Trabajo Fin de Grado

Grado en Ciencias Ambientales

Bibliographical review on the feral goat *Capra hircus*

Revisión bibliográfica sobre la cabra doméstica asilvestrada *Capra hircus*

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2022

Declaration of authorship

The Final Degree Project that I am submitting for presentation and defence is original and all the sources used for its composition have been duly cited.

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El Trabajo de Fin de Grado que presento para su exposición y defensa es original y todas las fuentes utilizadas para su realización han sido debidamente citadas en el mismo.

In Huesca, January 9th, 2023

En Huesca, 9 de enero del 2023

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Abstract

1. The feral goat *Capra hircus* is an important example of feralisation of a domesticated species. The intentional abandonment of herds, escapes, rural depopulation and abandonment of livestock and traditional agriculture has led original domestic goats to occupy different habitats freely. Their integration into the environment and feralisation was facilitated by the lack of predators and competitors, their strong tendency to form herds and their high fertility. Despite the fact the feral goat has been studied and is globally distributed, there are still many unknown biological and ecological aspects, as well as a lack of knowledge on its distribution, resulting in a challenge to manage populations.

2. The aim of this study was to review the current global knowledge on the feral goat, identify its gaps and provide insights on possible future research.

3. The data reviewed covers from 1966 to 2022. The majority of publications focus on islands, in the Mediterranean Basin and Oceania. The information is particularly encompassed in terms of population distribution, habitat use, monitoring methods, potential environmental impacts and management strategies.

4. The feral goat is considered one of the 100 worst invasive species, especially on islands, thus there are abundant studies supporting their eradication fundamentally due to its negative impact on vegetation. However, their role as food supply for endangered fauna taxa is not sufficiently understood. Oceania is the main advocate for feral goat eradication, along with meat production exploitation. The Mediterranean Basin initially opted for a conservation approach of old breeds, nevertheless, eradication has been gaining importance in the last years. Today, the most widespread management approach is eradication when it comes to dealing with feral goats, notably favoured in insular ecosystems. Notwithstanding, there is still a lack of updated numeric data available on the efficiency and efficacy of eradication interventions.

5. Further scientific investigation regarding the role played by the feral goat is advised. The insights obtained from deeper research could benefit management and conservation decision-making.

Keywords: ungulate, Bezoar goat*, Capra aegagrus,* Mediterranean goats, islands, Australia/Oceania, eradication, impact, conservation, management.

Resumen

1. La cabra asilvestrada *Capra hircus* es un ejemplo importante de asilvestramiento de una especie domesticada. El abandono intencionado de rebaños, las fugas, la despoblación rural y el abandono de la ganadería y la agricultura tradicionales han llevado a las cabras domésticas a ocupar distintos hábitats. Su integración en el medio y asilvestramiento se ha visto facilitado por la falta de depredadores y competidores, su fuerte tendencia a formar manadas y su elevada fertilidad. A pesar de que la cabra asilvestrada ha sido estudiada y está distribuida por todo el mundo, aún se desconocen muchos aspectos biológicos y ecológicos, así como su distribución, lo que supone un reto para la gestión de las poblaciones.

2. El objetivo de este estudio ha sido revisar el conocimiento global actual sobre la cabra doméstica asilvestrada, identificar sus lagunas y aportar ideas sobre posibles investigaciones futuras.

3. La bibliografía revisada abarca desde 1966 hasta 2022. La mayoría de las publicaciones se centran en islas, de la cuenca mediterránea y de Oceanía. La información abarca sobre todo la distribución de las poblaciones, el uso del hábitat, los métodos de seguimiento, las posibles repercusiones medioambientales y las estrategias de gestión.

4. La cabra asilvestrada está considerada una de las 100 peores especies invasoras, especialmente en islas, por lo que abundan los estudios que apoyan su erradicación debida fundamentalmente a su impacto negativo sobre la vegetación. Sin embargo, su papel como fuente de alimento para taxones de fauna amenazada no se conoce suficientemente. Oceanía es el principal defensor de la erradicación de las cabras asilvestradas, junto con la explotación de la producción cárnica. La cuenca mediterránea optó inicialmente por un planteamiento de conservación de las razas antiguas, aunque la erradicación ha ido ganando importancia en los últimos años. Hoy en día, el enfoque de gestión más extendido es la erradicación cuando se trata de hacer frente a las cabras asilvestradas, especialmente favorecido en los ecosistemas insulares. A pesar de ello, siguen faltando datos numéricos actualizados sobre la eficiencia y eficacia de las intervenciones de erradicación.

