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First data on the seasonal diet of the vulnerable *Gazella cuvieri* (Mammalia: Bovidae) in the Djebel Messaâd forest, northern Algeria

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Abstract. A good knowledge of food resource utilization is essential to understand how most wild ungulates meet their seasonal requirements in order to improve conservation of endangered taxa. Using faecal sampling, the diet of *Gazella cuvieri* has was investigated in the Djebel Messaâd Mountain (M'sila Province, Algeria) from September 2013 to August 2014. A microhistological analysis method revealed that gazelles ate 29 species of plants during the year. The grass *Stipa tenacissima* and the shrub *Artemisia herba alba* were the major food items throughout the year. The highest diversity was recorded in spring (17 taxa) despite a large consumption of *Helianthemum lippii*, the lowest in a dry summer (nine species), including the major consumption of the shrubs *Phillyrea media* and *Thymus algeriensis*, together with *Artemisia herba alba*, *Stipa tenacissima* and *Stipa parviflora*. An average relative numerical abundance of 50.5 % of the diet comprised shrubs and trees, mainly including *A. herba alba*, *T. algeriensis* and *Cistus libanotis*. Grasses and forbs accounted for 29.4 % and 20.1 % respectively. Based on this study, this gazelle species can be classified as an intermediate feeder (i.e. browser-grazer).

Key words: Cuvier's gazelle, faecal analysis, feeding ecology

Introduction

Food availability is one of the most important factors influencing the distribution of free-ranging ungulates (Fitzgerald & Waddington 1979, Holecheck et al. 1982, Gill et al. 1983). Some studies have based the classification of ungulate feeding types on the botanical compositions of the diet (Gordon & Illius 1994, 1996) along a continuum from frugivores to browsers and grazers (Hofmann & Stewart 1972, McNaughton & Georgiadis 1986, Hofmann 1989, Bodner 1990, Gagnon & Chew 2000). Dietary preferences of herbivores can vary, with some species specializing on either grass (grazers), woody vegetation (browsers), or a combination of these two food types (intermediate feeders) (Grzimek 1990). Understanding the basis to diet selection by mammalian herbivores is complex (Shipley 1999). Some fundamental differences exist between grass (monocotyledons) and browse (herbaceous and woody dicotyledons, such as forbs, shrub leaves and stems; Hofmann & Stewart 1972). Knowing the extent to which herbivores feed as grazers (diets containing ≤ 25 % browse) or browsers (diets i.e. containing ≥ 75 % fruits, dicot foliage, tree and shrub stems and foliage) is essential for the appropriate management and conservation of their populations (Hofmann & Stewart 1972).

African bovids are a diverse group of mammals that occur from tropical rainforests to deserts (Gagnon & Chew 2000). Woodland, maquis shrubland and steppe are their main natural habitats in the north-western part of the continent. Studies carried out across a range

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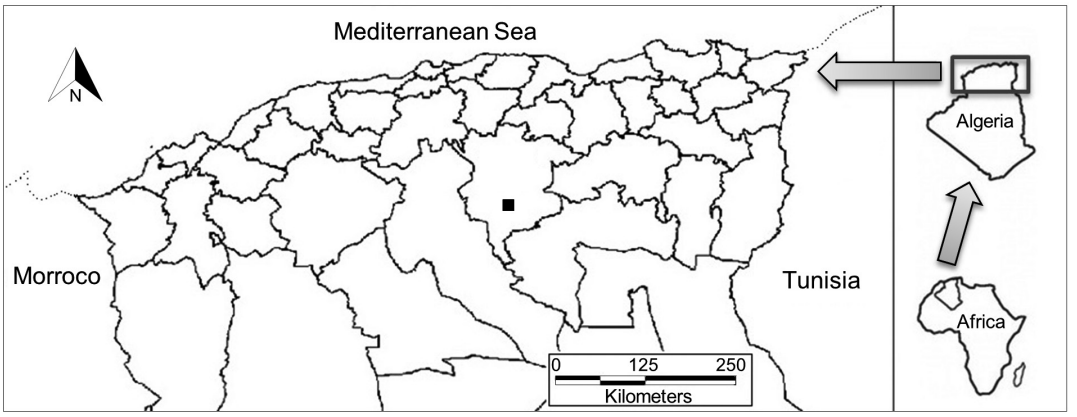

