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Contradiction in conservation of island ecosystems: plants, introduced herbivores and avian scavengers in the Canary Islands

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Abstract. Introduction of alien herbivores in sensitive island systems has resulted in massive effects on vegetation cover, floristic richness and composition of communities; some species can be even totally extirpated by grazing pressure. Goats *Capra hircus* and wild rabbits *Oryctolagus cuniculus* were introduced in the Canary Islands around 500 B.C. Barbary ground squirrels *Atlantoxerus getulus* were introduced in 1967. Traditional extensive livestock exploitations have been maintained to the present but in the last decades the number of goats has sharply increased up to densities of 53 heads/km^2. Overgrazing and trampling have heavily affected eleven island endemic plant species. Some populations have been reduced to less than 10 viable individuals. On the other hand, goat carcasses and wild rabbit and squirrel populations help to maintain populations of three endangered endemic subspecies of birds. This conflict presents important economic and social ramifications: whereas public funds (mainly through European LIFE projects) are devoted to conservation of plant and avian endemic taxa, the number of goats increases rapidly thanks to subventions derived from the European Common Agricultural Policy (CAP). Similar conflicts are apparent in other Mediterranean Basin insular systems. It is urgently necessary to harmonize farming and conservation objectives in the Canary Islands. The impact of goats on the vegetation should be minimized through limitation of grazing in sensitive areas with high degree of endemism. Creation of 'vulture restaurants' may reduce the dependence of scavengers on extensive livestock exploitations. We recommend a careful study of ecological relationships within island communities where non-native species are susceptible of playing a keystonrole as occurs in the Mediterranean Basin archipelagos.

Introduction

Invasions by alien species are a main cause of population reduction and, eventually, extinction, of native taxa, especially in island ecosystems (Williamson 1996; Wilcove et al. 1998; Mooney and Cleland 2001). In consequence, their eradication, when feasible, is usually recommended (Myers et al. 2000; Simberloff 2001). This kind of management, however, should not be initiated without information about relationships between alien and native species and changes in community composition (Zavaleta et al. 2001; Veitch and Clout 2002). Sometimes, introduced taxa play a role as 'keystone species' with one or

more native species depending on it (Myers et al. 2000). Thus, their eradication may provoke undesirable alterations of newly established relationships within food webs (Zavaleta et al. 2001).

Introduction of alien herbivores has been traditionally described as responsible for habitat alteration and destruction of plant species all over the world. Their release in sensitive island systems has resulted in considerable effects on plant cover, floristic richness, and, subsequently, communities structure (Donlan et al. 2002). Domestic goats *Capra hircus* and rabbits *Oryctolagus cuniculus* are considered ecological pests having altered many island biotas (Coblentz 1978; Wilson 1992). Eradication of these species is considered a first step for ecosystem restoration (Donlan et al. 2002). On the contrary, alien herbivores may play key roles in island ecosystems once native organisms have rarified (Hunter 1992). Little attention has been directed to the knowledge of this side of the problem, however.

Here we describe a case in the Canary Islands where goats and other introduced herbivores are responsible for the near-extinction of some endemic plants, whereas, on the other hand, their populations support native scavengers and predators. We show evidence supporting the belief that similar situations may be the rule in other archipelagos of the Mediterranean Basin. Finally, we discuss the need for integrating conservation projects in islands where extensive grazing systems are deeply inserted into local economies and traditional cultures.