5. Se aconseja una mayor investigación científica sobre el papel desempeñado por la cabra asilvestrada. Los conocimientos que se obtengan de una investigación más profunda podrían beneficiar la toma de decisiones en materia de gestión y conservación.

Palabras clave: ungulado, Cabra bezoar, *Capra aegagrus,* cabras mediterráneas, islas, Australia/Oceanía, erradicación, impacto, conservación, gestión, manejo.

1. Introduction

1.1 Taxonomy and systematics

Domestic goats *Capra hircus* (Figure 1) mainly descend from the wild goat *Capra aegagrus* (Papaioannou & Lovari, 2020). The wild goat was described from Dagestan in the north-eastern Caucasus, harbouring the typical subspecies *Capra aegagrus aegagrus* Erxleben, 1777 (Weinberg & Lovari, 2020). Some authors prefer the name *Capra hircus* for both wild and domestic goats (Ellerman & Morrison-Scott, 1966). However, the suggestion of the International Trust for Zoological Nomenclature (2003) is to keep the name *Capra hircus* for the domestic goat and *Capra aegagrus* for the wild one.

The systematics belonging to this species is stated below (Grubb, 2005):

Kingdom: Animalia
Phylum: Chordata
Class: Mammalia
Order: Artiodactyla
Family: Bovidae
Subfamily: Caprinae
Genus: *Capra*
Species: *hircus*

Figure 1. Adult feral goats in Crete, Greece. Male on the left (Photo: Anastasios Sakoulis) and female on the right (Photo: Konstantinos Fikas) (Papaioannou & Lovari, 2020).

1.2 Background

The origins of domestic goats, hereafter goats, remain uncertain and controversial. However, archaeological evidence indicates that the goat was one of the first animals to be domesticated 10,000 years ago during the Neolithic period in the Fertile Crescent (Luikart *et al.,* 2001; Joshi *et al.,* 2004), or even 11,000 years ago (Zheng *et al.,* 2020).

Goats have played a crucial role in the Neolithic agricultural revolution and in the expansion of human civilisations around the world (Luikart *et al.,* 2001). Today, the goat is an essential livestock species worldwide; fulfilling agricultural, economic, cultural, and even religious roles. Moreover, its economic importance is growing in Western countries (Joshi *et al.,* 2004).

There are two main approaches when it comes to studying feral goats: (1) Environmental impact, especially focused on islands. This approach is prominent in the Mediterranean Basin; and (2) Population control. These studies are mainly promoted in Oceania.

1.3 Justification

Although the feral goat has been studied worldwide, some aspects of its biology remain unknown. This makes it difficult to manage or conserve populations (Masseti, 2009a). For this reason, the development of this academic work is beneficial, as it compiles current knowledge on feral domestic goats and identifies areas for improvement and further research.

The approach and objective of this Final Degree Project is related to the Sustainable Development Goals of the United Nations Agenda 2030 number 15: protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss (UN, 2015).

1.4 Objective

The objective of this study is to complete a synthesis based on scientific literature reviews regarding the current global knowledge about the feral goat, identifying the ongoing gaps of knowledge and providing insight on possible lines of research that support the importance of understanding the role feral goats play in ecosystems.

2. Methods

To assess the knowledge of the feral goat populations, a thorough bibliographic compilation of scientific and technical literature (scientific articles, technical reports, books, official websites, etc.) has been carried out, using suitable search engines and an appropriate strategy to obtain reliable, high quality and updated sources of information.

The search engines used have been Web of Science, Google Scholar, Science Direct, and Dialnet. The bibliographic repository Researchgate was also visited. In addition, specific bibliography has been provided by the thesis supervisor and, the meta-search engine of the University of Zaragoza Alcorze has been considered. The searches were based on the following terms: ungulate, bezoar goat, *Capra hircus*, *Capra aegagrus*, Mediterranean goats, islands, Australia/Oceania, eradication, impact, conservation, management. The languages used were Spanish and English. Sources of information covered from 1966 to 2022.

Since this report is a bibliographic synthesis at a global level, the geographical space covered by this paper is, consequently, the whole Earth area. The study is conducted taking into account the information available to date, as well as recommendations for the future.

3. Results and Discussion

The number of publications reviewed for the elaboration of this report have been at least 200. However, the number of publications cited is a total of 59.

