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Research Article

Food Preferences of the Crested Porcupine *Hystrix cristata* L., 1758 (Rodentia: Hystricidae) in South-Eastern Tunisia

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Abstract: The present work is focused on the diet of the crested porcupine *Hystrix cristata* L., 1758 in South-Eastern Tunisia. Feeding habits of this species were assessed through faecal analysis in both cold and warm months: 105 samples of faecal pellets of porcupine were collected during two seasons. We found that wild species dominated the diet of this large rodent in both seasons, represented by 15 species. The most frequently recorded species in both seasons were *Stipa lagascae* (20.54%), *Hedysarum carnosum* (10.26%) and *Hordeum marinum* (9.69%). In summer, the diet included also potatoes (*Solanum tuberosum*), barley (*Hordeum vulgare*) and figs (*Ficus carica*), of which barley was the most common species.

Key words: *Hystrix cristata* , feeding habits , faecal analysis , South-Eastern Tunisia.

Introduction

Rodents represent an important link between plants and predators (Botkin & Mellilo 1981). Previous studies have shown that herbivores have important role in regulating biological processes at different temporal and spatial scales (e.g. Seagle et al. 1992). They can affect the production of an ecosystem through food selection, which can change the structure of the plant communities (Zimmerman & Neuenschwander 1984, Belsky & Blumenthal 1997). The porcupine *Hystrix cristata* L., 1758 (Rodentia: Hystricidae) is a protected rare species in Tunisia (Bernard 1969, Cuzin 2003, Mohamed 2011). It is a herbivore rodent, which is a subject of growing interest in agrosystems, especially in farms suffering from damages caused by this species on vegetable crops. However, there is a lack of information on the biology of the porcupine in Africa, both in general and in Tunisia. Contrary, several studies concerning the diet of *H. cristata* have been carried out in Italy (Santini 1980, Pigozzi & Patterson 1990, Bruno & Riccardi 1995, Lucherini & Lovari 1996, Massei et al. 1997, Bozzi & Lovari 1999, Lovari et al. 2013, 2017, Mori et al. 2014a, 2017).

Knowledge of diet of wild mammals in their natural environment is of fundamental interest for understanding the ecology and organising the management of species and habitats (Symondson 2002, Krahn et al. 2007). Two main approaches have been used ub studying diet of mammals: the "direct" approach, based on the observation of animals during their feeding phase, and the "indirect" approach, based on analyses of faeces or samples taken from digestive system of animals. Historically, the application of the indirect approach in dietary studies of a number of species relies on the identification of the stomach contents of killed individuals (Murie & Lavigne 1986, Perez & Bigg 1986). More recently, emphasis has been placed on the development of alternative non-destructive methods for determining diets (Butet 1987,

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Pierce & Boyle 1991, Baubet 1998, Iverson et al. 2004). In fact, there has been a growing interest in methods of coprological analysis and have largely replaced the analysis of stomach contents in the study of the diet of wild species (Holechek et al. 1982, Dellinger & Trillmich 1988, Bowen 2000, Tolllit et al. 2004).

In this context, our work explores food preferences of *H. cristata* in South-Eastern Tunisia during winter and summer.

Materials and Methods

Study area

This study was carried out in two governorates in South-Eastern Tunisia: Medenine and Tataouine. The study area included 60,973 km² (37.2% of the country; Fig 3) and spanned from Djerba (33°45'N, 10°47'E) and Fjaa (33º30'N, 10º38'E) in the north, to Ferech (32º57'N, 10º21'E) and Bir Amir (32º34'N, 10º16'E) in the south. The climate is arid to hyper-arid-Saharan. The mean temperatures range 10–12°C in winter, 18–20°C in spring, c. 30°C in summer and 20–22°C in autumn. The number of rainy days is relatively low but the intensity of the rains is very high. The vegetation is mostly steppe but the species composition is highly variable depending on relief and soil type. In the mountain zone, the vegetation cover is mostly made of *Stipa tenacissima, Artemisia herba alba, Reaumuria vermiculata* and *Gymnocarpos decander*. This is a result of the degradation of *Pinus halepensis, Juniperus phoenica* and *Pistacia atlantica*, which completely vanished in the area due to a long history of tree harvesting. Moving down from the hills*, Hammada scoparia* and *Helianthe-man kahiricum* replace *Stipa tenacissima*. Olives are grown in both jessour and tabias, being a dominant tree crop in the watershed. The wadi beds and water courses are characterised by high biodiversity, in particular plant species richness. The dominant species are *Retama retaem, Nerium oleander, Pennissetum elatum, Marrubium deserti, Juncus maritimus, Cenchrus ciliaris, Rhanterium suaveolens* and *Thymus adriensis* (Hanafi & Ouled Belgacem 2006).