The scenario

The Canary archipelago (13°23′–18°8′ W, 27°37′–29°24′ N) comprises seven main islands (La Palma, El Hierro, La Gomera, Tenerife, Gran Canaria, Lanzarote and Fuerteventura). Together with other Macaronesian insular systems (Cape Verde, Madeira, Azores), it forms part of the Mediterranean Basin, a region considered as an important 'biodiversity hotspot' (Médail and Quézel 1999). Twenty-eight percent of the 13,000 vegetal and animal species of the Canary Islands are endemic, the degree of endemism per area being among the highest in the world (Humphries 1979; Beltrán et al. 1999; Juan et al. 2000; Fernández-Palacios and Días 2001; Izquierdo et al. 2001). Fuerteventura (1662 km^2) is the most eastern island of the archipelago and the closest to the African continent (100 km). It was formed ca. 20 million years ago mainly by volcanic activity (Coello et al. 1992; Ancochea et al. 1996; Juan et al. 2000). Mean altitude is low, with some mountains reaching 600–800 m.a.s.l. (Criado 1991). The climate is extremely dry, with 105 mm of mean annual rainfall. Aridity is increased by strong northerly winds. The landscape was originally covered by semi-desert succulent scrub (principally *Euphorbia* spp. and *Kleinia neriifolia*) and woodland (mainly wild olive tree, *Olea europaea* ssp. *guanchica*) (Criado 1990; Rodríguez et al. 2000). Eastern Canary islands (Fuerteventura and Lanzarote) have in common similar ecological features whereas the rest of

the islands of the archipelago present more humid conditions, which favor the existence of a variety of ecosystems including pine and laurel forest.

People of Berber origin populated Fuerteventura and the rest of the archipelago around 500 B.C. (Macías 1995; Cabrera 1996). Human activities altered the original vegetal formations of the island, mainly through overgrazing (see below) and exploitation for firewood and agriculture. Consequently, grass and shrub communities belonging mostly to *Pegano-salsoletea* dominate at present (Rodríguez et al. 2000). The European colonization (between 1400 and 1500 A.D.) accelerated the degradation of the island's ecosystems.

Six hundred seventy-eight vascular plants have been recorded for Fuerteventura (Scholz in press). Thirteen species are endemic to the island, 33 to the Eastern islands (Fuerteventura and Lanzarote) and 42 to the Canary archipelago. Fuerteventura holds the highest percentage of north African and Saharo-sindian taxa (Sunding 1979); some species are exclusively found in this island: *Mesembryanthemum teurkauffii*, *Eritrichum sventenii*, *Pulicaria burchardii*, *Zygophyllum gaetulum*, and *Rhus albida* (S. Scholz, unpublished data).

The actors

Pre-European colonizers introduced goat herds in the Canary islands (Cabrera 1996, 2001). Number of goats increased rapidly in Fuerteventura to the extent that the island was called 'Capraria' by Pliny (I century A.D.) (Torriani 1978). Aborigine population was probably not higher than 1000–3000 inhabitants when the Europeans arrived; in that moment, the number of goats living in the island was estimated to be around 30,000–60,000 (18–36/km^2) (Cabrera 1996).

Following Cabrera (1996), indigenous people maintained goat herds within a subsistence system. Thus, the number of animals was strongly limited by droughts. The Europeans followed a similar extensive grazing strategy with maximum numbers of goats and sheep around 30,000 in years with enough pastures during the XVIIIth century. During prolonged droughts, on the contrary, the island was abandoned by humans and most of the livestock died (Roldán 2002). The main city of the island, today Puerto del Rosario, was for centuries called 'Puerto Cabras' (goat harbor) because of the large goat population maintained in neighboring areas.

The number of goats seems to have remained almost stable in Fuerteventura until the end of the XXth century. The first accurate census (1970) gave around 20,000 goats (12/km^2). From 1970 onwards, however, goats increased steeply: they were around 34,000 in 1984, 62,000 in 1990, 71,000 in 1998 and 88,000 (53/km^2) in 2000. Sheep *Ovis aries*, formerly rare in the island, have also increased during the last decades passing from 3000 to 21,000 between 1970 and 2001 (see reviews in González Morales 1989; Anonymous 2001). At present, most of goats and sheep are maintained in enclosures for milk production. Herds are left free during a part of the day because the animals need to ingest fiber in

order to avoid digestive disorders (Jarrige 1988). They return to corrals on their own at dawn to drink and be fed with maize and fodder.

A variable part of the livestock (up to 20,000 heads) is not subjected to continuous economic exploitation, living in mountain areas with difficult access. Several times every year traditional shepherd meetings 'apañadas' of pre-European origin are celebrated. In these occasions, herds are led from the mountains to stone enclosures where the animals are marked. Some of them are sacrificed, the meat being distributed amongst local people (Navarro 1989). Thus, at present Fuerteventura is the only Canary island where traditional grazing systems are partially maintained, although there is a clear tendency to modernize them; large numbers of animals are being concentrated in big farms with technological advances.