3.1 Distribution

The feral goat is an important example of feralisation of a domesticated species. The intentional abandonment of herds, escapes, rural depopulation and abandonment of livestock and traditional agriculture has led domestic goats to occupy different habitats. Their integration into the environment and feralisation was facilitated by the lack of predators and competitors, thus favouring the increase in feral goat populations (Gortázar *et al.,* 2000; Herrero *et al.,* 2013).

With regards to feral goats inhabiting islands around the world, populations are considered in many cases ancient feral breeds derived from domestic goats anthropogenically introduced as a food source (Papaioannou & Lovari, 2020), generally by European sailors (Chynoweth *et al.,* 2013). This occurred in the Mediterranean islands after the end of the 9th millennium BC, currently existing on five islands - Crete, Youra, Antimilos, Majorca and Montecristo - (Papaioannou & Lovari, 2020). As for the Eastern Atlantic islands, goats were introduced between 1000–2000 BC in the Canary Islands (Spain) (Papaioannou & Lovari, 2020), before 1481 in the Madeira Archipelago (Masseti, 2009a) and in 1513 into the Island of Saint Helena (British territory) (Coblentz, 1978). During the early 16th century, domestic individuals were introduced into several Pacific Islands (Chynoweth *et al.,* 2013), the West Indies (Parkes *et al.,* 1996) and into the Caribbean dry forests of Mona Island (Puerto Rico) (Rojas-Sandoval *et al.,* 2014). Reaching the tropical dry landscape of the Hawaiian Archipelago in 1778 (Coblentz, 1978) in the 18th century (Chynoweth *et al.,* 2015). In the 19th century, feral goats reached Guadalupe Island (Mexico) (Luna-Mendoza *et al.,* 2019). By 1959, goats had reached the Galapagos Islands (Campbell *et al.*2004).

In Europe, feral goats originated from rural abandonment as a result of human migration to the major industrial centres (Romero, 2010; Gortázar *et al*., 2000 & Moroni *et al.,* 2022). During the 1960s in Spain, this occurred in Galicia (Romero, 2010) and in Aragon (Herrero *et al*., 2013). Studies confirm that nowadays in Aragon, populations are stable from a distribution perspective (García-Serrano *et al.,* 2021). In the region of Piedmont (Italy) this transition took place in the 1990s (Moroni *et al.,* 2022).

In Oceania, goats were introduced by European settlement (Barton *et al.,* 2022) in 1773 into New Zealand (Coblentz, 1978) and in 1788 into Australia (Werdi *et al.,* 2007). In Australia, feral goats are found in all states, mainland and offshore islands. Although high densities occur in the highlands of the Great Dividing Range (Barton *et al.,* 2022). In New Zealand, feral goats inhabit 11% of the territory, mainly occupying land reserved for conservation of the indigenous biota (Parkes, 1993).

Despite the fact the feral goat is widely distributed, there is still a lack of global distribution maps of this species (Papaioannou & Lovari, 2020). On the other hand, however, there are available regional distribution maps of feral goat populations (García-Serrano *et al.,* 2021).

3.2 Habitat use and selection

Feral goats are the most adaptable and geographically widespread feral livestock species (Joshi *et al.,* 2004). Rangelands are their preferred habitat, where safety and isolation are highly guaranteed. Habitat selection is influenced by shelter and water availability as well as abundance of preferred food species (DAF, 2020).

They are versatile generalist herbivores able to process a higher number of plant species than other livestock (Lowe *et al.,* 2004). They are also capable of surviving on grasses, forbes, browse, and even marine algae (Chyboweth *et al.,* 2013). In tropical latitudes, the fungus *Auricularia sp.* is a principal and a preferred food in goat's diet (Parkes, 1984). They actively select the most palatable and highest quality forage first. When this one is consumed, poor quality forage is used to sustain populations (Coblentz, 1977; Parkes, 1993; Parkes *et al.,* 1996; Masters *et al.,* 2018).

These resistant animals are tolerant to drought in semi-arid areas (Parkes *et al.,* 1996) and are capable of surviving in insular environments, some of them characterised by low food availability and without artificial food supply (Masseti, 2009a). Goats have a minimum water requirement, deriving from plant foods the amount of hydration they need. This trait enables feral goats to thrive in arid insular environments (Chyboweth *et al.,* 2013). Survival in such habitats is complemented by exploiting mineral salts, either by licking the deposits that form on the shore or by consuming guano. For example, the goats of Montecristo occasionally feed on the excreta of yellow-legged gulls, *Larus michahellis michahellis* (Masseti, 2009a).

