

Seasonality and relationships of food resource use of *Martes martes*, *Genetta genetta* and *Felis catus* in the Balearic Islands

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Abstract

Year-round diet characteristics of pine martens (*Martes martes*), spotted genets (*Genetta genetta*), and feral cats (*Felis catus*) were studied on Mallorca, Ibiza, and Cabrera in the Balearic archipelago, Spain. Analysis of 2531 scats were used to describe seasonal food habits and its variation. Mallorcan pine marten diets varied least of all between seasons. Plant material (mainly fruit) was the dominant pine marten food followed by mammals which appeared in half of the seasonal samples. Mallorcan and Ibizan genet diets were most alike, while Cabreran genet diets were markedly different from the two. Mammals were the dominant year-round diet component on Mallorca and Ibiza, whereas mammals and birds were of equal importance on Cabrera. Genets preyed heavily on wood mice (*Apodemus sylvaticus*) on Mallorca and Ibiza, and rats (*Rattus*) on Cabrera. Avian predation was highest on Cabrera and Ibiza during autumn and winter. Mammals and reptiles were major year-round diet components of Cabreran feral cats. Human refuse and birds were seasonally important cat foods and were consumed when most abundant on the island. Trophic niche breadth values were greatest for Cabreran genets and lowest for Mallorcan genets. On Mallorca and Cabrera, coexisting carnivores had similar niche breadth values but exploited the available foods differently. Mallorcan and Ibizan genet diets were most similar while on Cabrera genets were opportunistic predators. The methodological limitations of genet diet descriptions from faecal mass analysis are presented. A method for determining correction factors for diet measures of faecal mass food items from scats is proposed.

Résumé

Les régimes alimentaires de la Martre (*Martes martes*), de la Genette (*Genetta genetta*) et du Chat haret (*Felis catus*) ont été étudiés tout au long de l'année dans l'archipel des Baléares sur les îles de Majorque, Ibiza et Cabrera (Espagne). L'analyse de 2 531 fèces a été utilisée pour décrire les habitudes alimentaires saisonnières et leurs variations. Le régime alimentaire de la Martre de Majorque est le moins variable des trois entre les différentes saisons. Le matériel végétal est l'aliment dominant de la Martre, suivi par les mammifères qui apparaissent dans la moitié des échantillons. Les régimes alimentaires des Genettes d'Ibiza et de Majorque sont très semblables alors que celui de la Genette de Cabrera est clairement différent des deux autres. Les mammifères sont la composante dominante tout au long de l'année à Majorque et Ibiza, alors que les mammifères et les oiseaux sont d'égale importance à Cabrera. Les Genettes se nourrissent beaucoup de mulots sylvestres (*Apodemus sylvaticus*) à Majorque et Ibiza et de rats (*Rattus* sp.) à Cabrera. Durant l'automne et l'hiver, la prédation d'oiseaux est la plus élevée à Cabrera et Ibiza. Tout au long de l'année, les mammifères et les reptiles sont les composantes majeures de l'alimentation du Chat haret de Cabrera. Les déchets et les oiseaux constituent une alimentation saisonnière importante pour les Chats et sont consommés lorsqu'ils sont les plus abondants sur l'île. L'amplitude de la niche trophique est la plus grande pour la Genette de Cabrera et la plus basse pour la Genette de Majorque. À Majorque et Cabrera les carnivores coexistants ont une amplitude de niche trophique similaire mais exploitent la nourriture différemment. L'alimentation de la Genette de Majorque est très similaire à celle d'Ibiza alors qu'à Cabrera les Genettes sont des prédateurs opportunistes. Les limites méthodologiques de la description de l'alimentation des Genettes à partir des analyses des masses fécales sont présentées. Une méthode de détermination des facteurs correctifs pour la mesure des restes alimentaires de la masse fécale à partir des crottes est proposée.

SEASONALITY AND RELATIONSHIPS OF FOOD RESOURCE USE
OF *MARTES MARTES*, *GENETTA GENETTA* AND *FELIS CATUS*
IN THE BALEARIC ISLANDS

Anthony P. CLEVINGER*

Diet studies increase our understanding of the foods available to a predator, the predatory capabilities of the species, and the limitations their environment places on their food choices. On small islands, information on the diet characteristics of carnivores is essential for assessing their role in regulating their prey populations and potential impacts on endemic prey species (Karl & Best, 1982 ; King, 1984 ; Fitzgerald & Veitch, 1985).

In the western Mediterranean Basin, carnivores occur on every major island, however, they have been the focus of relatively few studies. Several species have received attention due to their body size differences when compared to nearby mainland forms, but besides the taxonomic studies that have been carried out (Frechkop, 1963 ; Delibes, 1977 ; Hutterer & Geraets, 1978 ; Alcover *et al.*, 1986 ; Delibes & Amores, 1986), practically nothing is known about the species basic ecology.

Published diet studies from insular Mediterranean carnivore populations have been hampered by small sample sizes or restricted sampling periods. In this study year-round food habits data were collected from three carnivore species in the Balearic Islands. Seasonal diets are characterized, their variability measured, and diet diversity values calculated in order to describe the trophic relationships : 1) between pine martens (*Martes martes*) and spotted genets (*Genetta genetta*) on Mallorca ; 2) between spotted genets and feral cats (*Felis catus*) on Cabrera, and 3) among genets on Mallorca, Ibiza, and Cabrera.

STUDY AREA

The Balearic Island archipelago is situated in the western Mediterranean Basin (38°40' – 40°05' N, 1°17' – 4°23' E) and consists of three main islands, Mallorca, Minorca and Ibiza, and two lesser islands, Formentera and Cabrera (Fig. 1). Carnivores occur on all islands except Formentera. Eurasian pine martens

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are found on Minorca and Mallorca, while spotted genets inhabit Mallorca, Ibiza, and Cabrera. Feral cats are present on the island of Cabrera. Weasels (*Mustela nivalis*) occur on Minorca and Mallorca but were not included in the study. Diets were sampled from Mallorca, Ibiza, and Cabrera ; the latter is located within the newly-created Cabrera Archipelago National Park.

