

FRUGIVORY OF *MARTES MARTES* AND *GENETTA GENETTA* IN AN INSULAR MEDITERRANEAN HABITAT

Anthony P. CLEVINGER*

A great variety of mammals consume fleshy fruits and serve as potential dispersers of seeds of many plant species. Although mammalian carnivores are important dispersal agents, frugivory and seed dispersal among them has been addressed only recently (Debussche & Isenmann, 1989; Herrera, 1989; Bustamante *et al.*, 1992; Pigozzi, 1992; Willson, 1993; Pendje, 1994). Because most mammalian carnivores are highly mobile and capable of dispersing seeds far from parent plants and over a variety of microhabitats, they may have potentially important implications for seed-dispersal processes.

The mutualistic relationships between vertebrates (primarily birds) and fleshy-fruits in Mediterranean habitats have been the focus of numerous studies (Herrera & Jordano, 1981; Jordano, 1982; Herrera, 1984; Debussche & Isenmann, 1985a, 1985b, 1989; Herrera, 1989; Pigozzi, 1992). In contrast, frugivory among birds and mammals on Mediterranean islands has received surprisingly little attention (Debussche *et al.*, 1990; Traveset, 1992, 1995) although animal/plant interactions in environments with low species diversity, such as islands and deserts, are most likely forced and intense (Howe, 1986).

In the Western Mediterranean Basin, two introduced mammalian carnivores which are known to eat fruit occur in the Balearic Islands. Eurasian Pine martens (*Martes martes*) are found on Minorca and Mallorca, while Common genets (*Genetta genetta*) inhabit Mallorca, Eivissa and Cabrera. On their respective islands, both species are common and widely distributed (Clevenger, 1993a, 1994a, pers. obs.) which make them suitable subjects for studying their interactions with fleshy-fruited plants. In this paper, I present information on the year-round frugivory of Pine martens and genets on three Mediterranean islands. Of particular importance was how the carnivores seasonally exploited the available fleshy-fruits and their potential role as seed dispersal agents on the islands.

STUDY AREA

The study was conducted in the Balearic Island archipelago (38° 40' 40" 05' N, 1° 17' 4" 23' E) on the islands of Mallorca, Eivissa, and Cabrera. General descriptions of the physiography and vegetation of the Islands can be found in Riba *et al.* (1979) and Folch (1981).

* Present address : 3, rue Saint Guillaume, F-92400 Courbevoie, France.

Department of Forestry, Wildlife and Fisheries, University of Tennessee, Knoxville, TN 37901-1071 USA and Departamento de Biología Animal, Universidad de León, E-24071 León, Spain

Fieldwork on Mallorca was carried out in the Serra de Tramuntana. Topography is rugged and 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. The vegetation consists of disturbed mixed forests of *Quercus ilex* and *Pinus halepensis* while dominant understory and scrubland species include *Olea europaea*, *Pistacia lentiscus*, *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 Eivissa was conducted throughout the entire island. 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. The vegetation consists of *Juniperus phoenicea* and *P. halepensis* forests; the latter being predominant, especially in disturbed areas. Dominant scrubland species include *P. lentiscus*, *Erica* spp., *Rosmarinus officinalis*, and *Phillyrea* spp.

Cabrera is situated approximately 20 km south of Mallorca and is the smallest (11.3 km²) and least disturbed of the three islands studied. The topography is moderately rugged with the highest point being 172 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. The predominant vegetation type is Mediterranean scrubland dominated by *P. lentiscus*, *Phillyrea* spp., *O. europaea*, *J. phoenicea*, *Erica multiflora*, and *Cistus* spp. *P. halepensis* forest covers roughly a third of the island.

METHODS

Mallorcan Pine marten faeces were searched along established trails that ranged in length from 2 to 5 km ($N = 5$; a total of 19 km). The routes were walked once every three months from June 1992 to May 1993. Marten faeces were identified by their characteristic size and shape; those which could not be positively identified were discarded.