Fig. 1. Map showing the geographic location of the Djebel Messaâd forest, northern Algeria. The location of the study site is indicated by the black square.

of environments have documented the proportion of grass and browse consumed by Dorcas gazelle *Gazella dorcas* (Loggers 1991, Abdelhamid 1998, Cuzin 1998, Salem & Saleh 1998, Ait Baamrane et al. 2012, 2017). For Cuvier's gazelle *Gazella cuvieri*, Arbouche et al. (2012) reported direct observation of feeding ecology from the Djebel Metlili in the Belezma National Park in Algeria. The diet of this gazelle has also been characterised in unpublished graduate dissertations (Bouredjli 1989, Talbi 1989, Benamor 2014) and as part of an unpublished thesis (Sellami 1999), mainly in the Mergueb nature reserve (M'Sila, Algeria). However, Bounaceur et al. (2016) pointed out that a more comprehensive investigation of the diet of the Cuvier's gazelle is urgently needed to identify critical habitats and suggest necessary conservation.

Cuvier's gazelle is endemic to northwest Africa (Morocco, Algeria and Tunisia) and classified as "Vulnerable" by IUCN (IUCN SSC Antelope Specialist Group 2016) due to ongoing habitat degradation, mainly related to the loss of forest to cultivation and pasture. Widely distributed in Algeria until the 19th century, the species experienced a dramatic range decrease during the last century (Bounaceur et al. 2016). It has recently disappeared from a few localities and the remaining populations are highly fragmented, except possibly in the large national forests of native Aleppo pines, *Pinus halepensis* (Beudels et al. 2013). As such, conservation of this declining species, nationally listed as "Endangered" (Bounaceur et al. 2016), should be a priority.

As part of an extensive survey of Cuvier's gazelle in the Djebel Messaâd forest, where a small population of ca. 20 individuals persists, we investigated the seasonal diet composition over one year. This study is intended to show local optimal habitats for the species and support sympathetic management of vegetation.

Material and Methods

Study area

Field work was conducted in Djebel Messaâd (34°59′53.1″ N, 4°17′07.2″ E), M'Sila Province, northern Algeria, a mountainous area located 30 km south-east of Bou Saâda (Fig. 1). The highest