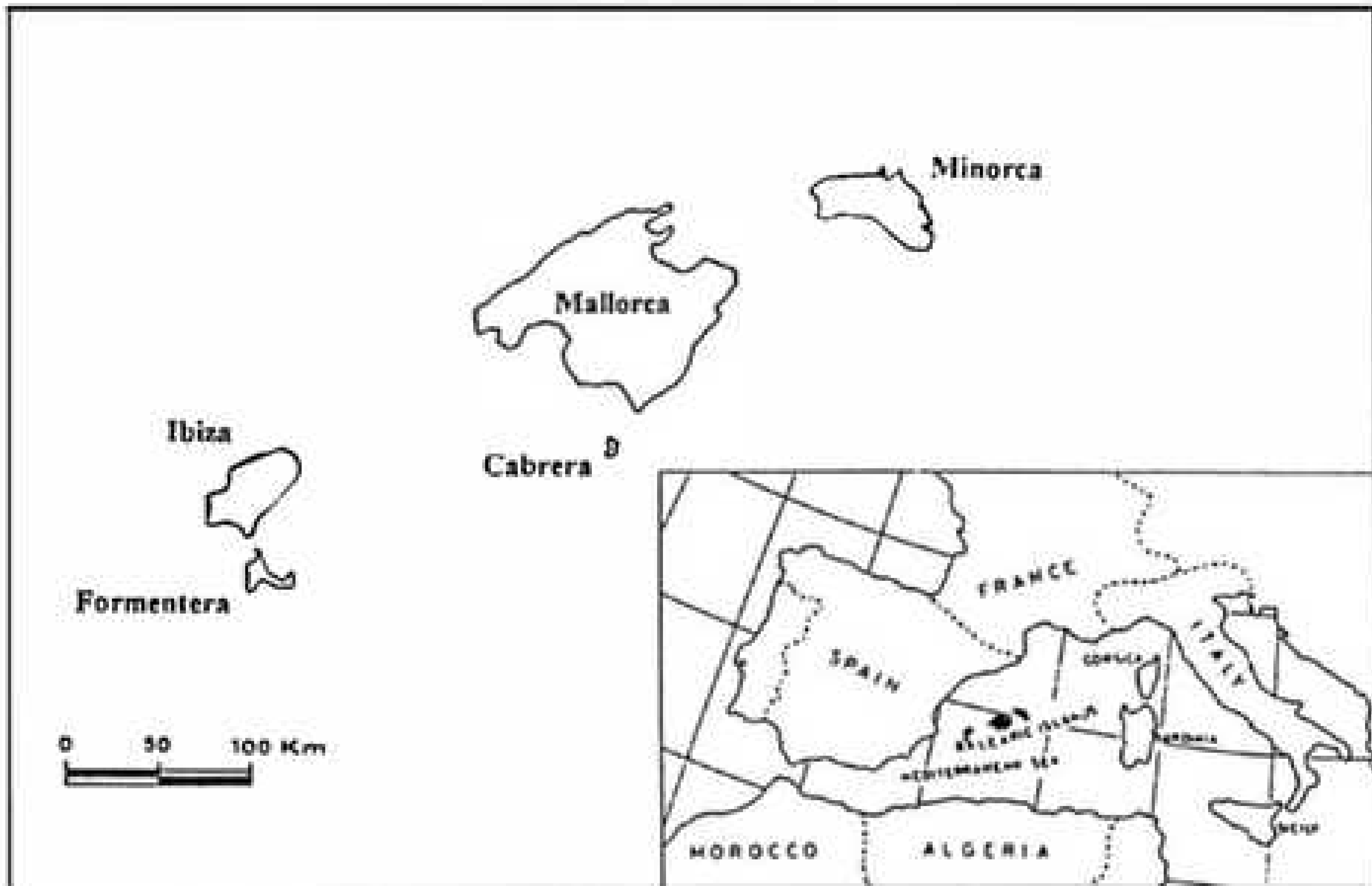


Figure 1. — Location of the Balearic archipelago and the three islands where carnivore diets were studied.

Mallorca is the largest island measuring 3 640 km². Fieldwork was conducted in the Sierra de Tramuntana whose highest point rises 1 447 m above sea level. Topography is rugged and is characterized by steep limestone canyons with intermittent fluvial activity in the high mountains. Climate is humid mediterranean and precipitation is unusually high (1 000-1 300 mm/year) for the Mediterranean region. Mean monthly temperatures range from 8-20 °C (Ministerio de Agricultura, 1986). The vegetation consists of mixed forests of holm oak (*Quercus ilex*) and aleppo pine (*Pinus halepensis*) while dominant understory and shrub species include wild olive (*Olea europaea*), lentisc (*Pistacia lentiscus*), strawberry tree (*Arbutus unedo*) and *Phillyrea* spp. Small farms (≤ 5 ha) composed of orchard and almond (*Prunus dulcis*) trees in varying stages of use are scattered throughout the study area.

Research on Ibiza was conducted throughout the entire island area which encompasses 540 km². Topography is varied, consisting of several mountain formations between 300-475 m in elevation and gentle lowland areas in cultivation. Climate is semi-arid mediterranean with annual rainfall of 300-600 mm. Mean monthly temperatures range from 11-26 °C (Ministerio de Agricultura, 1986). The vegetation consists of juniper (*Juniperus phoenicea*) and aleppo pine

forests ; the latter being predominant, especially in disturbed areas. Dominant shrub species include lentisc, heather (*Erica* spp.), rosemary (*Rosmarinus officinalis*), and *Phillyrea* spp.

Cabrera is the main island of the Archipelago National Park and is the smallest (11.5 km²) and least disturbed of the three islands studied. Human activity is low and restricted to the port area. Fieldwork was conducted throughout the island. The topography is moderately rugged with the highest point being 175 m above sea level, and < 1 % of the island is level lowland terrain. Climate is semi-arid mediterranean with annual rainfall of 200-555 mm. Temperatures are similar to Ibiza. The predominant vegetation type is shrub (*Phillyrea* spp., lentisc, wild olive, juniper), while aleppo pine forest covers roughly a third of the island.

METHODS

Between June 1992 and May 1993, dietary information were obtained from pine martens on Mallorca, spotted genets on Mallorca, Ibiza and Cabrera, and feral cats on Cabrera. On Mallorca, marten scats were collected once every three months along five established trails that ranged in length from 2 to 5 km. Scats which could not be positively identified were discarded. Feral cat scats from Cabrera were collected at 3-month intervals along three established routes and when randomly encountered. To facilitate the identification of individual genet faeces, at 6-week intervals scats from the three islands were collected from a series of regularly monitored latrines (Mallorca = 19, Ibiza = 17, Cabrera = 21). At each visit, scats which could be identified as whole were collected while the remaining faecal material was cleared from the latrine. On each island, all marten and genet scats collected were individually bagged and labelled with the date and site of deposition.

Scats were air-dried and placed in a freezer before analysis. They were then thawed, and crumbled gently between finger and thumb, and their contents examined. Food items were identified by microscopic and macroscopic analysis and compared to a reference collection of study skins, skulls, feathers, and seeds at the Universidad de León (Day, 1966 ; Reynolds & Aebischer, 1991). Small mammals and birds were identified to species level when possible. Small mammals were identified to genus on islands where congeneric species occurred. Prey-ages were estimated for small mammals and rabbits (*Oryctolagus cuniculus*) appearing in the diet. Juvenile small mammals were classified as those with premolars and molars showing little or no wear, while adults were those with advanced tooth-wear (Gosálbez, 1987). Juvenile and adult rabbits were determined by comparing with a reference collection at the Universidad de León. Invertebrate prey were identified to the ordinal level.

The identified food items were placed in one of six food categories : Mammals, Birds, Reptiles, Invertebrates, Plant Material, or Other. The percent volume of each food item was visually estimated, and pooling data from all samples, the mean percentage volume and frequency of occurrence was calculated. Total frequency of occurrence for food categories was determined by averaging seasonal values. Any error in scat content identification was minimized as the author analyzed ≥ 90 % of the total sample while one other person assisted with the rest.

In this study the sampling period was divided into four seasons: winter (16 December-15 March), spring (16 March-15 June), summer (16 June-15 September), and autumn (16 September-15 December).

Seasonal percentage of diet similarity was measured by Pianka's (1973) overlap index ($\times 100$). Differences in seasonal diet compositions were compared by 2-tailed Kolmogorov-Smirnov tests. Trophic diversity indices (Hespenheide, 1975) were calculated for each season using the 5 principal food categories and the niche breadth formula of Levins (1968).

RESULTS

SEASONAL DIETS

Martes martes - Mallorca

A total of 26 food items were identified from 728 analyzed scats. Plant material (primarily fruits) was the most important pine marten food during each season (Table I). Fruits were consumed most in summer when they appeared in $> 80\%$ of the sample. Of nine fruits identified in the diet, carob fruit (*Ceratonia siliqua*) was eaten most throughout the year. Other fruits of seasonal importance included myrtle berries (*Myrtus communis*) in autumn and winter, citrus (*Citrus* sp.) and cherries (*Prunus* sp.) during spring, and *Cneorum tricoccon* and figs (*Ficus carica*) in summer.

TABLE I

Food items expressed as percent frequency of occurrence in Martes martes scats from the island of Mallorca, 1992-93 (percent volume in parentheses).