Data collection

Since the porcupine is a rare species in Tunisia, the opportunities to collect faecal pellets of this species are rather scarce. During two pellet-collection sessions (winter 2016 and summer 2017), 105 samples were taken at random in the study area and stored in a freezer in plastic bags. Droppings of porcupines are

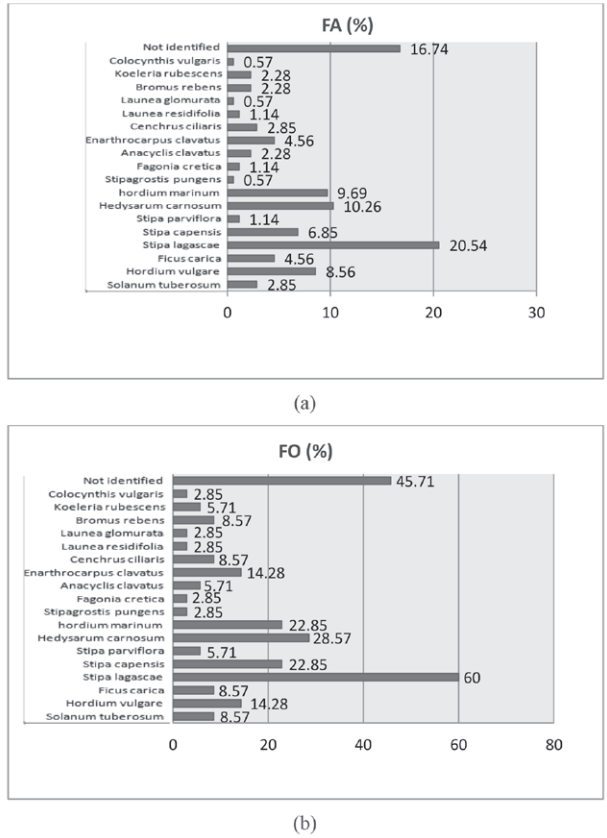

Fig. 1. Relative frequencies of appearance – FA (a) and frequencies of occurrence – FO (b) of plant species in the diet of the porcupine in SE Tunisia.

easily distinguishable from those of other species, as they take the form of a series of stacked pellets (Barthelmess 2006). The diet composition of *H. cristata* was determined using the microhistological analysis, which has largely replaced stomach content analysis in the study of wildlife diets (Holechek et al. 1982, Dellinger & Trillmich 1988, Bowen 2000, Tollit et al. 2004). It is based on the assumption that we can find in droppings plant fragments, which are characteristic for the particular consumed plant species; we can identify these fragments at the species level by comparison with published keys and guides or by using reference collections made by ourselves, as it is in this case.

Pellet samples were crushed and the obtained substrata were cleared and diluted in NaOH solution for two hours (Vavra & Holecheck 1980). The solution was filtered through a sieve of mesh sizes ranging from 0.2 to 0.4 mm. The obtained pellets were rinsed and studied under microscope. Five slides were prepared from each sample of porcupine dropping and each piece was identified taxonomically as accurate as possible. Finally, the number of each species and the total number of fragments could be calculated.

Data analysis

To be able to assess possible variations in porcupine diet and to compare between the two seasons, we calculated the relative frequency of appearance (FA). It was computed as FA=ni/Ni.100, where ni was the number of appearances of each food category and Ni was the total number of appearances of all food categories. The results were also expressed in frequency of occurrence, or frequency of ingestion of each item (FO), where the occurrence of a food item "i" was defined as the ratio of the number of samples containing "i" and the total number of analysed samples. It is expressed in percentage and allows to highlight the quantitative importance of the different items. Concerning the diversity of the diet of *H. cristata*, it was expressed with the Shannon-Wiener Index of Diversity (Shannon 1948, Colwell & Futuyma 1971, Zar 1999, Peetz 2001): H' = - Σ ((Ni / N). log2 (Ni / N)), where Ni was the number of individuals of a given species with i ranging from 1 to S (S total number of species) and N was the total number of individuals. We calculated also the Piélou Index (J'), also known as Evenness Index (Blondel 1979), representing the ratio between the real and the maximum diversity (Ramade 2003). The values of this index vary from 0 to 1 depending on the degree of specialisation of the diet (values close to 1 indicate suggests generalists and those close to 0 indicate specialists).

Finally we used the Chi2 test to evaluate the variations in the diet by comparing the frequency of occurrence of food items consumed in both seasons. The dietary similarity or overlap between seasons was estimated using the Morisita-Horn's index C (Morisita 1959). Its values vary between 0 and 1: when the value of Cλ is close to 0, the diets are completely different; if Cλ is equal to 1, the diets are the same; if Cλ exceeds 0.6, diets overlap significantly. The index was calculated according to the following formula:

$$C\lambda = 2\frac{\sum_{i=1}^{n}(P_{xi}P_{yi})}{(\sum_{i=1}^{n}P_{xi}^2 + \sum_{i=1}^{n}P_{yi}^2)}$$

In this formula, Cλ was the index of overlap between cold and warm season, Pxi was the number of times species i was represented in the total X during cold season, Pyi was the number of times species i was represented in the total Y during warm season and n was the total number of species.