3.3 Population structure and dynamics

In mild and uniform climates (e.g., tropical oceanic dry islands, Oceania) feral goats breed throughout the year (Shi *et al.,* 2005) producing up to three goatlings and can double their population every 1.6 years (Parkes *et al.,* 1996). Under these favourable conditions, mixed sex groups are frequent (Shi *et al.,* 2005) travelling to areas of recent vegetation green-up following pulse precipitation events (Chynoweth *et al.* 2015). In contrast, at higher latitudes (e.g., NE Atlantic islands, Scotland) where climatological conditions are less favourable, breeding is restricted to a few months (e.g., January to March in Isle of Rum, NW Scotland). Under these circumstances, single sex groups are prominent during spring and summer, while mixed sex groups form during winter (Shi *et al.,* 2005). Segregation in feral goats' populations is due to: predation, forage quality, social preferences, activity patterning (Chynoweth *et al.* 2015) and daylength (Shi *et al.,* 2005).

Male feral goats use two distinct tactics for mating:

(1) Tending. This tactic is used by mature (≥4 years old) higher ranking males and it is a more successful strategy for achieving mating success. It consists in defending mature (≥2 years old) oestrous females from other males.

(2) Coursing. This technique is preferred by males of all ages and dominance ranks, especially younger males. It consists in disturbing a tending pair therefore gaining access to oestrous females (Saunders *et al.,* 2005). The gestation period is 150 days (Parkes *et al.,* 1996). Feral goat lifespan is 10–15 years (Papaioannou & Lovari, 2020).

In terms of weight (Table 1), there are differences that can be territorially attributed to the breed of goat that has undergone feralisation.

Continent	**Location**		**kg**		**Reference**
			Males	**Females**	
Europe	Iberian Peninsula	Aragon, Spain	65.6	45	Gortázar *et al.,* 1997
	Mediterranean Islands	Crete, Greece	50	17	Papaioannou & Lovari, 2020
Oceania	Australia	-	60	45	DAF, 2020
Pacific Islands	Hawaiian Islands	-	25 - 55		Chynoweth *et al*., 2013

Table 1. Weights of adult male and female feral goat.

Hereafter, Table 2 indicates the available existing information regarding feral goat populations in various locations of the world. Further information is needed to complete and update the table.

Continent	Location		km²	Individuals	Reference
Europe	Iberian Peninsula	Guara Natural Park, Spain	474	2,245	García-Serrano *et al.,* 2021
		Serra da Capelada, Spain	12	511	Romero, 2010
	Mediterranean islands	Crete, Greece	150	1,000-1,500	Papaioannou & Lovari, 2020
		Youra, Greece	11.05	200	
		Antimilos, Greece	8	300	
		Majorca, Balearic Islands, Spain	3,640	1,500 - 2,000	
		Montecristo, Italy	10.39	200	
		Es Vedrà, Balearic Islands, Spain	0.6	20	Capó *et al.,* 2022
	Eastern Atlantic islands	Bugio, Deserta, Madeira archipelago, Portugal	14.21	60	Masseti, 2009a
		Inagua Natural Integral Reserve, Canary Islands, Spain	39.2	189	Viera-Ruiz *et al.,* 2016
		Fuerteventura, Canary Islands, Spain	1,660	88,000	Gangoso *et al.,* 2006
		Wicklow Mountains National Park, Ireland	24.2	207	Saunders *et al.,* 2005
		Isle of Rum, Scotland	104.6 (10km cliff line)	190	Shi *et al.,* 2005
Oceania	Australia	Western New South Wales	809,444	3.38 million	Barton *et al.,* 2022
	New Zealand	-	267,707	300,000	Parkes, 1993

Table 2. Occupancy and density of feral goat populations throughout the world.

3.3.1 Hybridisation

Anthropogenic activities such as habitat degradation, domestication and translocation of animals have increased the rate of hybridisation events worldwide (Iacolina *et al.,* 2018). Hybridisation between wild and domestic species is a special case of anthropogenic hybridisation (Moroni *et al.,* 2022). This phenomenon can be detected morphologically and confirmed through molecular data (Iacolina *et al.,* 2018). Although, the development of standardised and effective protocols for hybrid identification is advised (Moroni *et al.,* 2022).