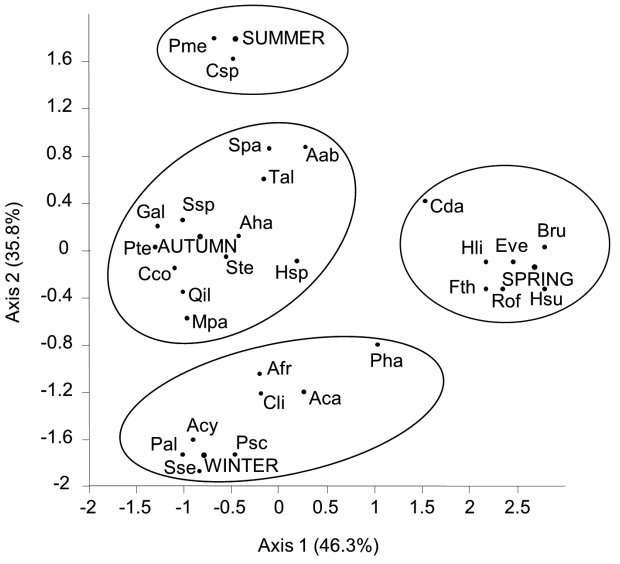

Fig. 2. First axes of a factorial correspondence analysis illustrating the seasonal variations in the diet of *Gazella cuvieri* from September 2013 to August 2014 in the Djebel Messaâd Mountain (northern Algeria), and first steps of a hierarchical classification on factorial co-ordinates: level 1 isolated plants associated with spring, level 2 isolated plants associated with winter, level 3 plants associated with summer separated from plants associated with autumn. (Acy: *Anacyclus cyrtolepidioides*; Afr: *Anarrhinum fruticosum*; Aab: *Artemisia absinthium*; Aca: *Artemisia campestris*; Aha: *Artemisia herba alba*; Bru: *Bromus rubens*; Csp: *Calicotome spinosa*; Cco: *Calligonum comosum*; Cli: *Cistus libanotis*; Cda: *Cynodon dactylon*; Eve: *Eruca vesicaria*; Fth: *Fumana thymifolia*; Gal: *Globularia alypum*; Hli: *Helianthemum lippii*; Hsp: *Helianthemum* sp.; Hsu: *Heliotropium supinum*; Mpa: *Malva parviflora*; Pme: *Phillyrea media*; Pha: *Pinus halepensis*; Pte: *Pistacia terebinthus*; Psc: *Pituranthos scoparius*; Pal: *Plantago albicans*; Qil: *Quercus ilex*; Rof: *Rosmarinus officinalis*; Sse: *Sedum sediforme*; Ssp: *Silybum* sp.; Spa: *Stipa parviflora*; Ste: *Stipa tenacissima*; Tal: *Thymus algeriensis*).

summit, Teniet Sidi Nasseur, is 1675 m a.s.l. The local climate is of a semi-arid Mediterranean type: winters (Dec-Jan-Feb) are cool and humid, summers (Jun-Jul-Aug) are hot and dry. Over the last 10 years temperatures averaged 2.8 °C (SD = 1.3) in January with an absolute minimum of 0.9 °C, and 25.9 °C (SD = 0.9) in July with an absolute maximum of 31.9 °C. Annual rainfall averaged 435 (SD = 137.8) mm with two peaks: September (65.1 mm) and April (80.4 mm), and a drought period from June to September (Kaabeche 1990).

Djebel Messaâd is a natural Aleppo pine, *Pinetum halepensis*, forest with vegetation including *Pistacia lentiscus*, *Rosmarinus officinalis*, *Globularia alypum*, *Hertia cheirifolia*, *Dorycnium suffruticosum*, *Fumana ericoides*, *Stipa tenacissima*, *Cistus libanotis*. Part of the forest belongs also to the association *Juniperetum phoenicea* characterised by *Artemisia herba alba*, *Lygeum spartum*, *Helianthemum cinereum*, and *Quercus ilicis* in relatively cool regions or sites less impacted by farming and grazing, and including *Cistus villosus*, *Jasminum fruticans*, *Muscari atlanticum*, *Dactylis hispanica* and *Ampelodesma mauritanica* (El-Attoui 1996).

Faecal sampling, epidermis references, and faecal analysis

Faecal pellets of Cuvier's gazelle were collected from September 2013 to August 2014 during the last week of each month in the whole Djebel Messaâd Mountain. We studied food composition during autumn (Sep-Oct-Nov) 2013, winter (Dec-Jan-Feb) 2013-2014, spring (Mar-Apr-May) and summer (Jun-Jul-Aug) 2014. Following the protocol of Stewart & Stewart (1971), who studied ten faecal pellets per area and season, we randomly collected three to four fresh

Table 1. Diet of *Gazella cuvieri* during autumn 2013, winter 2013-2014, spring and summer 2014 in the Djebel Messaâd Mountain, Algeria. (-): Not found in faeces. Others: plant species consumed by Cuvier's gazelle comprising < 3 % of the diet. Shrubs (*Globularia alypum*, *Rosmarinus officinalis*, *Calligonum comosum*); grasses (*Bromus rubens*); forbs (*Eruca vesicaria*, *Silybum* sp.).