Food category/food item	Winter		Spring		Summer		Autumn		Mean
Mammals	46.4	(31.6)	51.5	(32.6)	37.7	(24.0)	61.0	(42.8)	49.1
<i>Apodemus sylvaticus</i>	13.6	(9.8)	30.0	(17.8)	16.5	(10.1)	29.3	(20.2)	
<i>Mus</i> sp.	7.5	(5.1)	2.3	(2.1)	1.1	(0.5)	2.8	(.9)	
<i>Rattus</i> sp.	4.7	(4.2)	7.7	(6.5)	12.5	(8.8)	8.3	(5.1)	
<i>Oryctolagus cuniculus</i>	5.6	(3.4)	2.3	(1.1)	0.7	(0.5)	9.7	(7.1)	
<i>Eliomys quercinus</i>	—	—	—	—	1.8	(1.0)	—	—	
<i>Atelerix algirus</i>	—	—	—	—	0.7	(0.3)	—	—	
Domestic goat/sheep	7.5	(4.4)	3.0	(1.8)	1.1	(0.5)	0.8	(0.2)	
<i>Felis cattus</i>	0.4	(0.4)	—	—	1.1	(0.1)	2.6	(1.8)	
<i>Mustela nivalis</i>	—	—	—	—	0.4	(0.1)	—	—	
Unidentified	7.0	(4.3)	6.1	(2.3)	2.9	(0.6)	7.2	(7.4)	
Birds	13.6	(7.6)	20.0	(9.8)	9.2	(3.9)	15.0	(9.0)	14.4
Reptiles	0.4	(0.1)	10.0	(5.5)	3.6	(1.6)	5.3	(3.3)	4.8
Invertebrates	11.7	(3.6)	29.2	(11.4)	28.9	(15.1)	13.1	(4.8)	20.7
Coleoptera	9.4	(3.4)	23.1	(9.8)	10.3	(4.5)	8.8	(3.0)	
Orthoptera	0.4	(0.1)	5.4	(1.5)	16.2	(9.2)	1.7	(1.1)	
Araneae	1.8	(0.1)	0.7	(0.1)	1.4	(0.5)	—	—	

Food category/food item	Winter		Spring		Summer		Autumn		Mean
Hymenoptera	—	—	—	—	0.7	(0.3)	—	—	
Unidentified	—	—	—	—	0.3	(0.6)	2.6	(0.6)	
Plant Material	77.6	(56.2)	66.6	(41.4)	80.9	(55.2)	60.3	(34.4)	70.4
<i>Ceratonia siliqua</i>	53.0	(40.0)	30.7	(19.0)	18.0	(10.0)	22.1	(13.7)	
<i>Myrtus communis</i>	21.6	(14.9)	0.7	(0.1)	—	—	16.8	(10.2)	
<i>Arbutus unedo</i>	1.8	(1.0)	—	—	—	—	4.4	(2.1)	
<i>Cneorum tricoccon</i>	—	—	6.1	(1.8)	9.2	(6.7)	1.7	(0.6)	
<i>Prunus sp.</i>	—	—	12.3	(10.4)	1.5	(1.5)	1.6	(0.5)	
<i>Citrus sp.</i>	—	—	15.4	(9.8)	25.0	(20.1)	—	—	
<i>Ficus carica</i>	—	—	—	—	16.5	(9.7)	2.6	(1.3)	
<i>Rubus sp.</i>	—	—	—	—	2.6	(0.7)	—	—	
<i>Juniperus phoenicea</i>	—	—	—	—	0.4	(0.1)	0.8	(0.8)	
Other fruits:	0.8	(0.2)	0.7	(0.2)	5.7	(3.9)	3.3	(1.7)	
Graminoids	0.4	(0.1)	0.7	(0.1)	—	—	—	—	
Unidentified	—	—	—	—	2.0	(2.5)	7.0	(3.4)	
Other	1.4	(0.9)	1.5	(0.2)	0.7	(0.3)	12.4	(5.5)	4.0

Mammals were the second-most favored food of pine martens, on average appearing in half of the analyzed faeces. Their greatest use occurred during spring and autumn. Four species appeared in the diet regularly. Wood mice (*Apodemus sylvaticus*) were most prevalent during the year with peaks in occurrence in spring and autumn. Predation on wood mice appeared to be age selective as 71 % of 28 individuals taken were juveniles. Rats (*Rattus sp.*) were taken most in summer, and rabbits in autumn. Noteworthy were the remains of African hedgehog (*Atelerix algirus*), feral cat, weasel, and domestic goat and sheep in the diet. They were infrequent food items and most likely were roadkilled animals taken as carrion rather than prey.

Important secondary foods consisted of invertebrates and avian prey. Invertebrates were most frequent in spring and summer and were comprised mainly of beetles (Coleoptera) and grasshoppers (Orthoptera). Birds were taken most in spring, but less so during autumn and winter. Twenty-five individuals consisting of 11 species were identified from the total sample. Passerines accounted for 84 % of the birds taken; Sardinian warblers (*Sylvia melanocephala*) (N = 7) and robins (*Erithacus rubecula*) (N = 5) were preyed on most.

Reptiles were of minor importance in the Mallorcan martens diet, however, their greatest use occurred in spring. Other foods (human refuse, dirt, etc.) were scarcely represented in the diet.

Genetta genetta - Mallorca

A total of 17 food items were identified from 331 faeces. Mammals stood out as the dominant year-round component of the genet diet in Mallorca which on average appeared in > 90 % of the analyzed scats (Table II). They were a relatively

constant and stable food during the four seasons, but their greatest use occurred during winter and spring. All five Mallorcan small mammal taxa were taken by genets, but wood mice were consumed most.

TABLE II

Food items expressed as percent frequency of occurrence in Genetta genetta scats from the island of Mallorca, 1992-93 (percent volume in parentheses).

Food category/food item	Winter		Spring		Summer		Autumn		Mean
Mammals	95.9	(76.1)	93.9	(83.1)	87.0	(67.0)	85.7	(62.6)	90.6
<i>Apodemus sylvaticus</i>	72.5	(58.2)	68.1	(61.3)	64.9	(53.1)	57.1	(43.8)	
<i>Mus sp.</i>	11.2	(6.6)	7.9	(6.9)	5.2	(2.8)	12.7	(8.7)	
<i>Rattus sp.</i>	10.4	(5.9)	16.4	(13.5)	7.8	(4.4)	6.3	(4.4)	
<i>Oryctolagus cuniculus</i>	0.7	(0.7)	—	—	3.9	(3.3)	—	—	
<i>Eliomys quercinus</i>	—	—	—	—	1.3	(1.3)	6.3	(3.3)	
Domestic goat/sheep	0.8	(0.8)	1.5	(1.3)	1.3	(0.7)	1.6	(1.1)	
Unidentified	0.6	(3.8)	—	—	2.6	(1.3)	1.6	(1.2)	
Birds	30.6	(16.6)	20.9	(7.3)	15.6	(6.4)	14.3	(10.8)	20.3
Reptiles	4.8	(1.1)	19.4	(6.2)	6.5	(3.1)	3.1	(1.6)	8.4
Invertebrates	12.9	(2.5)	14.9	(1.7)	20.7	(6.6)	25.4	(5.1)	18.4
Coleoptera	11.3	(2.2)	11.9	(1.5)	2.6	(0.1)	17.5	(3.4)	
Orthoptera	1.6	(0.3)	—	—	18.1	(6.4)	6.3	(1.4)	
Araneae	—	—	3.0	(0.2)	—	—	—	—	
Unidentified	—	—	—	—	—	—	1.6	(0.1)	
Plant Material	24.2	(3.6)	16.4	(1.6)	63.6	(16.8)	52.3	(19.7)	39.1
<i>Ficus carica</i>	—	—	—	—	46.7	(14.0)	28.6	(13.7)	
<i>Chamaerops humilis</i>	8.0	(1.7)	—	—	—	—	—	—	
<i>Ceratonis siliqua</i>	2.4	(0.1)	—	—	—	—	1.6	(0.3)	
<i>Arbutus unedo</i>	0.8	(0.1)	—	—	—	—	3.1	(3.1)	
Other fruits	0.8	(0.1)	—	—	1.3	(0.1)	—	—	
Graminoids	11.3	(1.2)	16.4	(1.6)	11.7	(1.3)	15.9	(1.7)	
Unidentified	0.8	(0.1)	—	—	2.6	(1.4)	3.1	(0.9)	
Other	0.8	(0.1)	0.0	(0.0)	0.0	(0.0)	1.6	(0.1)	0.6

Wood mice appeared in > 50 % of the seasonal and total samples. Peaks in wood mice predation occurred in winter and spring, while consumption dropped slightly in summer and autumn. Predation on wood mice was equally distributed between adult and juvenile prey during the year (49 % vs. 51 %, respectively, N = 130 age-identified prey); however, seasonal differences in age-selection were observed (Fig. 2a). Adult wood mice were taken in higher quantities during spring and summer, whereas juveniles were selected in autumn and winter. House mice (*Mus sp.*) and rats were secondary prey species but constituted a substantial part of the mammal component. The two species frequency of occurrence in the scat sample peaked in autumn and spring, respectively.