During the same period genet faeces were collected on the three islands from a series of regularly monitored latrines (Mallorca = 19, Eivissa = 17; Cabrera = 21). To facilitate the identification of individual faeces, collections were made at 6-week intervals. At each visit, faeces which could be identified as whole were collected while the remaining faecal material was cleared from the latrine.

All faeces recovered were individually bagged and labelled with the date, species name, and place of deposition. Scats were air-dried and stored in a freezer. Diet analysis consisted of thawing faecal samples and then crumbling them gently between finger and thumb to examine their contents. Some faecal remains were soaked in water and washed through a 1.5 mm wire-mesh sieve to aid in the identification. Food items were identified by macroscopic analysis and all seeds and fruit remains identified by using a reference collection of fruits and seeds obtained from the three study areas. Measurements of diet and frugivory are presented as frequency of occurrence (%), representing the percentage of faeces in which a given fleshy-fruit species appeared. Any observer bias in food item identification and quantification was minimized as the author analyzed ≥ 90 % of the total sample.

RESULTS

Fruit remains and seeds from nine fleshy-fruited plant species were recovered in 82% of 728 Pine marten faeces (Table I). Marten foraged predominantly over human-modified habitats as cultivated fruit species predominated in the diet and occurred in 75 % of the annual sample. Remains of *Ceratonia siliqua* were most frequently found in the Pine marten sample followed by *Citrus* sp. Despite the two plant species prevailing presence in the diet, rarely did their seeds appear in the faeces as their remains were composed entirely of pulp. *Prunus* sp. fruit were most prevalent in March-May and nearly all belonged to the cultivated variety *P. domestica*.

TABLE I

Frequency of occurrence (F.O., %) by season of fleshy fruit remains identified in faeces of Martes martes and Genetta genetta from Mallorca (Balearic Islands). Figures in bold type indicate the species occurring most frequently for a given carnivore population and season.

	<i>M. martes</i>				<i>G. genetta</i>			
	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov
<i>Arbutus unedo</i>	1.8			4.4	0.8			3.1
<i>Ceratonia siliqua</i>	53.0	30.7	18.0	22.1	2.4			1.6
<i>Chamaerops humilis</i>					8.0			
<i>Citrus</i> sp.		15.4	25.0					
<i>Cneorum tricoccon</i>		6.1	9.2	1.7				
<i>Ficus carica</i>			16.5	2.6			46.7	28.6
<i>Juniperus phoenicea</i>			0.4	0.8				
<i>Myrtus communis</i>	21.6	0.7		16.8				
<i>Prunus</i> sp.		12.3	1.5	1.6				
<i>Rubus</i> sp.			2.6					
No. of spp/season	3	5	7	7	3	0	1	3
No. of spp/carnivore		9				4		
F.O. of fleshy fruit	76.4	65.2	73.2	50.0	12.1	0.0	46.7	33.3
n ^a	165	86	215	60	15	0	37	21
N	213	130	272	113	124	67	77	63

^a Number of faeces with fleshy fruit remains.

Pine marten were frugivorous throughout the year but highest levels were during June-August and December-February. Fruit remains appeared in more than 50 % of the Pine marten diet during each season. The total number of plant species represented in the Pine marten diet varied seasonally. The greatest diversity of fleshy-fruit species occurred in June-August and September-November. By contrast, the December-February diet was poorest in terms of species richness (3 of 9 species eaten).

Genets from the three islands consumed a total of six fleshy fruit species, however, no more than four in any population (Tables I and II). *Ficus carica* was the only fruit found in all three diets. Cultivated fruits occurred five times more often in the diet than wild fruits in Mallorca and Eivissa (79 % vs. 12 %, and 46 % vs. 7 %, respectively) ; however, wild fruits constituted nearly twice the former on Cabrera (27 % vs. 19 %). Fruits were eaten most by genets on Mallorca and Eivissa in June-August and September-November, while frugivory peaked in December-February on Cabrera. The average occurrence of fleshy fruits in the seasonal diets on the three islands was 17 % (range = 13-23 %). Plant species most frequently found in genet diets were *F. carica*, *J. phoenicea*, *C. siliqua*, and *Chamaerops humilis*.