Additionally, Europeans also introduced two other species in Fuerteventura. During the XVth century, wild rabbits *Oryctolagus cuniculus* were released in all the islands of the archipelago, large populations are now found in optimal habitats (Cabrera 1997). The Barbary ground squirrel *Atlantoxerus getulus*, native from northern Africa, was introduced in 1967. Nowadays it occupies the entire island, being abundant in rocky dry habitats (Machado 1979).

Three endemic Canarian bird subspecies regularly consume carcasses of introduced herbivores. The Egyptian vulture *Neophron percnopterus majorensis*, formerly occupying all the islands of the archipelago, is now restricted to Fuerteventura, where it maintains around 25 breeding pairs (Donázar et al. 2002). The Canarian subspecies of Eurasian buzzard *Buteo buteo insularum*, also formerly distributed in the entire archipelago has disappeared from Lanzarote during the last century but maintain apparently healthy populations in forested habitats of other islands (Martín and Lorenzo 2001). In Fuerteventura its population has clearly increased; it was considered very scarce 30 years ago but 85–90 territories are occupied at present (C.J. Palacios, unpublished data). The common raven, described as *Corvus corax canariensis* (Cramp and Perrins 1994), is present in all the islands, but its numbers have been much reduced, now being very scarce in Tenerife, Gran Canaria and Lanzarote. Fuerteventura holds the healthiest population with around 100 breeding pairs (Martín and Lorenzo 2001).

The conflict

Effects of grazing on vegetation

Goat overpopulation in territories subject to frequent droughts provokes the destruction of plant cover, thus increasing aridity, erosion advance and extinction of species (Kunkel 1977; Cabrera 1993; Rodríguez et al. 2000). Overgrazing directly affects plant growth, reproduction and survival, reducing the numbers and quality of individuals and, ultimately, leading to the local disappearance of populations and species. In addition, continuous trampling

damages vegetation even more severely than direct grazing. Hooves destroy young plants and the soil becomes exposed, being easily worn away by erosive agents. Estimations of soil losses on Fuerteventura are of roughly 75 tm/ha/year. These effects are particularly evident in the vicinity of corrals and other livestock exploitations (Aguilera et al. 1994).

Food habit studies indicate that goats are directly responsible for the population decrease of endemic Canary plant species (Nogales et al. 1992; Rodríguez-Piñero and Rodríguez-Luengo 1993). The effects of the other introduced herbivores, rabbits and Barbary ground squirrels, are poorly known although it seems reasonable to think that it may be not negligible (Machado 1979; Rodríguez-Piñero and Rodríguez-Luengo 1993). Summarizing (Table 1), 10 insular, 13 Eastern island and 4 Canarian endemic plants are affected by grazing and trampling derived from livestock practices. Of special concern is the critical situation of local endemic species: *Crambe sventenii* (300 individuals), *Argyranthemum winteri* (300 ind.), *Echium handiense* (200 ind.), *Onopordon nogalesii* (100 ind.), and *Salvia herbanica* (50 ind.).

Some Canarian endemics with still large populations on other islands (thus, not globally threatened), maintain in Fuerteventura extremely low populations surviving in abrupt slopes : *Convolvulus floridus* (50 individuals), *Ceballosia fruticosa* (6 ind.), *Lavatera acerifolia* (4 ind.) and *Bosea yervamora* (2 ind). The same applies to some Macaronesian endemics, such as *Heberdenia excelsa* (30 ind.), *Rubus bollei* (30 ind.), *Jasminum odoratissimum* (20 ind.), *Visnea mocanera* (10 ind.), *Picconia excelsa* (2 ind.) and *Sideroxylon marmulano* (1 ind.). These taxa may disappear in the near future if limiting factors continue operating. This seems to be the case for *Atalanthus pinnatus* a Canarian endemic species unrecorded in the island during the last two decades (S. Scholz, unpublished data).