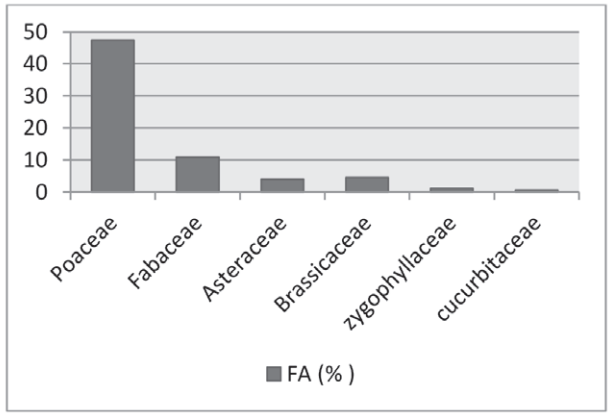

Fig. 2. Relative frequencies of appearance (FA) of wild species families in the diet of the porcupine in SE Tunisia.

Results

Overall diet

The microhistological analysis of collected pellets during the two sampling seasons in South-Eastern Tunisia identified 18 plant species. These included both wild and cultivated species (Fig. 1). We found that wild species were more important (FA 65.72%). They included 15 species, of which the most frequently observed were *Stipa lagascae* (20.54%), *Hedysarum carnosum* (10.26%) and *Hordeum marinum* (9.69%). In contrast, cultivated species represented only 15.97% of the total relative frequencies. This category was composed of potato (*Solanum tuberosum*), barley (*Hordeum vulgare*) and fig (*Ficus carica*), of which barley was the most common species. According to the frequency of occurrence of the different food items identified, the dominance of barley (*H. vulgare*) among cultivated species and *Stipa lagascae* among wild species was revealed.

Wild species belonged to six families. The dominant family was Poaceae (FA 47.38%). This family was essentially represented by three species: *Stipa lagascae, Stipa capensis* and *Hordeum marinum*. As for Fabaceae, it accounted for 10.84% of porcupine diet. Other families such as Asteraceae, Brassicaceae, Zygophyllaceae and Cucurbitaceae were less consumed and had frequencies of occurrence less than 5% in the diet of *H. cristata*. However, it should be noted that the proportion of wild species was higher and they were diversified than that of cultivated species, which were represented by three species (Figs. 1, 2).

Seasonal fluctuations in the diet of *H. cristata*

The Chi-square test revealed significant seasonal differences between the two categories of plant species (cultivated and wild) in the diet of the porcu-

Fig. 3. Presentation of the study area

pine (chi² = 14.93, p-value = 0.0001, ddl = 1). In term of species, there was no difference for the wild category (chi² = 9.55, p-value = 0.79, ddl = 14) and the dominant species were similar during both seasons. In contrast, cultivated species were mainly consumed during the warm months (Table 1) and a significant dependence between species of cultivated plants and the two seasons was recorded (chi² = 8.82, p-value = 0.012, ddl = 2). The representation of average diets expressed in relative frequencies of appearance confirmed these results. Wild species, especially *Stipa lagascae*, was an important resource in the diet of *H. cristata*, omnipresent during both seasons with high appearance frequencies (15.42% in winter and 7.42% in summer). In addition to *Stipa lagascae*, the diet of *H. cristata* was marked by the importance of other species, such as *Hedysarum carnosum*, *Hordeum marinum* and *Stipa capensis*. Cultivated species were characteristic only in the summer diet. In summer, we recorded high consumption of *Hordeum vulgare* (8.57%) and *Ficus carica* (4.57%) (Table 3).

Besides, the chi-square test showed that the consumption of the different families of plant species did not depend on season (chi² = 8.57, p-value = 0.28, ddl = 7). Species of Poaceae and Fabaceae dominated during the two seasons, contrary to Asteraceae, Brassicaceae and Solanaceae that were recorded during the two seasons with reduced frequencies (Table 2). The Morisita-Horn's quantitative index had a value close to 1 (Cλ=0.94), indicating that the dietary intake during the two seasons was comparable.