Plant material and birds were important seasonal foods of Mallorcan genets. During spring and autumn, plant material constituted a major portion of the diet, primarily due to the high use of figs. A relatively constant amount of assorted graminoids were consumed by genets each season, while dwarf palm (*Chamaerops humilis*) fruits formed a substantial part of the winter vegetal component.

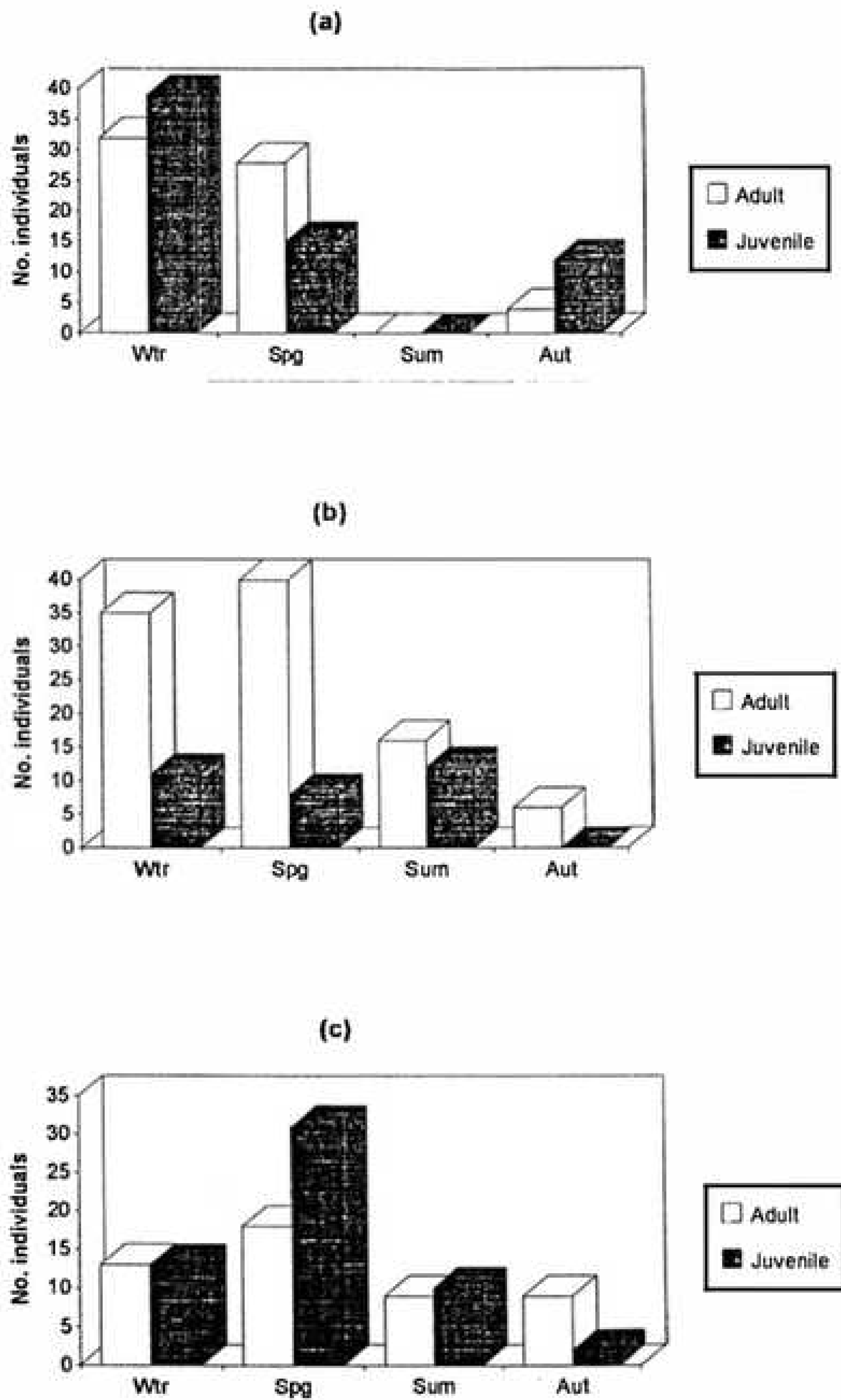


Figure 2. — Number of adult and juvenile *Apodemus sylvaticus* identified in seasonal scat samples from a) Mallorcan genets and b) Ibiza genets. c) Number of adult and juvenile *Rattus rattus* identified in seasonal scat samples from Cabrera genets.

Predation on birds was highest in winter and spring, but less so during the rest of the year. Invertebrate food items were a minor portion of the diet, consisting mainly of beetles and grasshoppers. There were scant remains of reptiles in the Mallorcan diet, however, they appeared in 20 % of the summer sample.

Genetta genetta - Ibiza

Fourteen food items were identified from 560 analyzed scats. Mammals were the most important food of Ibizan genets and averaged 92 % of the diet during the year (Table III). Their contribution to the diet remained nearly constant over the 4 seasons and was predominantly of wood mice.

Consumption of wood mice peaked in summer, and constituted more of the mammal component than all the other mammal prey combined. Ibizan genets preyed upon more adult wood mice than juveniles during the year (76 % of age-identified prey, N = 128) and in each season (Fig. 2b). Selection on adults was greatest during winter and spring.

Rats and house mice were both important seasonal secondary prey items ; the former in winter and spring, and the latter in autumn. Rabbits and white-tooth shrews (*Crocidura russula*) formed a minor portion of diet, appearing in ≤ 5 % of any seasonal sample.

A substantial portion of the Ibizan genet diet contained plant material. Graminoids constituted the bulk of the material during the year. Figs were an important vegetal component in summer and autumn, while carobs occurred most in winter.

Genets preyed upon birds primarily in autumn and winter, and appeared in roughly half of their samples. Predation on reptiles peaked during spring and summer but was low in winter and autumn. The majority of the reptile prey were Ibizan wall lizards (*Podarcis pityusensis*), while other Lacertids rarely appeared in the sample. The proportion of invertebrate remains in the diet was low except during summer when beetles were frequently taken.

Genetta genetta - Cabrera

Twelve food items were identified from 622 scats. Mammals formed a major portion of the overall diet ; however, birds were also an important dietary component and occurred in half of the analyzed sample (Table IV). Of the islands' three prey-species, rats were eaten most. During each season, rats appeared in the diet on average nearly twice as often as house mice. Rats formed more than half of the total mammal contribution and they were preyed upon most during summer. Genet preyed equally on adult and juvenile rats during the year (47 % vs. 53 %, respectively ; N = 105 age-identified prey) ; however, seasonal predation was greatest on juveniles in spring, while the rest of the year age-selection was not manifested (Fig. 2C). Rabbits accounted for a minor portion of the year-round diet whose greatest use occurred in winter and spring.

Birds were the most important food of Cabreran genets in autumn and formed a major portion of the winter diet. Of the 55 individuals taken, 95 % were passerines. Nine species appeared 31 times in the autumn sample ; 29 (94 %) were either resident or wintering birds, while only two (5 %) were migrants. Remains of ten species were identified in 24 winter scats and all were resident or wintering

TABLE III

Food items expressed as percent frequency of occurrence in Genetta genetta scats from the island of Ibiza, 1992-93 (percent volume in parentheses).