In Europe, hybridisation is relatively common amongst several ungulate taxa. In regards to the genus *Capra*, hybridisation events occur mostly between wild and domestic goats (Figure 2). There is evidence between Alpine ibex *Capra ibex* and domestic goats in the Alps (Iacolina *et al.,* 2018; Moroni *et al.,* 2022). The presence of these hybrids is more frequent in the Western Alps (Italy, France, Switzerland, and Austria) where the density of Alpine ibex is the highest. Likewise, there is hybridisation evidence between the Iberian wild goat *Capra pyrenaica* and domestic goats in the Pyrenees. Recently, the first cases of leucism in the Iberian wild goat have been reported, suggesting a hybridisation event and renewing the interest on the poorly investigated hybridisation phenomenon between wild Caprinae and feral goats (Herrero *et al.,* 2021).

In the African continent, risk of hybridization between the feral goat and the Ethiopian Walia ibex *Capra walie,* living in Semien Mountain National Park, has been expressed since the late 1990s (Shackleton, 1997). However, no evidence of hybridisation has been reported between the two species (Alemayehu *et al.* 2011; Wale, 2016). To exclude the possibility of hybridization occurrence in the future, the eradication of feral goats from the National Park is advised (Wale, 2016).

Despite hybridisation generally perceived negatively when considering conservation, it may be vital for the survival of some taxa under rapidly changing environmental conditions. On the other hand, the spread of domestic genes in native wild populations is of concern for conservation (Iacolina *et al.,* 2018) if the introgression jeopardises genetic integrity of wild species, or if it leads to changes in their ecology or behaviour (Moroni *et al.,* 2022). In the current management paradigm, hybrid populations are not given equal protection in many countries compared to 'pure' populations (Iacolina *et al.,* 2018). Clear guidelines on hybrid management are required (Moroni *et al.,* 2022).

Figure 2. Top image: Probable hybrid on the right and an Alpine ibex on the left in the Alpes-Maritimes, France. (Photo: Martin Dhermont) (Moroni *et al.,* 2022). Bottom image: Goat-like leucistic male, probable feral goat x Alpine ibex hybrid in Susa Valley, the Alpes between Italy and France (Photo: Luca Rossi) (Herrero *et al.* 2021).

3.4 Monitoring & control methods

Feral goat management is more effective when combinations of techniques are used (Kessler, 2002). The techniques mentioned below rely on technology and highly skilled staff allowing goat eradications on larger areas within a shorter time period and with increased cost-effectiveness (Campbell & Donlan, 2005).

- Mustering. It is an intensive capture method (Viera-Ruiz *et al*., 2016) that can be performed using motorcycles, horses or specially trained hunting dogs to aggregate goats into large herds (DAF, 2020). The option with dogs was the preferred measure used in an integral natural reserve in Fuerteventura (Canary Islands) due to the high number of difficult access areas (Viera-Ruiz *et al*., 2016).

- Shooting. There are two types: ground shooting and aerial shooting, using airplanes or helicopters. The first one is labour intensive but can produce adequate results if control programs are well planned and the effort is maintained (DAF, 2020). On occasions, bait poisoning (Hunnam *et al.,* 2018) and habitat alteration via fire (Campbell & Donlan, 2005) is used with ground shooting. The second one, although costly, is highly effective, especially when the numbers of feral goats to be reduced is large (DAF, 2020).

- Judas goat. GPS-collared sterilised goats which find feral goat groups that can then be targeted and eliminated (Masters *et al.,* 2018). This method is fundamental for detecting goats at low densities and a vital monitoring tool to confirm eradication (Campbell *et al.* 2004; Campbell & Donlan, 2005). Judas goats have been used successfully in a number of eradications: San Clemente and Santa Catalina islands (California); Kahoolawe Island (Hawaii); Ile Malabar and Ile Picard (Seychelles); Woody Island (Australia), and Pinta Island (Galapagos) (Campbell & Donlan, 2005).

- Geographic information systems (GIS) and remote sensing technology. This monitoring method provides information on home range use and movement patterns followed by feral goats. Especially useful in high density vegetation habitats (e.g., tropical dry islands). The Normalised Difference Vegetation Index (NDVI) is a valuable tool used for this purpose (Chynoweth *et al.* 2015).

Other techniques for managing feral goats are:

- Trapping. Consisting of a goat-proof fence surrounding a water point that is entered through one-way gates or ramps (DAF, 2020). During an eradication plan (Life + Inagua Project) carried out in the Canary Islands, intensive trapping appeared to be the most efficient population control method in terms of effectiveness and risk minimisation (Viera-Ruiz *et al.,* 2016).