Plant protection in the Canary Islands has been of special concern for European, Spanish and Canary administrations (Table 1). This multiplicity, however, complicates the legal status of endangered taxa and makes difficult the adoption of operative conservation strategies.

Dependence of endemic avian scavengers on introduced herbivores

Presence of the three avian scavengers species in the Canary Islands is proved to be prior to the arrival of humans (Rando and López 1996; Jaume et al. 2003), but their feeding habits are unknown. Most of the islands were inhabited by giant species of lizards and rodents (Crusafont-Pairó and Petter 1964; González et al. 1996). The Europeans recorded in Fuerteventura large numbers of monk seals *Monachus monachus* and huge seabird colonies (Cabrera 1996). Carcasses of seabirds and marine mammals are still today the main food resource for some coastal populations of New World vultures in South America (Wallace and Temple 1988). Thus, it seems reasonable to think that avian scavengers exploited these sources before the arrival of humans.

Table 1. Effects of goats on rare and endangered plants of Fuerteventura. Red List Categories – CR: Critically endangered; EN: Endangered; V: Vulnerable; R: Rare; K: Unknown (based on IUCN 1994, 2001).

	Effects of goats[a]	Endemism[b]	European Habitat Directive[c]	Habitat Red Data Book[d]	Canarian Red Data Book[e]	Canarian Endangered Species List[f]
Aichryson bethencourtianum	Grazing	FV			EN	Sensitive to habitat alteration
Aichryson tortuosum	Grazing	EI			R	
Argyranthemum winteri	Trampling*	FV	Included	EN	VU	Sensitive to habitat alteration
Bupleurum handiense	Grazing	EI	Included	EN	VU	Sensitive to habitat alteration
Caralluma burchardii	Trampling	EI	Included	VU		Sensitive to habitat alteration
Carduus bourgaei	Grazing	FV			VU	
Convolvulus caput-medusae	Grazing	CAN	Priority	VU	R	Sensitive to habitat alteration
Crambe sventenii	Grazing*	FV	Priority	EN	EN	Endangered
Crepis canariensis	Grazing*	CAN			VU	Sensitive to habitat alteration
Echium bonetii	Grazing	CAN			K	
Echium handiense	Grazing*	FV			VU	Endangered
Euphorbia handiensis	Trampling	FV	Priority	VU	EN	Sensitive to habitat alteration
Ferula lancerottensis	Grazing*	EI			VU	
Helianthemum thymiphyllum	Grazing	EI			VU	
Limonium burgeaui	Grazing Trampling	EI			VU	Sensitive to habitat alteration
Maytenus canariensis	Grazing	CAN			NT	
Minuartia platyphylla	Grazing	EI			R	
Minuartia webbii	Grazing	EI			K	
Ononis christii	Grazing*	FV			EN	Sensitive to habitat alteration
Ononis hebecarpa	Grazing Trampling	EI			R	
Onopordon nogalesii	Grazing	FV	Priority	CR	EN	Endangered
Nauplius sericeus	Trampling	FV				
Pulicaria canariensis	Grazing Trampling	EI			V	Sensitive to habitat alteration
Reichardia famarae	Grazing	EI			R	Sensitive to habitat alteration
Rutheopsis herbanica	Grazing*	EI			V	Sensitive to habitat alteration
Salvia herbanica	Grazing*	FV			E	Endangered
Senecio bollei	Trampling	EI			V	Sensitive to habitat alteration

Table 1. Continued.

	Effects of goats[a]	Endemism[b]	European Habitat Directive[c]	Habitat Red Data Book[d]	Canarian Red Data Book[e]	Canarian Endangered Species List[f]
Sideritis pumila	Grazing Trampling	EI				Sensitive to habitat alteration
Volutaria bollei	Grazing	EI			V	Sensitive to habitat alteration

[a]From Beltrán et al. 1999, and S. Scholz (unpublished data). *: Species heavily affected.
[b]CAN = Canary Islands; EI = Eastern Islands (Fuerteventura and Lanzarote); FV = Fuerteventura.
[c]European Directive 92/43/EEC, (21st May 1992), on the conservation of natural habitats and wild fauna and flora.
[d]Canarian endangered species list based on the European Habitat Directive 92/43/EEC.
[e]Red Data Book of the Canarian Government (Gómez Campo 1996).
[f]Canarian Legislation on Endangered species: Decreto 151/2001.