TABLE II

Frequency of occurrence (F.O., %) by season of fleshy fruit remains identified in faeces of Genetta genetta from Eivissa and Cabrera (Balearic Islands). Figures in bold type indicate the species occurring most frequently for a given carnivore population and season.

	Eivissa				Cabrera			
	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov
<i>Arbutus unedo</i>								0.6
<i>Ceratonia siliqua</i>	8.8	3.1	3.4	2.2				
<i>Cneorum tricoccon</i>						0.5	1.9	
<i>Ficus carica</i>	1.6	0.7	17.5	9.8	0.5		11.8	8.0
<i>Juniperus phoenicea</i>		1.5	1.8	3.0	19.6	1.0	2.9	9.3
No. of spp./season	2	3	3	3	2	2	3	3
No. of spp./carnivore			3			4		
F.O. of fleshy fruit	10.4	5.3	22.7	15.0	20.1	1.5	16.6	17.9
n ^a	12	10	38	28	38	3	17	28
N	121	129	148	162	183	188	101	150

^a Number of faeces with fleshy fruit remains.

Individual faeces of Pine martens and genets contained seeds from one to three different plant species, however, 80 % of the former and > 95 % of the latter had seeds from one species (Table III). Seed-mixing (≥ 2 species of seeds) in Pine marten faeces was detected during each season, except March-May, as > 20 % of faeces had seeds from more than one plant species. In contrast, genet faeces rarely contained more than one species of fleshy fruit and detections of seed-mixing was most common during June-August and September-November.

TABLE III

Proportional distribution of seeds of different plant species occurring in faeces of Martes martes and Genetta genetta in the Balearic Islands, Spain.

Season	Number of plant species		
	1	2	3
<i>Martes martes</i> - Mallorca			
Winter	79.5	19.2	1.4
Spring	100.0		
Summer	80.2	19.8	
Autumn	77.4	22.6	
All seasons	80.3	19.3	0.4
<i>Genetta genetta</i> - Mallorca			
Winter	100.0		
Spring			
Summer	92.2	7.8	
Autumn	100.0		
All seasons	94.9	5.1	
<i>Genetta genetta</i> - Eivissa			
Winter	100.0		
Spring	100.0		
Summer	97.2	2.8	
Autumn	90.0	10.0	
All seasons	96.1	3.9	
<i>Genetta genetta</i> - Cabrera			
Winter	97.3	2.7	
Spring	100.0		
Summer	94.4	5.6	
Autumn	100.0		
All seasons	97.6	2.4	

DISCUSSION

Throughout their range, Pine martens exhibit varying degrees of frugivory but they generally have one seasonal peak (autumn or winter) in fruit consumption during the year (Warner & O'Sullivan, 1982 ; Marchesi, 1989 ; Ruiz-Olmo & López-Martín, 1992 ; Selas, 1992 ; Gurnell *et al.*, 1994), including on nearby Minorca (Clevenger, 1993b, 1993c). The results indicate that Mallorcan Pine martens are highly frugivorous during the entire year. Fleshy fruits constituted more than 50 % of their diet during each season and averaged 70 % over the year. Comparable levels of frugivory among Pine martens have only been reported for

two areas of northern Spain (Braña & del Campo, 1982 ; Ruiz-Olmo & López-Martín, 1992). Fleshy fruits made up $\geq 70\%$ of the total diet in both studies, however, frugivory was also markedly seasonal.

The habitats sampled and subsequent fleshy-fruit species composition in the diets of Pine martens in Minorca and this study were similar. Nonetheless, on Minorca frugivory was seasonal (September-December), whereas on Mallorca it was year-round. Moreno *et al.* (1988) suggested that the high degree of frugivory and generalist diet of Mallorcan martens may be a result of resource partitioning with genet. For the moment there is no evidence that food is limiting for either species and that dietary partitioning may be occurring. Moreover, food selection among *Martes* is widely believed to be determined by what is most abundant and accessible (Weckwerth & Hawley, 1962 ; Brainerd, 1990 ; Clevenger, 1994b). The observed differences in seasonality and importance of fleshy-fruits in Mallorcan and Minorcan marten diets is most likely explained by the temporal availability and abundance of food resources on each island.