Plant categories and species	Autumn N (%)	Winter N (%)	Spring N (%)	Summer N (%)	Annual N (%)
Shrubs and trees	50.67	43.33	54.67	53.33	50.50
Artemisia herba alba (Aha)	21.33	14.67	7.33	17.33	15.16
Thymus algeriensis (Tal)	6.00	3.33	4.67	12.00	6.50
Cistus libanotis (Cli)	2.67	16.67	4.66	-	6.00
Helianthemum lippii (Hli)	-	-	20.00	-	5.00
Phillyrea media (Pme)	-	-	-	12.67	3.17
Pistacia terebinthus (Pte)	12.00	-	-	-	3.00
Artemisia absinthium (Aab)	2.00	-	3.33	5.33	2.66
Pinus halepensis (Pha)	-	3.33	4.67	-	2.00
*Fumana thymifolia (*Fth)	-	-	6.67	-	1.67
Artemisia campestris (Aca)	-	4.00	2.00	-	1.50
Calicotome spinosa (Csp)	-	-	-	6.00	1.50
Quercus ilex (Qil)	4.00	1.33	-	-	1.33
Others	2.67	-	1.33	-	1.00
Grasses	33.33	22.67	22.00	39.67	29.42
Stipa tenacissima (Ste)	26.67	20.00	6.00	17.00	17.42
Stipa parviflora (Spa)	6.67	2.67	6.67	20.00	9.00
Cynodon dactylon (Cda)	-	-	6.67	2.67	2.34
Others	-	-	2.67	-	0.67
Forbs	16.00	34.00	23.33	7.00	20.08
Helianthemum sp. (Hsp)	8.67	8.67	11.33	7.00	8.92
Malva parviflora (Mpa)	6.00	4.00	-	-	2.50
Heliotropium supinum (Hsu)	-	-	9.34	-	2.34
Pituranthos scoparius (Psc)	-	6.00	-	-	1.50
Sedum sediforme (Sse)	-	5.33	-	-	1.33
Anacyclus cyrtolepidioides (Acy)	-	4.67	-	-	1.17
Anarrhinum fruticosum (Afr)	0.67	2.00	0.67	-	0.84
Plantago albicans (Pal)	-	3.33	-	-	0.83
Others	0.67	-	2.00	-	0.67
Number of fragments	300	300	300	300	1200

pellets per month, recognizable by their colour and shiny appearance, each month in different latrine sites in order to investigate different individuals. Pellets were air-dried and stored in paper bags in the field.

Based on the work of García-Gonzalez (1983), we prepared a reference collection of the epidermis of the main 52 plant species (16 families) collected within the habitat of the gazelle. The method used to obtain the epidermis of the plant fragment involved carefully scraping it with a scalpel to separate tissues above the epidermis from different parts of the plant (adaxial and abaxial surfaces of leaves, stems, flowers). After rinsing in sodium hypochlorite solution (12 %), the epidermis was washed in distilled water, placed in a glycerine solution (50 %) and sealed on a slide with nail varnish (García-Gonzalez 1983). The diagnostic features of the plant epidermis, such as cells, fibres, trichomes, pores, stomata, vessels, intercellular structures and cell walls from each reference slide were photographed using a camera (Sony Cyber-Shot DSC-W380) fitted to an optical microscope at (10 × 0) and (10 × 40) magnification. Following Chapuis (1980) we identified the first 300 epidermal fragments by comparison with reference slides.

Data analysis

Results of diet analysis are expressed as average relative numerical abundance (N%) for each plant taxon. Relative abundance is the ratio of the number of fragments of a species or category (n_i) to the total number of fragments of all plant taxa (Zaime & Gautier 1989). The seasonal values of trophic diversity were calculated using the Shannon-Wiener formula. We investigated seasonal variation in diet by computing a factorial correspondence analysis (FCA) of the number of fragments for each plant taxon followed by a hierarchical classification on factorial co-ordinates using PAST 1.37 (Hammer et al. 2001).