Avian scavengers of Fuerteventura depend heavily on domestic ungulate carcasses in present day (Table 2). Pellet contents reflect that Egyptian vultures consume mostly goat and sheep carrion, which figured in 79% of pellets. Of other food items, only rabbits and birds (domestic dove and Barbary partridge) are of some importance. Eurasian buzzards feed mainly on Barbary ground squirrels (53% of pellets) and rabbits (21%). Goat carrion appears in 19% of pellets. Common ravens are omnivorous birds consuming preferentially invertebrates and fruits (88 and 76% of pellets, respectively). Among mammals, rabbits and goats (probably consumed as carcasses) dominate (26 and 12% of pellets).

Although pellet analyses may be subject to potential biases they give an acceptable idea of the main prey items consumed by the studied species (Newton et al. 1982). In the case of large scavengers as the vultures, the frequencies of large items as ungulates may be underrepresented (Houston 1976). In consequence, the above-mentioned data may be considered as conservative. The figures show the importance of introduced herbivores in the diet of the three species. These preys appeared in $>80\%$ of the pellets of Egyptian vultures and Eurasian buzzards and reached almost 50% in the common raven's

Table 2. Food habits of three avian scavenger species in Fuerteventura island. Figures show frequency of appearance (%) in pellets. Footnotes show authorship and the most common species within some prey categories.

	Egyptian vulture[a]	Eurasian buzzard[b]	Common raven[c]
Mammals			
Crocidura canarensis			0.3
Mus musculus			5.1
Rattus sp			1.3
Atlantoxerus getulus	0.6	52.6	8.4
Oryctolagus cuniculus	12.0	21.0	25.6
Atelerix algirus	1.7	2.1	0.3
Capra hircus	78.9	18.9	12.0
Ovis aries	2.5		2.0
Unidentified livestock			5.5
Birds	39.7[d]	15.8[f]	9.8
Reptiles	0.6		2.7
Fish	1.1		
Invertebrates	13.6[e]	8.4	87.5[g]
Fruits			75.8[h]
Excrements	1.3		
Total number of pellets	523	95	296

[a]Medina (1999).
[b]Authors (unpublished data).
[c]Nogales and Hernández (1994).
[d]Domestick chicken (*Gallus domesticus*) and pigeons (*Columba livia*).
[e]Beetles (Coleoptera).
[f]Domestic pigeons (*Columba livia*).
[g]Snails, beetles (Coleoptera) and grashoppers (Acrididae).
[h]Fruits of fig-tree.

food. Food analyses carried out in other Canary Islands confirm the importance of rabbits for the Eurasian buzzard (Martín and Lorenzo 2001) and the regular apparition of rabbits (up to 67%) and remains of livestock carcasses (up to 23%) in pellets of common raven (Nogales and Hernández 1994).

Observations at feeding places give further evidences about the importance of goat carcasses for avian scavengers in Fuerteventura. Despite the existence of sanitary laws, large numbers of goat carcasses are deposited in fixed places in the open generally associated to livestock exploitations. Many animals also die in remote places and are not removed. In addition, there is a 'vulture restaurant' where goat carcasses (1–4 per week) and slaughterhouse remains (ca. 200 kg/week) are regularly deposited by the nature conservation authorities. Weekly counts of avian scavengers were carried out between 1998 and 2002. We detected in a single day up to 50 Egyptian vultures that accounted for 38% of the island population (130 individuals; see Donázar et al. 2002). Capture-recapture estimations based on color-ringed birds revealed that around 50% of immature and 25% of breeding adults could be found at a single day in this area (authors, unpublished data). In addition, up to 40 Eurasian buzzards and 100 common ravens frequent daily the 'vulture restaurant'. Finally, radio telemetry of 6 immature and 4 adult Egyptian vultures revealed that the birds devoted 52% of their foraging time in 'vulture restaurants' and 36.3% in areas next to corrals where goat carcasses were abandoned (authors, unpublished data).