- Fixed-point method. It consists of counting the number of individuals taking advantage of the geographical features in mountainous and steep areas and using them to sample the visible territory (Herrero *et al.,* 2013; García-Serrano *et al.,* 2021). This was the method used in a natural park in Aragon, Spain.

3.5 Impacts on ecosystems

Feral goats have caused major problems worldwide. Mainly because of its negative impact on vegetation and as a potential disease vector. In 2004, the International Union for Conservation of Nature (IUCN) updated the list of the world's 100 worst invasive alien species, including 14 mammal species: the feral goat is one of them (Lowe *et al.,* 2004). Feral goats are responsible for:

- Overgrazing native vegetation. Communities are often unable to recover from persistent herbivory resulting in their replacement by more tolerant and resilient non-native species, causing the desertification of entire islands. In Santa Fe Island (Galapagos) feral goats eliminated 100% of seedlings from large trees (Chynoweth *et al.,* 2013). It is generally considered that densities above 20 goats km^{-2} can cause damage to vegetation (Parkes *et al*. 1996), although this will depend on the habitat, the degree of isolation of the area and the presence of species vulnerable to the action of these herbivores (Romero, 2010).
- Causing habitat destruction to vertebrate and invertebrate fauna through over browsing (Nogales *et al.,* 2006), often leading to ecosystem degradation and biodiversity loss (Coblentz, 1978).
- Modification of food webs (Nogales *et al.,* 2006).
- Alteration of nutrient cycles (Chynoweth *et al.,* 2013).
- Nitrification (Capó *et al.,* 2022).
- Soil erosion. Particularly on sand dunes, caves and watering points (Masters *et al.,* 2018).
- Interfering with the breeding of marine birds (Capó *et al.* 2022), even contributing to the collapse of large seabird populations, as seen on Desecheo Island (Puerto Rico Archipelago) (Will *et al.,* 2019).

3.5.1 Islands

Feral goats have been introduced into at least 397 islands worldwide (Campbell *et al.,* 2004) and are considered a common pest in island ecosystems (Masters *et al.,* 2018), accountable for a great part of the damage caused in insular ecosystems worldwide (Nogales *et al.,* 2006). Primarily, islands are important for conservation because they harbour high rates of endemic species, act as refugia for the last remaining translocated individuals (Masters *et al.,* 2018) and are considered areas with interesting population genetics. Insular endemic species are highly

vulnerable to herbivory due to a lack of defences against introduced herbivores, a low tolerance to herbivory or high palatability (Capó *et al.,* 2022).

The removal of feral goats from islands have shown positive effects in regards to endemic insular species of fauna and flora (Chynoweth *et al.,* 2013). However, the success rate is higher on temperate islands than on tropical islands (Will et *al.,* 2019). Amongst tropical islands, there are two main examples of success in terms of invasive species management: Seychelles (Rocamora, 2015) and Hawaii (Pejchar *et al.* 2020).

There are multiple examples of success following feral goat removal from islands: On Santiago Island (Galapagos) the Galapagos crake *Laterallus spilonotus* has been recovered (Chynoweth *et al.,* 2013). Ecological replacement tortoises (*Chelonoidis* spp.) have been proposed as substitutes for extinct native herbivores in Pinta Island (Galapagos), resulting in effective ecosystem restoration agents for plant communities (Hunter & Gibbs, 2013). A presumed extinct shrub taxon (*Ceanothus arboreus*) has been recovered from seed banks on Guadalupe Island (Mexico). Other Mexican Pacific islands (e.g., Espiritu Santo Island and Maria Cleofas Island) are following the same steps and clearing their territory from herbivores (Luna-Mendoza *et al.,* 2019). In the Caribbean, in Desecheo Island (Puerto Rico Archipelago) the Indian fig opuntia *Opuntia ficus-indica* resurged from the suppression caused by herbivory (Will *et al.,* 2019).

With regards to vegetation, although direct benefits are not often seen from feral goat presence on islands, it is possible that native species could benefit from nutrients that are being moved from inaccessible areas through fertilisation via faeces. In addition, goats are known for being used as a biological control method for weeds, improved pasture management and vegetation control in fuel breaks (Chynoweth *et al.,* 2013).