The results of this study and others indicate that genets are occasional frugivores (Delibes, 1974 ; Cugnasse & Riols, 1984 ; Lodé *et al.*, 1991 ; Hamdine *et al.*, 1993). In the Balearic Islands genets consumed fruits during each season although consumption was notably seasonal. *F. carica* and *J. phoenicea* were the most important fruits eaten by genets and their consumption followed the pattern of fruit ripening of the two plant species. Also, fruit consumption was greater than what has been reported for genet populations elsewhere (Cugnasse & Riols, 1984 ; Delibes *et al.*, 1989 ; Lodé *et al.*, 1991 ; Hamdine *et al.*, 1993).

Of particular importance was the consumption of *Cneorum tricoccon* fruit. This fleshy-fruited plant has a restricted distribution in the western Mediterranean Basin (Heywood, 1993 ; Bolós, 1958) and has a seed dispersal system which is primarily lizard-dispersed (Traveset, 1995). On Mallorca I detected Pine marten eating *C. tricoccon* fruit, however, not genets. Conversely, Alcover (1984) reported that Mallorcan genets occasionally consume *C. tricoccon* fruit. Nonetheless, Pine martens appear to be the only legitimate disperser on Mallorca as there are no lizards present (see Traveset, 1995). In absence of Pine martens on Cabrera, genets serve as dispersal agents for the plant along with the endemic lizard *Podarcis lilfordi*. I found no evidence of the fruit being consumed by Eivissan genets although Alcover (1984) was able to. Likewise, the endemic lizard *P. pytiusensis* in Eivissa plays a major dispersing the seeds of *C. tricoccon* there (Traveset, 1995).

The data from this study agree with Herrera's (1989) claim that in human-modified habitats (e.g., Mallorca & Eivissa) carnivores readily shift to feed on the fruits of cultivated plants, however, differences in local abundances and availability of the types of fruits eaten by the two carnivores on each island is likely more of a determining factor. The attributes of fruit eaten in this study was also concordant with Herrera's (1989) observations. The carnivores preferred scented, brown fruit that grew on trees, and fell to the ground after ripening.

The widespread consumption of fruit by Pine martens, and to a lesser extent genets, suggests that they may be important dispersal agents for plant species in the insular environments where they occur. Carnivores are assumed to be legitimate seed dispersers (Herrera, 1989 ; Bustamante *et al.*, 1992), however, nothing is known regarding the efficiency of martens or genets as dispersers or their seed shadows. Both have the capacity to deliver seeds far from parent plants due to their large home ranges, high mobility and prolonged digestive tract

retention time. On Minorca Pine martens range over areas up to 9 km² (Clevenger, 1993d), and while nothing is known of genet ranges in the Islands I assume they are comparable (see Lodé *et al.*, 1991 ; Palomares & Delibes, 1994). Dispersal efficiency (probability that a seed dispersed by a vector will land in a safe site and germinate ; Reid, 1989) may be low, however, in the areas I studied many of the faeces I collected were found on dirt roads or trails and therefore may not provide optimum conditions for germination. On the other hand, certain behavioural attributes of martens may benefit seed dispersal. Their arboreal habits may enhance seed dispersal, as below canopy microhabitats can be suitable germination sites (Chavez-Ramírez & Slack, 1993) ; however, this is variable among plant species.

Genets, like other carnivores which regularly deposit faeces in latrines, should produce seed shadows differing in quality from those of avian dispersers and other carnivores which do not use defecation sites. Pigozzi (1992) demonstrated that the microhabitat and soil conditions at badger (*Meles meles*) latrine sites in a Mediterranean coastal habitat favored seed germination and survival. On the contrary, genet latrines I visited in the Balearic Islands appeared to be seed traps for fleshy fruited plants. Of the 57 latrines monitored in this study, 77 % were situated in dry rock crevices and/or on sea cliff-edges, exposed to high temperatures. Although genet-generated seed shadows may be large enough to enhance seedling survival (Howe & Smallwood, 1982) and seed-mixing was so infrequent (Table III) that sibling competition should not be an important mortality factor, most of their latrine substrates and microhabitats in this study probably inhibited seed germination.