Results

Over the year, Cuvier's gazelle fed on 29 plant species from 16 families (Table 1). About 50.5 % of the diet was made up of four plant species: the grasses *Stipa tenacissima* (17.4 %) and *S. parviflora* (9 %), the woody *Artemisia herba alba* (15.2 %), and the forb *Helianthemum* sp. (8.9 %). The remaining plants included *Thymus algeriensis* (6.5 %), *Cistus libanotis* (6 %), *Helianthemum lippii* (5 %), *Phillyrea media* (3.2 %), *Pistacia terebinthus* (3 %), and 20 other species with less than 3 % of each (for a total of 25.8 %).

Shrubs and trees, including *A. herba alba*, were the dominant plant category (50.5 %), followed by grasses (29.4 %), including *S. tenacissima*, and forbs (20.1 %) (Table 1). Gazelles fed on forbs mainly during winter (20 %) in contrast to summer (7 %) when the consumption of shrubs and trees was greatest (53.3 %).

The highest species richness of plants in the diet was recorded in spring (17 species, 10 families) despite high consumption of *H. lippii* (20 %), while the lowest was in summer (nine species, six families), including the relevant consumption of *P. media* (12.7 %) and *Calicotome spinosa* (6 %), winter (15 species, ten families) and autumn (12 species, nine families) were intermediate. We demonstrated a relatively higher Shannon diversity index in spring (3.71) in comparison with winter (3.44) and autumn (3.49), with the lowest in summer (0.99).

Factorial correspondence analysis clearly showed seasonal variation in diet (Fig. 2). The spring diet was the most distinct, with the autumn diet intermediate between winter and summer. Seven species characterised the spring diet on the first axis: *H. lippii*, *Heliotropium supinum*, *Fumana thymifolia*, *Rosmarinus officinalis*, *Eruca vesicaria*, *Bromus rubens* and *Cynodon dactylon*. Summer and winter diets were the opposite on the second axis, with *P. media* and *C. spinosa* in summer, eight species including *Pituranthos scoparius*, *Sedum sediforme*, *Anacyclus cyrtolepidioides* and *Plantago albicans* in winter. The autumn diet was associated with species consumed throughout the year, such as *A. herba alba* and *S. tenacissima* with the unique occurrence of *P. terebinthus*.

Discussion

Annual diet

With 29 plant species consumed by Cuvier's gazelle in the Djebel Messaâd, the species richness of the diet was intermediate between estimates obtained for the Mergueb Nature Reserve (Sellami 1999) and Djebel El Achch (Talbi 1989) (Table 2). However, the former study used faecal analysis as we did, while the latter used direct observation of grazed species, a method which tends to underestimate food diversity (Bouredjli 1989). The microhistological method also underestimates digestible plant species (Brand 1978) or species rarely included in the diet, while overestimating plant species that readily break up into small fragments (Johnson et al. 1983). Our preliminary work, based on 300 fragments, gave a clear picture of the diet of Cuvier's gazelle and its seasonal changes. Nevertheless, accumulation curves should be used to ascertain this sampling design in further studies.

Table 2. Plants consumed by *Gazella cuvieri* in different localities of Algeria reported in previous studies and this study (the lists are ordered by decreasing importance). *observation of direct browsing, **faecal analysis.

