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Indirect seed dispersal by the feral cats *Felis catus* in island ecosystems (Canary Islands)

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In this paper we present an unusual incidence of an introduced Carnivora *Felis catus* as indirect seed disperser of plants that produce fleshy fruits in different ecosystems in the Canary Islands. Four hundred and twenty six seeds from at least 8 fleshy fruit plant species have been identified in the analysis of 1047 scat groups, the majority of them being found in the lower habitats (<600 m a.s.l.) of the Canary archipelago. Seeds from two plant species were significantly matched with the presence of lizard prey, and fruits of *Juniperus phoenicea*, *Neochamaelea pulverulenta* and *Withania aristata* were directly consumed by the cats. Passing through the gut of the *Gallotia galloti* (Lacertidae) and *Felis catus* apparently does not damage the seeds. At the moment, the phenomenon studied in this paper does not seem to have a great quantitative importance in the natural regeneration of the plants if we compare the direct vs indirect seed dispersal.

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The domestic cat (*Felis catus* L.) has been introduced by humans to many parts of the world and has frequently become feral. This phenomenon has also occurred on islands, even those that are uninhabited (Fitzgerald 1988).

Generally, the availability of information on the impact of feral cats on islands is restricted to the direct effect upon animal prey populations. For instance, the decline or extinction of endemic populations of reptiles, birds and mammals has been documented (e.g. Fitzgerald 1988 and references therein). However see Tidemann et al. (1994) for a positive indirect effect of feral cats upon the native species in Christmas Island.

In the Canary Islands, feral cats are widely distributed over all the main islands and islets and are top predators in the food chain in the various ecosystems (Nogales et al. 1992). The oldest bone remains of feral cats in this archipelago has been associated with skeletons of human aboriginal populations (Sarrion 1985, Hutterer 1990), whose first arrival has been estimated as no more than 4000 years ago (Schwidetzky 1976).

Despite the fact that introduced mammals (mainly rabbits) are the most important prey in the diet of feral cats in the Canaries, a large number of omnivorous endemic reptiles (mainly *Gallotia* spp. F. Lacertidae) has been found predated in some habitats (Nogales et al. 1990, Medina and Nogales 1993).

It is well-known that some carnivorous mammals commonly ingest fleshy fruits and defecate their seeds (Rogers and Applegate 1983, Moreno et al. 1988, Herrera 1989, Bustamante et al. 1992, Pigozzi 1992, Willson 1993).

Although the potential of birds of prey as indirect seed dispersers has been indicated by some authors (Ridley 1930, van der Pijl 1982, Howe and Smallwood 1982), little information is available on this phenomenon (Damstra 1986, Hall 1987, Dean and Milton 1988).

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Table 1. Percentages of prey of *Gallotia* spp. in scat groups of *Felis catus* and number of seeds of fleshy fruit species observed in the scats in the various habitats in the Canary Islands.

Habitats and islands	Altitude m a.s.l.	No. of seeds	% occurr. of seeds	% occurr. of lizards	No. scat groups	References
Xerophytic scrub (Alegranza)	0 300	1	0.9	4.5	110	Nogales et al. (1992)
Xerophytic scrub (Tenerife)	0–600	293	29.0	54.0	200	Medina and Nogales (1993)
Juniper forest (El Hierro)	300–600	133	13.7	37.5	248	Nogales et al. (1988)
Laurel forest (La Gomera)	500–900	10	3.7	24.4	135	Nogales and Medina (1996)
Pine forest (Gran Canaria)	800–1800	–	–	24.1	133	Santana et al. (1986)
High mountain (Tenerife)	1800–3700	–	–	74.2	221	Nogales et al. (1990)

It was because of this lack of information on indirect seed dispersal by carnivores, that we sought to determine the incidence of feral cats as a secondary disperser in different habitats of the Canary Islands.

Study area and methods

The Canary archipelago is situated in the Atlantic Ocean ca 100 km (at the closest point) from the African continent, between 27°37′–29°25′N and 13°20′–29°25′W.

A total of 1 047 scat groups of feral cats has been analyzed in the last eight years in the main habitats (see references in Table 1).

The habitats are distributed basically as a function of altitude and orientation. The xerophytic scrub is located in the lower zones which are characterized by species belonging to the genus *Euphorbia* and other phanerophytes that produce fleshy fruits (*Plocama pendula*, *Rubia fruticosa*, *Neochamaelea pulverulenta*, etc). The open *Juniperus* forest is still present in the upper parts of some islands as El Hierro and it is basically constituted by trees of *J. phoenicea* and some fleshy-fruited scrub species. The dense evergreen laurel forest along the north-facing slopes of the western islands is constituted by trees and bushes that present fleshy fruits, such as *Laurus azorica*, *Persea indica*, *Ilex canariensis*, *Viburnum tinus*, among others. The next habitat in altitude is the monospecific pine forest of *Pinus canariensis*, a open and dry woodland. The vegetation of the highest parts are occupied by the high mountain scrub, which is dominated by two species of leguminous plants (*Spartocytisus supranubius* and *Adenocarpus viscosus*). Generally the last two habitats show a lack of plant species that produce fleshy fruits. (For more information of the vegetation from the Canaries, see González et al. 1986 and Bramwell and Bramwell 1990).

The scats were analyzed according to the groups in which they were found and their contents were treated as a single sample. Eaeh scat segment were inmersed in water and the contents separated. For more information on methodology see Jones (1977), Santana et al. (1986) and Nogales et al. (1988). Damaged seeds were counted in each scat.