3.5.2 Feral goats as vectors of parasites and disease

Feral goats have been found to carry parasites and diseases that infect livestock, especially sheep *Ovis aries*. One of these diseases is the foot-and-mouth disease (FMD). It is a highly contagious viral disease that affects cloven-hoofed animals. It is transmitted directly through saliva and aerosols from respiration, and indirectly via consumption of infected tissue (Hunnam *et al.,* 2018). It is present in many parts of Africa and Asia (Gortázar *et al.,* 2021). Australia has been free from FMD since 1872 (Hunnam *et al.,* 2018). Nonetheless, there have been recent cases of FMD in Europe, the first one in the United Kingdom in 2001 and the second in Bulgaria

in 2011. Recovered or vaccinated animals subsequently exposed to FMD may become carriers and subclinically infected animals are contagious (Gortázar *et al.,* 2021), acting as a viral amplifier (Hunnam *et al.,* 2018).

Lumpy skin disease (LSD) is a vector-borne viral infectious disease that affects cattle *Bos taurus* and several wild ruminant species, feral goats amongst them. European goat and sheep breeds are more susceptible to infection than African and Asian ones (Gortázar *et al.,* 2021).

The first report describing feral goats as intermediate hosts of a species of parasite *Linguatula* has been published in Australia (Barton *et al.,* 2022). Zoonotic diseases such as tuberculosis, brucellosis, rabies (Chynoweth *et al.,* 2013) Halzoun or Marrara disease (Barton *et al.,* 2022) are potentially transferable to humans. Apart from this recent report, the last scientific effort made within this field was in the 1980s (Weinberg & Lovari, 2020; Barton *et al.,* 2022). Further studies are required regarding feral goat biology, ecology, and their potential biosecurity risks (Barton *et al.,* 2022).

3.5.3 Food webs

Feral goats are considered pests in numerous environments, responsible for grazing endemic plant species to extinction, or at least very close to reaching this outcome. However, their populations also have an important positive effect: to support native and endangered avian scavengers and predators (Gangoso *et al.,* 2006; Margalida *et al.,* 2009), such as, the bearded vulture *Gypaetus barbatus* in the Pyrenees (Margalida *et al.,* 2009) and the endemic Egyptian vulture to the Canary Islands *Neophron percnopterus majorensis* (Gangoso *et al.,* 2006). Although the bearded vulture is considered a bone-eating species, small animal preys are vital for their young during the breeding season (Margalida *et al.,* 2009). Nonetheless, in this case the author does not distinguish between the domestic goat or the feral goat.

Other species that include feral goats into their diets are the Eurasian buzzard *Buteo buteo*, the common raven *Corvus corax* (Gangoso *et al.,* 2006) and the dingo *Canis lupus dingo* (DAF, 2020). Reports on feral goat relationships with grey wolves *Canis lupus* are absent (Papaioannou, 2010). In addition, there is a need within conservation projects to integrate extensive grazing systems and hunting practices for wild ungulates into local economies and traditional cultures (Gangoso *et al.,* 2006; Margalida *et al.,* 2009).

3.6 Management strategies

Learning about population trends is essential to guarantee their effective management and conservation. Depending on the geographical area, the management of feral domestic goats has different objectives: conservation, eradication & population control and exploitation (Herrero *et al.,* 2013).

3.6.1 Conservation

In the Mediterranean Basin, over 10 years ago, the feral goat was considered to be of unique historical and cultural significance. Therefore, its protection and study could provide an opportunity to test different evolutionary theories (Masseti, 2009b). The current situation has changed. Environmental management has developed to eradicate goats in many parts of the world in order to restore the natural equilibrium in islands, and these efforts have been especially intense in the Mediterranean Basin since 2020 (Capó *et al.,* 2022).

However, it is likely that feral goats inhabit protected areas, such as National Parks or areas included in the European Natura 2000 network. Thus, benefiting from the protection strategies offered by the territory (Papaioannou, 2010).

The current conservation criteria aim to prevent the spread of domestic or non-native genes in native populations (Iacolina *et al.,* 2018). Therefore, it is advised that current and future conservation plans implement a range of measures which:

- Determine the genetic origin of possible source populations.
- Protect native populations from the risk of crossbreeding with non-native ones.
- Establish permanent monitoring.

3.6.2 Eradication and population control

Eradication management approach is by far the most widely used. When it comes to eliminating populations of alien vertebrates, New Zealand is the highest contributor, followed by Australia, the USA and Mexico (Rocamora, 2015).