Table 1. Seasonal fluctuations of overall diet of *Hystrix cristata* in SE Tunisia

Food plants by origin	Relative abundance (FA%)	
	Cold season	Warm season
Wild species	43.95	24.53
Cultivated species	1.71	14.28

Table 2. Seasonal fluctuations of different families of plant species in the porcupine diet in SE Tunisia

Food plant families	Relative abundance (FA%)	
	Cold season	Warm season
Poaceae	31.4	24.55
Fabaceae	7.42	3.42
Zygophyllaceae	0.0	1.14
Asteraceae	2.28	1.71
Brassicaceae	2.85	1.71
Cucurbitaceae	0.0	0.57
Solanaceae	1.71	1.14
Moraceae	0.0	4.57

Table 3. Seasonal differences of plant species in the porcupine diet in SE Tunisia

Food species	Relative abundance (FA%)	
	Cold season	Warm season
Solanum tuberosum	1.71	1.14
Hordeum vulgare	0.0	8.57
Ficus carica	0.0	4.57
Stipa lagascae	15.42	7.42
Stipa capensis	5.14	1.71
Stipa parviflora	0.57	0.57
Hedysarum carnosum	7.42	3.42
Hordeum marinum	5.14	4.57
Stipagrostis pungens	1.14	0.0
Fagonia cretica	0.0	1.14
Anacyclis clavatus	1.14	1.14
Enarthrocarpus clavatus	2.85	1.71
Cenchrus ciliaris	2.85	0.0
Bromus rebens	1.14	0.0
Launea glomurata	0.0	0.57
Bromus rebens	0.0	0.57
Koeleria rubescens	1.14	1.14
Colocynthis vulgaris	0.0	0.57

Diet diversity

Results on diversity (H ') and evenness (E) showed that the diet of *H. cristata* was constantly diversified across the two seasons. The H' values during winter and summer were close to each other. Concerning the evenness values, they were close to zero, which implied that the food spectrum of this rodent was imbalanced and concentrated on a single species – *Stipa lagascae* (Table 4).

Table 4. Diet diversity indices during cold and warm seasons

Indices	Overall diet	Seasonal diet	
		Cold season	Warm season
H'	1.92	1.21	1.09
H'max	2.89	2.48	2.70
E (%)	66	48	40

Discussion

We found that *H. cristata* fed mainly on wild species that were present throughout the year. On the other hand, during the warm season, when cultivated species reached their maximum of production in the study area, *H. cristata* consumed mainly barley and fig, in addition to wild species. Our observations are similar to those by Mori et al. (2017), who have recorded wild fruits in the porcupine diet in Italy during the cold months and have been replaced by agricultural products (oat, figs, watermelons, sunflower and apples) during the warm months. Similar are the findings of Lucherini & Lovari (1996), Massei et al. (1997) and Lovari et al. (2013), who have shown that the "natural" forage, i.e. roots and wild fruits, are primarily consumed by the porcupines between October and March, while during the warm months, when wild fruit production reaches its annual minimum, *H. cristata* is found in other areas that contain agricultural products. Another study in favour of the consumption of agricultural products in summer is that of Pigozzi & Patterson (1990) who have analysed the feeding habits of porcupine in a Mediterranean area in July, without reference to the rest of the year. They observed that sunflower and cereals were the main food sources used. According to Alkon & Saltz (1985), the partial transformation of the natural habitats of porcupines into agricultural fields for potato production resulted into the formation of two distinct "guilds" in their population: "crop foragers" having smaller home ranges, losing their abilities for feeding on natural resources and becoming dependent on the crop production, and "natural foragers" feeding mainly on wild food sources.

Another finding of this study is that during the summer the consumption of barley and figs is greater than that of potato. Therefore, we could speculate that even if potatoes are become abundant in a particular part of the year, the porcupines continue to prefer other items such as barley and figs that are relatively more easily accessible. This behaviour corresponds to the mechanism of food choice in the optimal foraging approach (Roze 1989). In general, the grass species of the family Poaceae are the most palatable to *H. cristata* during the two study seasons, in which they have significant vegetative growth (Bowman & McDonough 1991). The significant consumption of these plants is likely owing to the fewer cellulose contents, making them easier to digest (Baubet 1998).

The absence of animal food in the diet of porcupines from the studied region could be explained by the fact that *H. cristata* is a herbivorous species that feeds mainly on roots, bulbs and fruits. It also feeds on above-ground and below-ground parts of the plants (Santini 1980, Bruno & Riccardi 1995, Bozzi & Lovari 1999) and tree bark (Nowak 1999). Insects and small vertebrates are sometimes ingested, and the bones of the latter may represent a source of calcium (Nowak 1991, Bartos et al. 1996). Food selectivity of herbivores is difficult to be understood because it is linked not only to measurable data, such as nutritional value or palatability, but also to poorly known elements of the species behaviour (Hofmann 1989).

Our results have shown that *H. cristata* in SE Tunisia prefers to feed rather on wild plants than on cultivated plants during both studied seasons. Moreover, even in terms of grassland, it has been demonstrated that this species consumes members of the family Poaceae much more than those of other plant families. This may be related to the behaviour of the species seeking for food at the safest locations. Therefore, to better understand the preferences of *H. cristata* for the plants present in its habitat, it is necessary to carry out targeted studies on the behaviour of this species.

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