Djebel El Achch (Saïda) Talbi (1989)*	Mergueb Reserve (M'sila) Bouredjli (1989)*	Mergueb Reserve (M'sila) Sellami (1999)**	Djebel Messaâd Mountain (M'sila) (This study)**
Olea europea	*Artemisia herba alba*	*Salsola vermiculata*	*Stipa tenacissima*
Arbutus unedo	*Sonchus asper*	*Helianthemum lippii*	*Artemisia herba alba*
Pistacia lentiscus	*Crepis vesicaria*	*Cynodon dactylon*	*Stipa parviflora*
Phillyrea angustifolia	*Stipa tenacissima*	*Gastridium scabrum*	*Helianthemum* sp.
Quercus coccifera	*Anabasis articulata*	*Herniaria mauritanica*	*Thymus algeriensis*
Calycotome spinosa	*Noaea mucronata*	*Ziziphus lotus*	*Cistus libanotis*
Lonicera implexa	*Asphodelus fistolosus*	*Anabasis articulata*	*Helianthemum lippii*
Ruta montana	*Ephedra major*	*Sedum sediforme*	*Phillyrea media*
Lavandula stoechas	*Lycium arabium*	*Bromus* sp.	*Pistacia terebinthus*
Lycium arabicum	*Olea europea*	*Medicago hispida*	*Artemisia absinthium*
Jasminum fruticans	*Phytoranthus chlorontus*	*Stipa retorta*	*Malva parviflora*
Cytisus triflorus	*Asparagus albus*	*Asparagus albus*	*Cynodon dactylon*
Rhamnus alaternus	*Phus tricuspidata*	*Artemisia herba alba*	*Heliotropium* sp.
Asparagus albidus	*Helianthemum lippii*	*Psoralea bituminosa*	*Pinus halepensis*
Salvia pratensis	*Salsola vermiculata*	*Cupressus* sp.	*Fumana thymifolia*
Stipa tenacissima		*Aristida plumosa*	*Artemisia campestris*
Asphodelus microcarpus		*Paronychia capitata*	*Calicotome spinosa*
Globularia alypum		*Artemisia campestris*	*Pituranthos scoparius*
Ferula communis		*Echium pycnanthum*	*Quercus ilex*
Cytisus arborium		*Vicia monantha*	*Sedum sediforme*
Rosmarinus sp.		*Atractylis caprinus*	*Anacyclus cyrtolepidioides*
Teucrium sp.		*Medicago* sp.	*Anarrhinum fruticosum*
		Cutandia dichotoma	*Plantago albicans*
		Sedum amplexicaule	*Bromus rubens*
		Stipa plumosa	*Eruca vesicaria*
		Thymelaea hirsuta	*Globularia alypum*
		Lotus creticus	*Rosmarinus officinalis*
		Olea europea	*Silybum* sp.
		Eruca vesicaria	*Calligonum comosum*
		Marrubium supinum	
		Fumana thymifolia	
		Launaea resedifolia	
		Lolium multiflorum	
		Anarrhinum fruticosum	
		Pistacia atlantica	
		Thymus algeriensis	

Browse was highly predominant in the diet throughout the year, a result that is congruent with Ait Baamrane et al. (2012, 2017) for the Dorcas gazelle in M'Sabih Talaa Reserve (Morocco). With a diet that included 50.5 % shrubs, 29.4 % grasses and 20.1 % forbs our results corroborate those obtained by Arbouche et al. (2012) by direct observation at Djebel Metlili in the Belezma National Park. From faecal analysis, shrubs

accounted for 77.3 % and 36.1 % of the diet in Djebel El Achch (Talbi 1989) and the Mergueb Nature Reserve (Sellami 1999), respectively.

According to Hofmann & Stewart (1972), a diet containing more than 25 % browse and less than 75 % fruits, dicotyledon foliage, and shoots, *G. cuvieri* can be classed as an "intermediate or mixed feeder". Among the six dietary categories identified by Gagnon & Chew (2000) for African bovids, Cuvier's gazelle falls again into the "browser-grazer" or "mixed feeder" whose diet includes 30-70 % of dicots and monocots and less than 20 % fruits.

Steppe species, such as *S. tenacissima* (17.4 %) and *A. h. alba* (15.2 %), were the main food species of *G. cuvieri* in the Djebel Messaâd. This finding is in agreement with the data of Bouredjli (1989) and Bel Hadj Kacem et al. (1994) in Tunisia. However, Talbi (1989) and Arbouche et al. (2012) mentioned only the first of these species, and Sellami (1999) the second, possibly in accordance with their availability at the different sites.