Results and discussion

A total of 953 seeds (426 from fleshy and 527 unfleshy fruits) belonging to 12 species has been identified in the analysis of the scats. The largest numbers of seeds from 8 fleshy-fruit species were found in only two of the five habitats studied (island xerophytic scrub and juniper forest) (see Tables 1 and 2).

Seeds from two of the plant species mentioned in the Table 2 co-occurred significantly with remains of lizards, *Rubia fruticosa* ($\chi^2_1 = 12.4$ $p < 0.001$) and *Plocama pendula* ($\chi^2_1 = 4.79$ $p < 0.05$) both species being dispersed by lizards (Valido and Nogales 1994). These results could indicate that seeds of *P. pendula* and *R. fruticosa* are also dispersed indirectly by the cats. At this respect, when comparing the mean number of seeds/dropping and the frequency of appareance of seeds/dropping of *P. pendula* and *R. fruticosa*, it is important to stress that direct seed dispersal (saurochory) is more highly relevant than indirect seed dispersal. The mean number of seeds appeared in lizard's droppings is 18.9 (*P. pendula*) and 4.8 (*R. fruticosa*) vs 0.2 and 0.01 respectively, and if we also take into account the frequence of occurrence, a markedly difference is observed (66.5% and 80.5% vs 7.5% and 3.5%, respectively). Furthermore, the density of lizards is clearly higher than cats in practically all the habitats of the Canary Islands.

Most of these lizards, which are widely distributed throughout all the islands (Klemmer 1976), play an important role in the seed dispersal of fleshy fruits in the Canary Islands (Barquín and Wildpret 1975, Barquín et al. 1986, Valido and Nogales 1994).

From the rest of the species mentioned in the Table 2 non significant matched differences were found with the lizard's presence ($p > 0.05$). In the case of *Juniperus phoenicea*, *Neochamaelea pulverulenta* and *Withania aristata*, the analysis indicate that this fruits could be dispersed both by directly consume and by predation upon lizards ($p > 0.05$). The opposite case is observed in *Opuntia dillenii*, where the cats feed directly on its fleshy-fruits ($\chi^2_1 = 12.09$ $p < 0.001$).

It is important to mention that the fruit size consumed directly are markedly bigger than fruits ingested incidentally (9.6–34.6 vs 3.5–5.6 mm respectively). Furthermore the direct consumption of several *Juniperus* fruit species by other species of Carnivora has also been

Table 2. Number of seeds and frequency of occurrences of each plant species observed in the scat analysis of feral cats *Felis catus* in the Canary Islands. Data from xerophytic scrub on Tenerife and from the juniper forest on El Hierro (between brackets).

Plant species	No. of seeds	% seeds damaged	% occurrence
Plocama pendula	194	1	7.5
Rubia fruticosa	12 (61)	– (–)	3.5 (6.5)
Scilla haemorrhoidalis	4	–	1.0
Neochamaelea pulverulenta	3	–	1.5
Withania aristata	14	7.1	1.5
Opuntia dillenii	66	15.2	19.0
Opuntia ficus-barbarica	(1)	(–)	(0.4)
Juniperus phoenicea	(71)	1.4	(6.9)

mentioned by Herrera (1989), Debussche and Isenmann (1989) and Willson (1993).

Despite the high frequency of occurrence of lizards consumed in the high mountain scrub, no seeds from fleshy fruits has been found, because fleshy fruit plants are absent.

The results in Table 2 show that passing through the gut of *Gallotia galloti* and *Felis catus* does not cause any apparent external damage to the seeds.

Hall (1987), working on secondary seed dispersal by raptors, observed that the majority of the seeds (from fleshy and unfleshy fruits) were also undamaged. Available data on raptors suggest that the phenomenon is common enough (see also Dean and Milton 1988).

In the Canary Islands, the majority of the species cited in this paper are actively dispersed by several species of reptiles and birds (Barquín et al. 1986, Valido and Nogales 1994, Valido and Nogales unpubl.). As the feral cat has been recently introduced by man, it seems unlikely that natural regeneration of this species is strongly dependent upon seed dissemination by the Carnivora. Furthermore, a potential disadvantage is that the scats of *F. catus* remain unaltered for very long periods of time before disintegrating. For this reason, in these dry habitats environmental factors, such as temperature, could have an effect on the dehydration of the seeds and act negatively in the establishment of many seeds.

The results obtained in this paper do not show a movement of seeds among the main habitats (with different environmental conditions). However, the high predation of *Gallotia* spp. by *F. catus* could produce a wider spatial pattern of the seeds within each habitat (xerophytic scrub and juniper forest) than occurs with limited range of movement of *Gallotia*. Nevertheless, it is not very important if we compare the direct vs indirect seed dispersal commented before.

Wide indirect seed dispersal could also occur naturally as a consequence of the intensive predation upon the lizards by the kestrel *Falco tinnunculus*, a raptor indigenous to the Canaries (Carrillo et al. 1994).

Finally, now a days, this case does not seem to have great quantitative importance in the recruitment of some plant species with fleshy fruits, because the population density of the lizards in the Canary Islands is very high. Apart from that, the majority of plant species cited in the Table 2 are being actively dispersed by other agents such as warblers, ravens, blackbirds, etc (Barquín and Wildpret 1975, Barquín et al. 1986, Nogales unpubl.).

Nevertheless, the indirect seed dispersal could be important in those cases in which two factors coincide: 1) the frugivorous species could be actively consumed by introduced predators (producing a marked decline in their populations), and 2) there are some plant species that could have a high mutualistic dependence (for the reproductive biology) on this animal prey.

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