Food category/food item	Winter		Spring		Summer		Autumn		Mean
Mammals	91.8	(72.0)	89.6	(77.3)	97.3	(62.1)	88.8	(52.6)	91.8
<i>Apodemus sylvaticus</i>	65.2	(53.1)	65.4	(61.3)	79.0	(53.3)	66.6	(37.2)	
<i>Mus sp.</i>	6.9	(5.1)	3.9	(2.0)	5.4	(1.5)	11.2	(7.2)	
<i>Rattus sp.</i>	15.6	(11.0)	10.8	(8.3)	6.7	(4.4)	8.6	(6.7)	
<i>Oryctolagus cuniculus</i>	2.5	(1.9)	5.4	(2.2)	—	—	0.6	(0.6)	
<i>Crocidura russula</i>	0.8	(0.1)	3.1	(1.0)	2.7	(1.0)	—	—	
Unidentified	0.8	(0.8)	1.0	(2.5)	3.4	(1.9)	1.8	(0.8)	
Birds	40.7	(19.2)	17.8	(6.1)	16.2	(5.5)	52.5	(29.4)	31.8
Reptiles	4.4	(0.8)	29.4	(8.9)	32.4	(11.0)	6.2	(1.1)	18.1
Invertebrates	3.5	(1.0)	6.2	(0.4)	23.0	(4.1)	14.2	(2.4)	11.7
Coleoptera	3.5	(1.0)	4.6	(0.3)	17.5	(3.3)	11.7	(1.9)	
Orthoptera	—	—	—	—	2.7	(0.3)	—	—	
Hymenoptera	—	—	—	—	—	—	1.2	(0.3)	
Unidentified	—	—	1.6	(0.1)	2.8	(0.5)	1.2	(0.2)	
Plant Material	33.6	(6.8)	31.7	(7.2)	55.4	(16.9)	46.3	(14.0)	41.7
<i>Ficus carica</i>	1.6	(1.5)	0.7	(0.1)	17.5	(6.9)	9.8	(4.5)	
<i>Ceratonia siliqua</i>	8.8	(2.8)	3.1	(0.9)	3.4	(2.0)	2.2	(0.3)	
<i>Juniperus phoenicea</i>	—	—	1.5	(1.3)	1.8	(0.1)	3.0	(0.7)	
Other fruits	—	—	2.4	(0.5)	3.0	(0.6)	2.4	(0.7)	
Graminoids	21.2	(2.4)	24.0	(4.4)	26.6	(6.1)	24.1	(6.7)	
Unidentified	1.7	(0.1)	—	—	3.1	(1.1)	4.8	(1.1)	
Other	1.7	(0.9)	0.0	(0.0)	0.6	(0.1)	1.8	(0.3)	1.0

species. The most common prey was the meadow pipit (*Anthus pratensis*) which appeared in 29 % of the 2-season sample, followed by the Sardinian warbler in 20 %.

Plant material was commonly eaten by Cabreran genets during the year. Graminoids and figs were prevalent in summer, whereas juniper berries were the dominant vegetal food in winter.

Reptiles were the second-most important food type after mammals in summer, however, they formed a small part of the diet during the other seasons. All reptiles were identified as Lilford's wall lizard (*Podarcis lilfordi*). Genets consumed a relatively stable but small amount of invertebrates throughout the year, mainly beetles, and were most abundant in the autumn diet.

Felis catus - Cabrera

Ten food items were identified in 290 faeces analyzed. Mammals and reptiles were the predominant food types of feral cats (Table V). Predation on mammals was heavy throughout the year, but was highest in spring, and slightly lower in winter and summer. The three Cabreran mammal prey-species formed an impor-

TABLE IV

Food items expressed as percent frequency of occurrence in Genetta genetta scats from the island of Cabrera, 1992-93 (percent volume in parentheses).

Food category/Food item	Winter	Spring	Summer	Autumn	Mean				
Mammals	74.3	(45.3)	87.7	(53.1)	79.2	(46.9)	40.6	(22.8)	70.4
<i>Mus musculus</i>	20.7	(10.2)	22.8	(9.2)	27.7	(10.1)	14.0	(4.7)	
<i>Rattus rattus</i>	39.3	(25.9)	51.0	(35.7)	41.6	(29.1)	21.3	(15.1)	
<i>Oryctolagus cuniculus</i>	12.0	(8.2)	11.1	(7.3)	8.9	(7.1)	2.6	(1.7)	
Unidentified	2.1	(0.9)	2.4	(0.8)	1.0	(0.6)	2.6	(1.2)	
Birds	56.8	(35.3)	41.5	(28.3)	21.7	(9.1)	70.0	(52.3)	47.5
Reptiles	9.3	(1.8)	25.0	(10.3)	60.4	(27.9)	10.0	(3.4)	26.1
Invertebrates	22.9	(3.8)	18.0	(3.1)	12.8	(3.0)	28.6	(5.3)	20.5
Coleoptera	22.4	(3.8)	16.5	(2.5)	7.9	(0.9)	27.3	(4.8)	
Orthoptera			0.5	(0.1)	4.9	(2.1)	0.6	(0.4)	
Unidentified	0.5	(0.1)	1.0	(0.5)			0.6	(0.1)	
Plant Material	36.0	(13.7)	11.7	(3.2)	42.1	(11.0)	32.6	(14.7)	30.6
<i>Ficus carica</i>	0.5	(0.2)			11.8	(3.9)	8.0	(5.9)	
<i>Cneorum tricoccon</i>			0.5	(0.1)	1.9	(0.4)			
<i>Juniperus phoenicea</i>	19.6	(9.8)	1.0	(0.5)	2.9	(1.2)	9.3	(4.2)	
<i>Arbutus unedo</i>							0.6	(0.4)	
Other fruits	0.5	(0.1)					1.6	(0.3)	
Graminoids	12.0	(1.9)	9.0	(2.0)	22.7	(5.1)	12.0	(3.6)	
Unidentified	3.2	(1.6)	1.2	(0.6)	2.8	(1.0)	0.6	(0.3)	
Other	5.4	(0.4)	4.7	(1.9)	3.9	(2.1)	3.3	(1.2)	4.3
Human refuse	3.8	(0.2)	2.1	(0.6)			2.0	(0.3)	
Other	1.1	(0.1)	1.6	(0.4)	2.9	(1.1)			
Unidentified	1.6	(0.1)	1.0	(0.8)	1.0	(1.0)	1.3	(0.9)	

tant part of the cats' diet, but house mice were preyed upon most. House mice formed roughly half of the mammal component in each season except autumn when rats were slightly more abundant in the diet. Both prey-species appeared in greatest proportions in the diet during summer. Cats preyed most on adult house mice (65 % of 31 age-identified prey), whereas juvenile rats were taken more than adults (70 % of 23 age-identified prey). Rabbits were an important secondary prey-species, in particular during winter and spring.

Reptiles were preyed upon most during summer ; however, they formed a substantial part of the diet the rest of the year, greater than the other food types except mammals. All reptile remains in the cats diet were identified as *P. lilfordi*.

Noteworthy was the high incidence of human refuse or garbage in the cat diet throughout the year (\bar{x} = 30 % frequency of occurrence), Refuse appeared most frequently during summer and roughly 25 % of the sample the remainder of the year. Some common refuse items consisted of paper, plastic string, and occasionally fish vertebrae, suggesting that scavenging among garbage on the island was relatively common.

Birds and plant material were minor food components of the feral cat diet. Predation on birds was greatest in autumn and winter, while it was low the

TABLE V

Food items expressed as percent frequency of occurrence in Felis catus scats from the island of Cabrera, 1992-93 (percent volume in parentheses).

Food category/food item	Winter		Spring		Summer		Autumn		Mean
Mammals	64.1	(34.2)	82.9	(57.9)	65.0	(32.7)	47.6	(31.6)	64.9
<i>Mus musculus</i>	30.7	(12.0)	37.2	(20.7)	32.5	(14.3)	19.0	(10.1)	
<i>Rattus rattus</i>	12.8	(5.9)	27.1	(21.1)	23.7	(11.4)	23.8	(18.7)	
<i>Oryctolagus cuniculus</i>	20.5	(16.3)	16.3	(14.6)	8.7	(6.9)	4.7	(2.8)	
Unidentified	—	—	2.3	(1.6)	—	—	—	—	
Birds	23.0	(15.6)	10.0	(6.8)	3.7	(2.4)	35.7	(21.7)	18.1
Reptiles	51.2	(34.6)	44.1	(21.7)	65.0	(33.0)	47.6	(28.4)	51.9
Invertebrates	0.0	(0.0)	0.7	(0.5)	3.7	(0.3)	4.7	(0.4)	2.2
Coleoptera	—	—	—	—	3.7	(0.3)	4.7	(0.4)	
Unidentified	—	—	0.7	(0.5)	—	—	—	—	
Plant Material	12.8	(1.6)	13.9	(2.5)	13.7	(1.9)	21.4	(6.1)	15.4
<i>Cnecorum tricoccon</i>	—	—	1.5	(0.1)	—	—	—	—	
<i>Ficus carica</i>	—	—	—	—	—	—	4.7	(3.4)	
Graminoids	12.8	(1.6)	10.8	(2.2)	13.7	(1.9)	14.2	(2.0)	
Other material	—	—	1.5	(0.1)	—	—	—	—	
Unidentified	—	—	—	—	—	—	2.3	(0.6)	
Other	28.2	(13.8)	22.4	(10.5)	47.5	(29.5)	23.8	(11.5)	30.4
Human refuse	25.6	(11.3)	20.9	(9.9)	45.0	(26.8)	23.8	(11.5)	
Unidentified	2.5	(2.5)	1.5	(0.5)	5.0	(2.7)	—	—	

remainder of the year. Nearly all plant material ingested consisted of graminoids. Invertebrates were rarely eaten by cats and formed an insignificant part of their diet.

