed a total of 141 faecal pellets, and we observed that the local diet of the crested porcupines was mostly composed by underground storage organs (absolute frequency = 50.38%; volume = 60.13%). Insects were detected in 6.8% samples, all collected in February–March ([Figure 1a](#)). The trophic niche breadth was similar to previous works on this species ($B_{STA} = 0.40$). Insects included coleopteran larvae of false wireworms belonging to the Tenebrionidae family (in four samples), dipteran larvae (in three samples) and hymenopterans (Formicidae: *Lasius emarginatus* and *Messor capitatus*, in six samples). Although we cannot exclude the hypothesis of accidental ingestion, all the insect larvae are harmless and showed signs of chewing. Indeed, false wireworms and dipteran larvae are usually some of the most common insects which have been used with the purpose to produce food and feed, also for human consumption ([Van Huis et al. 2013](#)). Throughout the year, insects contributed to the 10% of total diet of the porcupine ([Figure 1b](#)). A high index of trophic niche overlap was found between our results and all other areas, with underground storage organs as the main component of the diet in all the populations except for the suburban area ([Table 1](#)).

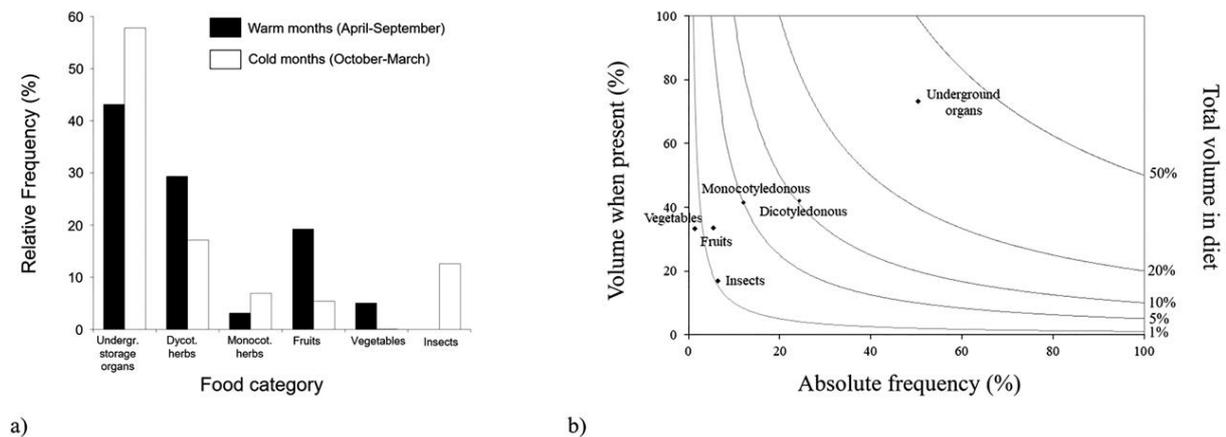


Figure 1: (a) Relative frequency of the six food categories in the diet of the crested porcupine in our study area. (b) Diet of the crested porcupine: absolute frequency plotted *versus* volume of each food category, when present. Isopleths connect points of the same total volume in diet.

Table 1: Trophic niche overlap between the present study and all other published works on the diet of the crested porcupine: rural area (Bruno and Riccardi 1995), suburban area (Lovari et al. 2017), scrubland area (Mori et al. 2017a), subdesert area (Ettiss et al. 2020).

	Our study	Rural area	Suburban area	Scrubland area	Subdesert area
Our study	-	0.98	0.63	0.94	0.91
Rural area	-	-	0.63	0.93	0.90
Suburban area	-	-	-	0.82	0.52
Scrubland area	-	-	-	-	0.88
Subdesert area	-	-	-	-	-

Fore limb structure and the rodent teeth make the crested porcupine an adept digger and consumer of underground organs, with an excellent ability to extract roots (Mori et al. 2017b). The high consumption of roots (including bulbs, tubers and rhizomes) found in this study confirms results from other rural areas covered by woods or scrubs where human pressure was low (Bruno and Riccardi 1995; Ettiss et al. 2020; Mori et al. 2017a). Conversely, in suburban areas, where poaching is known to occur (Lovari et al. 2017), porcupines feed mostly on epigeal plant parts and fruits, which represent nutrient trophic resources, readily available and spatially clumped (Lovari et al. 2017). This may explain the limited trophic niche overlap between the suburban areas and all the other study sites. Where human pressure is the highest, i.e. in suburban and urban areas, porcupines directly feed on epigeal food items, mostly including fruits and herbs, to increase vigilance time. Accordingly, digging for roots and bulbs is time-consuming and requires concentration, which may be dangerous where predation and poaching pressure are high (Lovari et al. 2017). Moreover, in urban and suburban areas impervious artificial surfaces including concrete and paved roads prevent porcupine to dig. Vegetables and cultivated plants were only consumed in warm months, but serious damages only occur in small vegetable or private gardens (Laurenzi et al. 2016). This negligible crop damage is related to a good local tolerance for the crested porcupine and, presumably, to a reduced level of poaching (Cerri et al. 2017), which could help explain the high consumption of underground organs, requiring time for excavation, throughout the year. For the first time, remains of insects were also found in the diet of the crested porcupine. Although numbers are not so high to suggest an active research, insect consumption indicates that porcupines may need to integrate in their diet elements rich in calcium and phosphorus, particularly at their birth peak (Mori et al. 2018) or, at least, they do not avoid to ingest harmless insects which may provide them with supplemental proteins. Insects consumed by porcupines are common ground-dwelling species of wooded environments (cf. Keis et al. 2019) and in the case of the false wireworms, the larvae feed in the surface layers of the soil

on roots or gnaw the stems of plants just below the surface of the ground ([Allsopp 1980](#)), thus are probably intercepted by porcupines during the feeding behavior. Previous studies on porcupine diet did not report any insects, despite having been conducted throughout the year ([Bruno and Riccardi 1995](#); [Ettiss et al. 2020](#); [Lovari et al. 2017](#); [Mori et al. 2017a](#)).

Old World porcupines are monogamous rodents, showing socio-sexual behaviors even outside the reproductive period, to maintain pair bonds ([Mori et al. 2016](#)). In Italy, reproduction of the crested porcupine can occur throughout the year, but the peak of births has been recorded in February ([Mori et al. 2016](#)). In this period of the year, a peak of bone-gnawing by females was also detected, most likely to integrate calcium and phosphorus in the diet during lactation ([Mori et al. 2018](#)). Consistently, the consumption of insects also occurs on this period of the year, most likely due to female nutritional needs in the last weeks of gestation ([Carlson 1940](#); [Pillay et al. 2015](#)). In laboratory experiments, calcium and phosphorus have been recognized to be essential components in the porcupine diet ([Duthie and Skinner 1986](#)). Accordingly, in natural environments, insects and bones seem to be mostly consumed when diets are low in phosphorus and calcium ([Keis et al. 2019](#); [Pillay et al. 2015](#)). The role of bones and insects as a source of minerals and proteins for wild herbivorous mammals has also been described for ungulates and rodents ([Càceres et al. 2013](#); [Grasman and Hellgren 1993](#); [Mitchell et al. 2005](#); [Schmidt and Hood 2012](#)). Findings highlighted in this note set the stage for further physiological research on mineral and protein acquisition by crested porcupines.

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