There is a consensus that carnivores as seed dispersal agents have received little attention (Debussche & Isenmann, 1989 ; Herrera, 1989 ; Pigozzi, 1992 ; Willson, 1993) and that vertebrate-dispersed plant systems need to be studied in their whole complexity (Herrera, 1986). However, the degree to which some carnivores might negatively affect the dispersal process of some plants has not been contemplated, but might occur on small islands such as Cabrera.

In the Mediterranean region, wintering birds are well-known seed dispersers and play an important role in ecosystem function via plant reproduction (Herrera & Jordano, 1981 ; Jordano, 1982 ; Herrera, 1984, 1987 ; Debussche & Isenmann, 1985a, 1985b, 1989). Cabreran genets were important predators of wintering birds during this period (70 % of their diet ; Clevenger, 1995), of which 60 % of the identified avian prey (N = 125) were major seed dispersing frugivores (*Turdus*, *Sylvia* spp., and *Erithacus rubecula* ; Clevenger & Purroy, unpubl. data). Although I am not able to provide quantitative data, seeds (primarily *F. carica*) carried by avian frugivores constituted a substantial portion of the avian prey remains identified in Cabreran genet faeces during autumn-winter. Despite their co-occurrence with feathers, these seeds were readily identifiable from those encountered in fruit-bearing genet faeces.

Vertebrate-dispersed plant systems in insular ecosystems, such as Cabrera, differ from mainland ones by their overall reduced species diversity. With fewer functioning components, the interactions of their participants are more acute to the physical and biological processes occurring within them. On Cabrera, the inclusion of a fleshy-fruited plant consumer which acts negatively as 1) a dispersal agent by releasing seeds in poor microhabitats for seedling survival and germination (seed traps), and 2) a significant predator of the avian seed-dispersing component which again releases avian-ingested seeds (assuming them to not

damaged or broken) to sites not propitious for germination, may have an antagonistic role in the system ; however it is most probably insignificant. Lastly, the effect of Cabreran genets and feral cats (*Felis catus*) as predators of *Podarcis lilfordi* (Clevenger, 1995), an important seed disperser and pollinator of some plants with very restricted distributions (A. Traveset, pers. comm.) must also be considered.

SUMMARY

Fruit consumption and seed dispersal by introduced Eurasian Pine martens (*Martes martes*) and Common genets (*Genetta genetta*) was investigated in the Balearic Islands, Spain. Pine martens and genets were frugivorous year-round ; nine species of fleshy fruits were eaten by Pine martens while no more than four appeared in the genet diets. Pine martens were highly frugivorous and may serve an important role in seed dispersal. Seeds from cultivated fruit seeds were more prevalent than wild-native fruits for both species on all islands except Cabrera. Microhabitat characteristics at most genet latrine sites did not appear favourable for seed survival and germination. It is speculated that Cabreran genets may have a secondary effect on the seed dispersal process by being poor quality seed dispersers and important predators of the avian seed-dispersing component on the island.

RÉSUMÉ

La consommation de fruits et la dispersion des graines par la Martre (*Martes martes*) et la Genette (*Genetta genetta*) ont été étudiées dans les îles Baléares (Espagne). Les Martres et les Genettes sont frugivores tout au long de l'année ; 9 espèces de fruits charnus sont mangées par la Martre alors que pas plus de 4 le sont par la Genette. Les Martres sont très frugivores et jouent un rôle important dans la dispersion des graines. Les graines provenant de fruits cultivés prévalent sur celles de fruits sauvages pour les deux espèces sur toutes les îles, sauf Cabrera. Les caractéristiques du microhabitat de la plupart des latrines ne semblent favorables ni à la survie ni à la germination des graines. Il est suggéré que les Genettes de Cabrera puissent avoir un effet secondaire sur le processus de dispersion des graines en tant que mauvais disperseurs et importants prédateurs des oiseaux disperseurs de graines.

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