DIET SIMILARITIES

Among-population

Of the five carnivore populations, seasonal diets were least similar for Cabreran genets ($\bar{x} = 84\%$ overlap, $SE = 0.04$), whereas they were most similar for Mallorcan pine martens ($\bar{x} = 95\%$, $SE = 0.01$). Seasonal diets were relatively stable for genets on Ibiza ($\bar{x} = 94\%$, $SE = 0.01$) and Mallorca ($\bar{x} = 93\%$, $SE = 0.01$), and feral cats on Cabrera ($\bar{x} = 92\%$, $SE = 0.02$).

Between-population

Seasonal diet overlap means were not significantly different between pine martens and genets on Mallorca (Mann-Whitney U-test, $U = 21$, $P = 0.6$) nor

between genets and feral cats on Cabrera ($U = 28$, $P = 0.1$). Diet overlap means approximated significance between Cabreran genets and those on Mallorca and Ibiza (both $U = 30$, $P = 0.06$), while overlap means were not different between Mallorcan and Ibizan genets ($U = 22$, $P = 0.5$).

Food habits contrasted most between Mallorcan pine martens and genets, and between Cabreran and Mallorcan genets as diet compositions were significantly different during 3 of the 4 seasons (Table VI). Significant variation in diet occurred between Cabreran genets and feral cats, and Cabreran and Ibizan genets (2 of 4 seasons). Mallorcan and Ibizan genet diets were alike during each season.

TABLE VI

Differences in seasonal diet composition of Martes martes, Genetta genetta and Felis catus in the Balearic Islands

	Winter	Spring	Summer	Autumn
Mallorca, <i>M. martes</i>				
Mallorca, <i>G. genetta</i>	***	***	***	NS
Mallorca, <i>G. genetta</i>				
Ibiza, <i>G. genetta</i>	NS	NS	NS	NS
Mallorca, <i>G. genetta</i>				
Cabrera, <i>G. genetta</i>	***	NS	**	***
Ibiza, <i>G. genetta</i>				
Cabrera, <i>G. genetta</i>	*	NS	NS	***
Cabrera, <i>G. genetta</i>				
Cabrera, <i>F. catus</i>	***	NS	NS	*

NS : Not significant. * $0.01 < P < 0.05$. ** $0.001 < P < 0.01$. *** $P < 0.001$.

TROPHIC DIVERSITY

Diet diversity measures of Mallorcan pine martens and genets were greatest in spring for the former and summer and autumn for the latter ; for both species diet breadth was lowest during winter (Table VII). On Cabrera, trophic diversity of genets and feral cats were identical, being most diverse in autumn and least diverse in spring. Among the three genet populations, diet breadths were high in summer ; however, on Mallorca and Cabrera they were equally broad during autumn.

Mean food niche breadths values were greatest for Cabreran genets and smallest for Mallorcan genets. There was no significant difference between niche breadth values of pine martens and genets on Mallorca, nor genets and feral cats on Cabrera (Paired t-test, $P = 0.4$ and $P = 0.09$, respectively). Among genet populations, Cabreran and Mallorcan had significantly different diet breadths ($P = 0.07$), as did Mallorcan and Ibizan ($P = 0.03$), while Cabreran and Ibizan genets approached significance ($P = 0.05$).

TABLE VII

Seasonal and mean trophic diversity indices for Martes martes, Genetta genetta and Felis catus in the Balearic Islands.

	<i>M. martes</i> Mallorca	<i>G. genetta</i> Mallorca	<i>G. genetta</i> Ibiza	<i>G. genetta</i> Cabrera	<i>F. catus</i> Cabrera
Winter	2.64	2.60	2.70	3.73	3.08
Spring	3.74	2.71	2.98	3.23	2.53
Summer	2.89	3.02	3.51	3.80	2.64
Autumn	3.08	2.99	3.32	3.88	3.92
Mean	3.09	2.83	3.12	3.66	3.04
SE	0.23	0.10	0.18	0.14	0.31
N	728	331	560	622	290

DISCUSSION

SEASONAL DIETS AND THEIR VARIABILITY

Martes martes

Pine marten diets on Mallorca were the most stable of the five carnivores, with slight variation in food composition between seasons. Frugivory among martens was extensive and was closely correlated with the fruiting pattern of most species in the sampled areas. Carob fruits were most preferred and, unlike the other fruits, were eaten all year-round though they ripen during winter. Because they are relatively abundant throughout the year, and high in lipids and carbohydrates, they provide martens with an easily-acquired, stable, and energy-rich food source.

Other fruits were seasonally important, but for any given season, only citrus, during summer, appeared in the diet more than carobs. Marten use of citrus has not been documented in any previous studies. Like carobs, marten preference for citrus can best be attributed to their high energy rewards and availability in the study area.

Three of the five most important fruits, and four of the nine appearing in the marten diet were orchard varieties, suggesting that marten foraged among farmland or disturbed (Herrera, 1989) habitats. However, because where I sampled many of the farms were abandoned or seldom occupied by tenants, does not necessarily imply that Mallorcan martens tended to live closer to human dwellings than documented for the species elsewhere (Delibes, 1983; Marchesi, 1989). Martens use of this relatively open habitat on an island void of predators does, however, suggest that their occurrence in non-forested areas may be greater than previously reported (Lockie, 1961; Brainerd, 1990).

Wood mice were the most prevalent prey-species in the diet, while predation on the others was low. Relative prey abundances were not quantified for this

predator population, nor the others reported herein. However, small mammal capture data from Mallorca have shown that wood mice were the most abundant prey-species and population densities were generally highest during autumn when young are recruited into the population (Alcover, 1983 ; pers. comm.). The seasonality of marten consumption of wood mice and age-selection towards juveniles suggests that predation might only become important when wood mice are most abundant and/or easiest to obtain.

Bird predation was relatively low and constant throughout the year, with little evidence off a seasonal trend. Marten did not appear to actively select for any prey-species as the birds most commonly taken were habitat generalists and overall most common on the island (Muntaner, 1991). Invertebrate prey were secondary foods that fluctuated seasonally and probably according to their availability.

Mallorcan pine marten food habits were similar to other pine marten populations where they have been described as opportunistic predators with a generalized diet (Clevenger, 1994). However, the extensive frugivory of Mallorcan martens is noteworthy and only comparable to published results from northern Spain where fleshy fruits accounted for > 75 % of the diet (Braña & del Campo, 1982 ; Ruiz-Olmo and López-Martín, 1992). Fruits, in particular carobs, comprised a significant part of the Minorcan pine marten diet, but only in autumn were they are the predominant dietary component (Clevenger, 1993a, b).

Genetta genetta

The Ibizan and Mallorcan genet diets varied little between seasons, while on Cabrera they were markedly different from the other two and exhibited great seasonal fluctuations. Mammals were the overall dominant food type in all three genet populations forming > 90 % of the diet on Mallorca and Ibiza, and > 70 % on Cabrera. Mammals were a seasonally stable food among Ibizan and Mallorcan genets, but showed strong seasonal variation on Cabrera. Wood mice were the single most important prey-species of Mallorcan and Ibizan genets ; they are absent on Cabrera where genets preferred rats over house mice.

Predation on wood mice was nearly identical on Mallorca and Ibiza despite lower densities being reported from latter (Alcover, 1984a). The predominance of wood mice in the diet on Mallorca and Ibiza suggests that the genets were efficient predators of wood mice. Other prey species were of lesser importance and their contribution to the diet as alternative prey may depend on their abundance and availability in habitats where genets normally hunt. Of particular interest were white-tooth shrews in the Ibizan genet diet. Shrews in general are reportedly disliked or ignored by most carnivores (King, 1980 ; Erlinge, 1981), nonetheless, their presence in the diet is most likely due to their high densities on the island (Alcover, 1984a).