The density of goats and sheep is at present well above the requirements to sustain the Egyptian vulture population (Donázar et al. 2002) but it is reasonable to think that a future reduction of livestock would risk the viability of endemic bird numbers as has been described for other sheep-farming systems supporting avian scavenger populations (Newton et al. 1982). Analyses of food habits in the Mediterranean region have demonstrated that Egyptian vultures may consume a very broad range of prey. However, an important part of the diet of this species is based on carcasses of large or medium-sized animals as domestic ungulates (see Donázar 1993; Cramp and Perrins 1994; for reviews). The endemic species living at present in Fuerteventura hardly could maintain healthy populations of Egyptian vultures, Eurasian buzzards and common ravens. There are not medium-sized or small native mammals with the exception of the Canarian shrew *Crocidura canariensis*. Medium-sized birds are relatively scarce and/or patchily distributed (Martín and Lorenzo 2001). Finally, reptiles (lizards) do not grow above 20 cm. In conclusion, the reduction and eventual disappearance of introduced herbivores may be considered as a real threat to the maintenance of raptor endemic populations in Fuerteventura as there is not alternative prey of similar food value.

The recent evolution of avian scavenger populations in the neighbor and ecologically very similar island of Lanzarote may be also illustrative. There, the number of goats and sheep increased from 10,000 in 1970 to 18,000 heads in 2001. But at the same time, the extensive exploitations almost disappeared. Intensive farming has determined that carcasses of goats are buried or

destroyed, and very rarely are abandoned in the field. 'Vulture restaurants' do not exist. During the sixties, in parallel to changes in the farming system, European buzzard becomes extinct in Lanzarote (Trotter 1970). The numbers of Egyptian vulture and ravens also dropped dramatically, passing respectively from 20 to 2 and from 150 to 50 pairs (see Martín and Lorenzo 2001; for review). This apparently numeric response of avian scavengers to changes in livestock practices may have been be favored by the lack of other introduced herbivores. There are not Barbary ground squirrels in the island and wild rabbit populations are less common that in Fuerteventura because the intensive agricultural land uses in part of the territory. The dramatic decline of common ravens in other islands as Tenerife and Gran Canaria has been also closely related with the almost disappearance of extensive goat exploitations and also with lack of feeding places for scavengers (Martín and Lorenzo 2001, pers. observ.).

The economic and social components

The above-described conflict is enhanced by contradictions provoked by legislative and economic aspects. First, two European Union Directives (Bird 79/409/CEE, and Habitat 92/43/CEE) establish strict protection for endemic plants and animals. Second, legislation of European states (in this case, Spain) promotes the conservation of endemic taxa by means of their inclusion in Red Data Books. It obliges Spanish and regional governments to take active measure in favor of these species (see above, Table 1). The new Red Data book of threatened birds in Spain assigns the endemic Canarian scavengers to some category of risk. The Egyptian vulture, Eurasian buzzard and common raven are respectively considered as 'Critically Endangered', 'Near Threatened' and 'Endangered' (Palacios 2004; Atienza et al. 2004; Barone 2004).

Public funds for conservation programs of insular endemic taxa are increasingly important. Two European LIFE projects aimed to recover Canarian flora have been recently developed with a total funding of Euro 1.23 million. Another LIFE project amounting to Euro 0.8 million will be aimed to the conservation of the Egyptian vulture in Fuerteventura during the next four years (2004–2008). In addition, important state and regional public funds are also assigned to programs appointed to the recovery of populations of Egyptian vulture and common raven in the Canary Islands (Palacios et al. 2002).

On the other hand, the European Union Common Agricultural Policy (CAP) supports traditional livestock exploitations with huge subventions, especially those for goat and sheep herds in southern countries. In Fuerteventura, shepherds annually receive Euro 20 per goat, which means a total inversion of over one million of Euro per year. Moreover, modernization of exploitations for milk and cheese production has also been supported by

European funds. It is not surprising, therefore, that goats and sheep in the island have sharply increased during the last decades (see above) thus accelerating the destruction of natural vegetation.