Seasonal diet

In spring, Cuvier's gazelles consumed the greatest diversity of plant species, including a large amount of shrubs (54.7 %, mainly *Helianthemum lippii*, followed by *Fumana thymifolia*) and forbs (23.3 % including mainly *Helianthemum* sp. and *Heliotropium supinum*). Grasses (22 %) were also more diversified with four species, including *Cynodon dactylon* and *Bromus rubens*, typical of this season. Spring is an important season for gazelles with moulting, parturition and lactation (Olmedo et al. 1985). To meet their elevated energy requirements, growing plant tissue derived from browse are favoured since these are the most nutritious form of food due to their highly soluble cell content (van Soest 1982).

In summer, the number of plant species in the gazelle's diet decreased, together with the amount of forbs (7 %), the availability of which is dramatically reduced under the effects of heat, drought and overgrazing by domestic animals. Westoby (1974) and Belovsky (1978) suggested that herbivores would specialise when resource levels were high and generalise when they were low. In contrast, during this dry season, *G. cuvieri* restricted its diet to few species of shrubs, including *A. h. alba*, *Phillyrea media*, *Thymus algeriensis* and *Calicotome spinosa*, and grasses, mainly *S. parviflora* and *S. tenacissima*. The seasonal contribution of grasses (39.7 %) does not support the more extensive consumption of dicots during the dry season, when monocots show reduced protein and increased fibre content (Stelfox & Hudson 1986). This high grass contribution to the diet is likely due to the shortage of forbs, which is not counterbalanced by a switch to browse when good quality grass runs out (see Kleynhans et al. 2011).

In autumn, plant diversity in the diet increased together with the amount of forbs, whereas the consumption of *S. tenacissima* and *A. herba alba*, the two main food species for *G. cuvieri* at Djebel Messaâd, reached a maximum. *Pistacia terebinthus*, and *Quercus ilex* which offer both deciduous leaves and fruits during this season, were also heavily browsed by gazelles, together with 8000 to 10000 sheep and goats, which are in the area throughout the year. The large amount of grasses (33.0 %), mainly *S. tenacissima*, is probably linked to the same food limitation that is seen in the dry summer due to limited rainfall until November.

During the winter and wet season, the gazelle's diet included a large diversity of plant species, and the largest amount of forbs (34 %) with some species consumed only during this season: *Pituranthos scoparius*, *Sedum sediforme*, *Anacyclus cyrtolepidioides* and *Plantago albicans*. In contrast to more northern or mountainous areas, the growth of vegetation in the study area is stimulated by rainfall (Zedam et al. 2016). The diet in this season is also characterised by lower quantities of shrubs (43.3 %), with less species consumed compared to other seasons when shrubs, such as *Cistus libanotis* and *Artemisia campestris*, are more palatable.

These annual variations highlight the seasonal plasticity of the diet of *G. cuvieri* beyond the regional variations reported so far (Bouredjli 1989, Talbi 1989, Bel Hadj Kacem et al. 1994, Sellami 1999, Arbouche et al. 2012). Such variation reflects the availability of palatable green plant material and has similarly been reported in mountain gazelle *Gazella gazella* in lower Galilee (Baharav 1981) or in the Dorcas gazelle in the Negev Desert (Ward & Saltz 1994) and central plains of Morocco (Loggers 1991, Ait Baamrane et al. 2012, 2017).

Conclusion

Based on its diet in the Djebel Messaâd *G. cuvieri* should be classified as an intermediate browser-grazer. Two plant species, the grass *S. tenacissima* and the shrub *A. h. alba,* were important food sources throughout the year, but were supplemented by a variety of species that contributed to the seasonal variation in the diet. From a conservation perspective, it would be useful to safeguard the availability of these and other key food resources, particularly in

summer when vegetation is rarer and competition with livestock is magnified. With respect to predicted climate change scenarios, which suggest increasing probability of heatwaves and droughts in summer, the Cuvier's gazelle may be able to adapt its diet as long as a sufficient quantity of food is available, even if restricted to dry grasses such as *Stipa parviflora*. Interactions with other wild species, such as wild boar *Sus scrofa*, as well as domestic herbivores (primarily sheep and goats), should be investigated to better inform the conservation and management of this vulnerable gazelle species.

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