In summer the density of wood mice on Mallorca is low and composed mainly of adults, but in autumn it increases rapidly as juveniles are recruited into the population (J. Alcover, pers. comm.). Mallorcan genet predation on wood mice was also low during summer and directed towards adults ; however, in autumn consumption did not increase but instead decreased. Prey-age selection data showed that Mallorcan genets took more juvenile wood mice in autumn than any other season, which suggests that they may be more abundant at that time of year.

In contrast, Ibizan genets took more adult wood mice than juveniles year-round. On this island genets may be selective predators of adults, but more age-selection data are needed with indices of prey abundance over several years to confirm this phenomenon.

Reasons why wood mice predation was not higher during autumn on both islands when their densities are normally greatest cannot be explained without concomitant data on relative prey abundances. Densities of small mammals on Mediterranean islands are influenced by many factors extrinsic and intrinsic to their populations (Navajas y Navarro *et al.*, 1989), and seasonal trends of species abundance may vary between years. The sudden influx of wintering birds to Ibiza and their high contribution to the diet during autumn appears to explain, at least partially, the drop in wood mice consumption by genets on this island.

The results from Mallorca and Ibiza do confirm earlier studies indicating that genets are specialized predators on wood mice (Delibes, 1974 ; Cugnasse & Riols, 1984 ; Lode *et al.*, 1991 ; Palomares & Delibes, 1991 ; Hamdine *et al.*, 1993). Cabrera is unique, however, since it is the only Mediterranean population where wood mice do not occur, although they once did and have gone extinct in recent times (Alcover, 1988). Alcover (1993) reported that the combined effects of a rapidly colonizing rat population and deforestation of the island probably caused the species disappearance on Cabrera. Rats, house mice and wood mice presently coexist on another Mediterranean island (Corsica) where Granjon & Cheylan (1988) found that wood mice were the weakest competitor of the three, and its demographic cycle and habitat use were severely affected by the other two species.

On Cabrera, mammals were the most important food in the genet diet, but were seasonally variable. In the absence of wood mice, rats were taken more than house mice. Possible explanations for differential predation on the two murids is discussed later in this paper.

The importance of birds in the genet diets was greatest in Cabrera and lowest in Mallorca. Predation rates varied greatly among seasons on Ibiza and Cabrera, though on Mallorca it was constant. Birds were taken most during autumn-winter in Cabrera and Ibiza when they are most abundant as wintering and migratory birds augment the resident population (Luis & Purroy, 1981). The bulk of the avian prey from Cabrera and Ibiza were shrubland species, most of which feed, or sleep on the ground (e.g., meadow pipits and thrushes (*Turdus spp.*)), thereby being more vulnerable to predation. During summer, bird predation was lowest among the three diets and likely due to their reduced numbers (Luis & Purroy, 1981).

Reptiles were an important secondary prey only on Ibiza and Cabrera, and seasonally variable on both islands. The island reptile fauna is impoverished, however, *P. lilfordi* were abundant on Cabrera and formed an important part of the genets' summer diet. Due to the mild mediterranean climate *P. lilfordi* were active year-round, but peak activity occurs during summer, and their densities are highest then also (A. Traveset, pers. comm.).

Contrary to my results, Alcover (1982, 1984b) documented that reptiles were the most important food of genets on Cabrera ; however, his findings were probably influenced by sampling bias as faecal material was collected from four latrines during summer and therefore are likely not representative of the species true food habits (year-round). Nevertheless, my results also confirmed that *P. lilfordi* were an important summer food (though mammals occupied more volume), though during the rest of the year genets concentrated on other more accessible and seasonally abundant prey.

Invertebrates formed a minor but regular part of the diets on Mallorca and Cabrera, however, on Ibiza they fluctuated seasonally. Beetles were consumed year-round and largely more important than grasshoppers on the three islands, while predation of the latter was limited to summer. Both genets and martens took substantial amounts of the two kinds of invertebrates on Mallorca, which suggests that differences in local abundances between populations may account for the observed variance.

Plant material constituted an important secondary food for genets although its occurrence in the three diets was highly variable throughout the year. A substantial but seasonally stable amount of vegetal material consisted of graminoids. Reasons why carnivores eat grass have not been studied but suggestions include providing trace elements and vitamins (Achterberg & Metzger, 1978), helping to disgorge indigestible material (Pettersson, 1968), and helping to void parasites (Borkenhagen, 1979).

Although sources of garbage (or other non-natural foods) were available to all three populations, its use was regularly observed only on Cabrera. The energetic gains accrued by exploiting readily available, high-caloric foods at refuse disposal sites has been documented for other carnivores (Harris, 1981 ; Boitani, 1982 ; Herrero, 1983). It is possible that some genets may have become partly, or entirely habituated to the few inhabitants of the small island National Park, whereas approaching villages or human dwellings on the more-populated islands of Ibiza and Mallorca is much more life-threatening.

Felis catus

Feral cat diets on Cabrera did not change markedly between seasons. Mammals were one of two major food types and their seasonal occurrence was highly variable. Like Cabreran genets, cat predation on mammals was highest during spring. However, unlike genets, cat preyed most on house mice rather than rats.

Because of the high proportion of human refuse in the cats diet, and presumably greater association with this non-natural food and where it is found, one might expect that where cats hunt, rats rather than mice would be the most abundant prey-species. Similarly, if larger body size confers advantages in seizing and capturing large prey (Rosenzweig, 1966 ; Erlinge, 1987 ; Vezina, 1985), then Cabreran cats, which are nearly twice as large as genets (Cabrera National Park, unpubl. data), would have been expected to prey more on rats as well. Unfortunately, data on distribution and densities of Cabreran carnivores and their prey are unavailable, nonetheless, the difference in prey-species selection is surprising.

Several factors may explain the observed prey-selection by the two carnivores. Firstly, adult rats are a formidable opponent for any medium-sized predator (Biben, 1979 ; Childs, 1986). Cats may simply be fearful of rats even though they may be found in higher localized densities than house mice (Leyhausen, 1979 ; Caro, 1980). Preferred prey size among the two carnivores also might be imprinted on them early on when their mothers bring them prey (Leyhausen, 1956). Lastly, differential predation on the two murids might be explained by temporo-spatial segregation between the two prey-species and genet activity patterns (Granjon & Cheylan, 1988).

Conclusive evidence to demonstrate that cats are fearful of rats, or that they are more abundant than house mice is lacking, but prey-age selection data

indicated that Cabreran cats had a tendency to take more juvenile rats than adults. In contrast, genets took equal numbers of adult and juvenile rats during the year except in spring when young were preyed on most. Genets are primarily nocturnal predators (Lode *et al.*, 1991 ; Palomares & Delibes, 1988, 1994), while feral cat activity is generally arrhythmic (Turner & Meister, 1988 ; Haspel & Calhoun, 1993). Prey choices might therefore be explained by temporo-spatial differences in prey availability and predatory behaviour of the two Cabreran carnivores.

Rabbits were consumed least of all feral cat mammal prey. On the contrary, Fitzgerald (1988) found that rabbits formed the major part of feral cat diets on islands, while rats occupied a minor part. During this study, however, rabbits were common (pers. obs.) on Cabrera but genets were not significant predators, which does not account for their scarcity in the cats diet. The greater availability or access to other prey and food types, such as house mice, lizards, ground-dwelling passerines, and human refuse compared to other cat populations most likely accounts for rabbits being secondary prey.

Reptiles were the second-most important food of Cabreran cats and were a seasonally stable food throughout the year. Feral cats were efficient predators of *P. lilfordi* throughout the year, whereas genets focused on other seasonal prey. The importance of reptiles in feral cat diets has been reported for other islands as well (Karl & Best, 1982 ; Laurie, 1983 ; Konecny, 1987).

Feral cats consumed human refuse year-round but its seasonal importance was highly variable and probably related to its availability. Refuse appeared in nearly half of the summer scats, while only 25 % the other seasons. The high use during summer is most likely attributed to the large amount of garbage produced during this period as the number of tourists visiting Cabrera increases then. The remainder of the year there is a low but constant number of people on the island, which helps explain the relative scarcity of non-natural foods in the diet.