There are also important social and cultural aspects in this conflict. The goat is considered the animal symbol of Fuerteventura, because during centuries, even before the European colonization, it was the most important protein source for inhabitants (Cabrera 1996). This high esteem for the goat makes it difficult to familiarize local populations with any kind of restrictive measure for grazing activities. In fact, although 29% of the land of Fuerteventura is protected by some conservation figure, from 'Natural Park' to 'Site of Scientific Interest', management plans for the protected areas are still often lacking and goats and sheep move freely in these areas as they do on the whole island. On the other hand, the Egyptian vulture is a respected bird, being the center of numerous local legends, many of them related to pre-European oral traditions (Palacios et al. 2002).

A widespread conflict in Mediterranean Basin insular systems

Humans invariably introduced domestic herbivores and rabbits in islands of the Mediterranean basin (Médail and Verlaque 1997; Hill et al. 1998). Probably, livestock density reached very high values in many of those islands during the last centuries although, logically, information is scarce. The first accurate censuses for Canary Islands were made in 1970; there was 22.8 goats and sheep/km^2. This number has progressively increased up to 55.4/km^2 in 2001 (González Morales 1989). There is a lack of similar long-term trends in other Mediterranean archipelagos but current numbers of domestic ungulates seems to be extremely high in some islands. Thus, grazing pressure is concentrated in mountain areas of Mallorca where there are 10,000 goats and sheep (10/km^2). Extremely high densities are reached in Cape Verde (75,000 goats; 19/km^2), and Crete (750,000 goats and sheep; 90/km^2) (Tejón 1989; Tewes et al. 1998; Xirouchakis and Nikolakakis 2002). These high grazing pressure have deep impact on vegetation, erosion rates and landscape conservation (see Médail and Quézel 1999).

Four vulture species breed in Mediterranean basin islands: Egyptian, *G*riffon *Gyps fulvus*, Cinereous *Aegypius monachus*, and Bearded *Gypaetus barbatus* (see Cramp and Perrins 1994 for specific distribution patterns). Before the arrival of humans, scavenger species in Mediterranean island systems probably depended on native ungulates and other endemic species as dwarf deer, dwarf elephants and cave goats. These species were extinct at the time of arrival of humans (see review in Martín 1989). In addition, wild ungulates, as the wild sheep *Ovis ammon* of Corsica and Sardinia, decreased sharply (Mitchell-Jones et al. 1999). Probably, following humanization, scavenger species switched their diet preferences from native animals to domestic ungulates; carcasses of sheep and goats form the bulk of their diet at present (Congost and Muntaner

1974; Thibault et al. 1992; Donázar 1993; Tewes et al.1998; Xirouchakis and Nikolakakis 2002). In addition, other introduced herbivores as the rabbit represent locally the main food resource form medium-sized and large avian predators of some Mediterranean islands (see e.g. Massa 1981).

As mentioned above, during the last decades, populations of Egyptian vultures, common buzzards and common ravens have vanished from some Canary Islands or became extremely rare. Although a multiplicity of causes may be operating (see Donázar et al. 2002) lack of food resources linked to traditional goat farming has been claimed as one of the main factors determining the decrease in numbers of scavengers (Carrillo and Delgado 1991; Nogales 1992) and, at the end, can limit the possibility of recuperation of the populations. A relatively similar scenario may have occurred in other insular systems, where the decrease of livestock together with direct and indirect human persecution and habitat destruction determined the rarefaction, and eventually the extinction, of vulture populations (Houston 1996). The present precarious situation has determined ambitious conservation projects with high economic costs. They have in common the recovery of small (less than 10 pairs) populations, as that of the cinereous vulture in Mallorca and the bearded vulture in Corsica and Crete (respectively Euro, 0.6, 0.9, and 1.4 million) (European LIFE Nature Database; http://europa.eu.int/comm/life/home.htm). Among other measures, these projects contemplate the maintenance of food resource availability (extensive exploitations of domestic ungulates) and the creation of regular feeding places 'vulture restaurants' (Tewes et al. 1998; Thibault et al. 1992; Donázar et al. 2002).

Management implications

Management conflicts between endangered species requiring apparently contradictory conservation strategies have been previously described (see Graham 1990 for Everglades snail kites *Rostrhamus sociabilis plumbeus* vs Wood storks *Mycteria Americana*; Goldingay et al. 1997 for Giant Kangaroo rats *Dipodomys ingens* vs the native threatened plants, and Roemer and Wayne 2003 for San Clemente Loggerhead shrikes *Lanius ludovicianus mearnsi* vs San Clemente island foxes *Urocyon littoralis clementae*). In the case of the Canary islands and other insular systems as those described in this paper, a shallow conservation approach could recommend total prohibition of free-living goats and sheep, which would be, in turn, clearly negative for the conservation of avian scavengers of Fuerteventura, especially the highly endangered Egyptian vulture. Generalizing, this means that eradication of introduced herbivores (especially goats) in Western Palearctic insular systems should not be carried out without a detailed knowledge of their relationships with the native fauna. Goats and other introduced herbivores, as rabbits should not be exclusively regarded as detrimental for conservation purposes. Although their proliferation menaces the survival of plant endemism, as occurs in many insular systems of the world

(Coblentz 1978; Melville 1979), once native large animals have disappeared, they represent the main and even the sole food source for endemic scavengers and predators.

We favor the urgent creation of a fixed system of fenced plant reserves, especially inside the protected areas, which could grant the conservation of the endemic species. Some decades ago Kunkel (1977) proposed that those slope areas in Fuerteventura where presence of endemic plants and erosion risk were higher should be permanently closed for grazing. Unfortunately, nothing was done to this end, but in 2002 a part (3 ha) of the 'Pico de la Zarza'; one of the mountains with higher degree of endemics was fenced following a local initiative. For other mountain zones of the island, a more rational use of the pastures, including estimation of the carrying capacity, rotation systems and planting of fodder species in some places, would reduce the pressure on endemic species, but it would not reverse the trend to extinction in those more endangered taxa. Extensive exploitations could be maintained in areas with few endemic plants and low slopes, always taking into account the potential number of livestock heads in relation to pasture carrying capacity (Mata et al. 2000). Traditional exploitation of some herds could be also maintained for ethnographic interest as well as for educational and tourist purposes.

The conservation of avian scavengers depending on goat carcasses could be based on two kinds of actions. First, it is needed a legal support for the provision of carcasses from extensive exploitations in fixed places near corrals. Following this strategy, French legislation permits, under veterinary authorization, the disposal in the open of livestock carcasses (Arrêté 7 août 1998 relatif à l'elimination des cadavres d'animaux et au nourrissage des rapaces nècrophages; Journal Officiel de la République Française, 20 août 1998:12713–12714). Second, food resources may be increased with the creation of more feeding places or 'vulture restaurants'. These places would be supplied with both goat carcasses originating in farms and remains from those sacrificed in slaughterhouses. A recent development of the regulation (CE) 1774/2002 of the European Parliament and Council allows supplying these places with remains of animals free of the 'bovine spongiform encephalopathy' (see Tella 2001 for details on this conflict). The creation of permanent feeding places would allow the achievement of different benefits: First, animal remains, otherwise difficult to treat, would be naturally 'recycled' (see above). Second, 'vulture restaurants' are predictable places acting as an 'insurance' against temporal food shortages, and poisoning; thus, mortality risks may be substantially reduced (see Donázar 1993). Finally, educative programs and recreational uses (ecotourism) could be promoted in those areas where rare, but spectacular birds, concentrate and can be easily observed.

In conclusion, this research remarks that conservation of unstable ecosystems, as those found in oceanic islands, should be focused from an ecosystem viewpoint (Simberloff 1998; Drake et al. 2002), paying attention not only to individual endemic species but also to the complex interrelationships established between native and introduced taxa. In our case and as a general aim, it

is urgently needed to harmonize farming and environmental objectives in insular systems of the Mediterranean basin. European Union subventions promoting extensive livestock in fragile ecosystems need to be reexamined taking into account broader conservation goals. This may be favored because the CAP is slowly but increasingly including environmental objectives within its strategies (Pain and Pienkowski 1997; MacDonald and Johnson 2000; Donald et al. 2002).

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