The observations reported herein support other studies describing cats as versatile opportunistic predators able to exploit a wide range of prey and switch readily from one prey to another (Konecny, 1987 ; Fitzgerald, 1988). Because cats on islands usually are confronted with fewer prey types compared to mainland populations, their diets most times are disproportionately concentrated on one or two prey groups (Jones, 1977 ; Furet, 1989 ; Fitzgerald *et al.*, 1991). From the results presented, Cabreran cats apparently live in a food-rich environment uncommon among other island feral cat populations. The diversity of prey groups available, and the relative abundance of each in the diet appeared high compared to most other insular cat populations (see Fitzgerald, 1988).

Furthermore, human refuse was accessible to Cabreran cats which other insular cat populations usually lack.

TROPHIC RELATIONSHIPS

On Mallorca seasonal food resource use differed greatly between pine martens and genets. Although both species had similar food niche breadths, they exploited a completely different group of foods. Martens primarily consumed fruits, while genets fed heavily on small mammals throughout the year.

Pine martens on Mallorca and Minorca appear to occupy the same habitat and food niche as *M. foina*. However, my results indicated that Mallorcan pine martens

specialize on fruits and to a lesser degree mammals, while the Minorcan race is clearly a generalist feeder (Clevenger, 1993a, b). The differences in marten diet characteristics between islands may be responsible for the observed craniometric variation (Alcover *et al.*, 1986) and product of having to share resources with genets on Mallorca while not on Minorca.

There was a moderate amount of food resource overlap between genets and feral cats on Cabrera. Though diet breadth values were similar both carnivores exploited the foodbase differently. Genets utilized a much broader range of foods compared to feral cats. Mammals were the only food used intensively by both carnivores year-round, however, there were strikingly different choices of mammal prey taken by each. During this study feral cat predation on the *P. lilfordi* was noteworthy. The effect feral cats have on the endemic lizard population should be measured and appropriate management action taken.

Diet characteristics of Cabreran genets varied greatly from those on Ibiza and Mallorca. Cabreran diets were seasonally variable and highly diverse, while those on Mallorca were the most seasonally stable and least diverse of all. Food resource use by Ibizan genets was most similar to Mallorcan; both diets tended to be specialized as mammals were the dominant food component year-round. Conversely, Cabreran genets concentrated on foods that were seasonally abundant, as noted by the high take of birds in autumn-winter and reptiles in summer. The non-specialized resource use exhibited by Cabreran genets contrasts with most other populations documenting genets as specialized predators of mammals, wood mice in particular (Cugnasse & Riols, 1984; Delibes *et al.*, 1989; Palomares & Delibes, 1991; Lode *et al.*, 1991). The relatively recent arrival of genets to Cabrera (Alcover, 1993) and highly opportunistic food habits described herein demonstrate their adaptability to new environments, plasticity in food resource use, and potential for population expansion.

BIAS AND ERROR

The scat sample used in the analyses was not appreciably affected by biases otherwise associated with scat collection along subjectively selected routes. Selection of sampling routes and latrines on each island was not performed randomly but based on prior knowledge of species abundance and was designed to sample a broad geographical area. Seasonal sample sizes from the four populations were large (> 70/season), but probably below the recommended number to attain high confidence intervals (Reynolds & Aebischer, 1991).

In this study genet diets were quantified by individualizing scats through frequent sampling. This method was chosen so that dietary data will subsequently allow for comparisons of feeding ecology between Balearic islands and other carnivore populations.

Some previous studies of genet food habits have used whole latrine faecal masses to count food items (Alcover, 1982, 1984b; Delibes *et al.*, 1989). This method provides an estimate of the minimum number of individuals consumed (vertebrate and invertebrate prey), however, the procedure has some methodological limitations which should be recognized.

From faecal masses it is not possible to determine the number of scats present, the season when food items were consumed, or differentiate between prey

food and genet prey. Furthermore, calculation of the minimum number of food items from a faecal mass is complicated during analysis due to fracture, erosion and subtle differences among specific food item fragments. The deficiencies are considerable, therefore trophic diversity or food niche breadth calculations based on this method will tend to be unreliable and inadequate for comparing diets from other populations, especially those derived from scat analysis. Only if these biases can be reduced, then faecal masses may be used to describe general food habits. Future work should be carried out to possibly determine correction factors for diet measures of faecal mass food items from scats. This could be achieved by comparing values for food items analyzed from individualized latrine scats with the same faecal remains later reanalyzed as a faecal mass.

SUMMARY

Year-round diet characteristics of pine martens (*Martes martes*), spotted genets (*Genetta genetta*), and feral cats (*Felis catus*) were studied on Mallorca, Ibiza, and Cabrera in the Balearic archipelago, Spain. Analysis of 2531 scats were used to describe seasonal food habits and its variation. Mallorcan pine marten diets varied least of all between seasons. Plant material (mainly fruit) was the dominant pine marten food followed by mammals which appeared in half of the seasonal samples. Mallorcan and Ibizan genet diets were most alike, while Cabreran genet diets were markedly different from the two. Mammals were the dominant year-round diet component on Mallorca and Ibiza, whereas mammals and birds were of equal importance on Cabrera. Genets preyed heavily on wood mice (*Apodemus sylvaticus*) on Mallorca and Ibiza, and rats (*Rattus*) on Cabrera. Avian predation was highest on Cabrera and Ibiza during autumn and winter. Mammals and reptiles were major year-round diet components of Cabreran feral cats. Human refuse and birds were seasonally important cat foods and were consumed when most abundant on the island. Trophic niche breadth values were greatest for Cabreran genets and lowest for Mallorcan genets. On Mallorca and Cabrera, coexisting carnivores had similar niche breadth values but exploited the available foods differently. Mallorcan and Ibizan genet diets were most similar while on Cabrera genets were opportunistic predators. The methodological limitations of genet diet descriptions from faecal mass analysis are presented. A method for determining correction factors for diet measures of faecal mass food items from scats is proposed.

RÉSUMÉ

Les régimes alimentaires de la Martre (*Martes martes*), de la Genette (*Genetta genetta*) et du Chat haret (*Felis catus*) ont été étudiés tout au long de l'année dans l'archipel des Baléares sur les îles de Majorque, Ibiza et Cabrera (Espagne). L'analyse de 2 531 fèces a été utilisée pour décrire les habitudes alimentaires saisonnières et leurs variations. Le régime alimentaire de la Martre de Majorque est le moins variable des trois entre les différentes saisons. Le matériel végétal est l'aliment dominant de la Martre, suivi par les mammifères qui apparaissent dans la moitié des échantillons. Les régimes alimentaires des

Genettes d'Ibiza et de Majorque sont très semblables alors que celui de la Genette de Cabrera est clairement différent des deux autres. Les mammifères sont la composante dominante tout au long de l'année à Majorque et Ibiza, alors que les mammifères et les oiseaux sont d'égale importance à Cabrera. Les Genettes se nourrissent beaucoup de mulots sylvestres (*Apodemus sylvaticus*) à Majorque et Ibiza et de rats (*Rattus* sp.) à Cabrera. Durant l'automne et l'hiver, la prédation d'oiseaux est la plus élevée à Cabrera et Ibiza. Tout au long de l'année, les mammifères et les reptiles sont les composantes majeures de l'alimentation du Chat haret de Cabrera. Les déchets et les oiseaux constituent une alimentation saisonnière importante pour les Chats et sont consommés lorsqu'ils sont les plus abondants sur l'île. L'amplitude de la niche trophique est la plus grande pour la Genette de Cabrera et la plus basse pour la Genette de Majorque. A Majorque et Cabrera les carnivores coexistants ont une amplitude de niche trophique similaire mais exploitent la nourriture différemment. L'alimentation de la Genette de Majorque est très similaire à celle d'Ibiza alors qu'à Cabrera les Genettes sont des prédateurs opportunistes. Les limites méthodologiques de la description de l'alimentation des Genettes à partir des analyses des masses fécales sont présentées. Une méthode de détermination des facteurs correctifs pour la mesure des restes alimentaires de la masse fécale à partir des crottes est proposée.

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