In Oceania, the eradication approach has been happening since at least 1966 (Williams & Rudge, 1969). Feral goats have been hunted intensively every year since 1972 in Raoul Island (New Zealand) (Parkes, 1984). In Kangaroo Island (Australia), an eradication program (2005-2016) was

carried out using white Judas goats (Masters *et al.,* 2018). Amongst tropical islands, in Seychelles, eradication procedures have been taking place since the 1920s (Rocamora, 2015). The largest goat removal efforts on the Pacific islands have been made in Hawaiian National Parks (Pejchar *et al.,* 2020). In Desecheo island (Puerto Rico Archipelago) goat eradication was completed in 2003 (Will *et al.,* 2019), and in Guadalupe Island (Mexico) it was concluded in 2007 (Luna-Mendoza *et al.,* 2019). Most European Alpine countries lack clear regulations enabling procedures for effective removal of feral goats (Moroni *et al.,* 2022).

The main techniques proven to successfully eradicate goats from islands include Judas goats, ground and aerial hunting (Campbell et al. 2004). Resulting in successful eradications from 120 islands worldwide (Campbell & Donlan, 2005). The construction of fences to exclude invasive mammals from ecologically important areas is widely used when island eradication is unfeasible considering island size, topography, habitat complexity, or lack of public support. This method has been applied in New Zealand and Hawaii to protect important seabird colonies (Pejchar *et al.*, 2020).

The reasons eradication campaigns fail is primarily due to lack of political support, the use of inappropriate methods, lack of effort, and the absence of implementing a monitoring programme post-eradication to detect the final goats at low densities (Campbell *et al.*, 2004; Campbell & Donlan, 2005).

The last research paper analysing the efficiency and efficacy of feral goat eradication campaigns on insular regions was carried out over more than 15 years ago (see Appendix 1. in Campbell & Donlan, 2005). In the following Table 3, numeric data is presented regarding the number of feral goats removed during these campaigns since 2006 till the present day. Despite this management method being the most preferable worldwide, there is still a lack of updated information and numeric data available.

Location		**km²**	**Goats eradicated (n)**	**Reference**
Mediterranean Islands	Es Vedra Island, Balearic Islands, Spain	0.6	66 (2016-2019)	Capó *et al.,* 2022
Oceania	Kangaroo Island, Australia	1,400	1,200 (2006-2016)	Masters *et al.,* 2018
Pacific Islands	Galapagos Islands, Ecuador	7,194	201,825	Carrion *et al.,* 2011

Table 3. Number of feral goats removed during eradication campaigns since 2006 - present day.

Nevertheless, killing large mammals is contentious and increasingly faces opposition from the public (Masters *et al.,* 2018; Cowan *et al*., 2020). Fertility control is an adaptive management approach to limit population size that is being explored in North Wales, United Kingdom (Cowan *et al*., 2020). On the other hand, some studies (Capó *et al.,* 2022) show that if feral goats are not completely eradicated, especially from islands, their impact on native flora reappears a few years later. Hence, their complete eradication is required to preserve the natural plant communities in insular ecosystems over the long-term (Campbell & Donlan, 2005; Capó *et al.,* 2022). Conversely, multiple forests transitioned into grasslands or bare ground even after feral goat eradication in Nakoudojima island (Japan), suggesting that canopy trees died by natural disturbances in addition to the lack of seedlings by the grazing of feral goats (Hata *et al.,* 2007).

3.6.3 Exploitation

In Australia, the goat industry is providing a viable alternative livestock enterprise to livestock producers (NSW Department of Primary Industries, 2021). These goats are considered to provide an excellent basis for exploitation and exportation. The focus is on cashmere, mohair, leather and meat production (Werdi *et al.,* 2007). Feral goats make up approximately 90% of goats sent to slaughter in Australia, mainly coming from the arid areas of western New South Wales (NSW) and South Australia (Barton *et al.,* 2022). Once processed, the majority of goat meat (95% in 2020) is exported, mainly to the United States (64% of export volume) followed by Taiwan, South Korea, Canada, Japan and Trinidad & Tobago. Live exports by air to Malaysia, the Philippines and China also take place (NSW Department of Primary Industries, 2021).

In the Mediterranean Basin, the Island of Rhodes (Greece) has recently established a new management program for feral goats along these lines. The aim is to donate the meat produced from the captured animals to charitable organisations. The public is also involved and can actively participate by submitting digital data (photos, coordinates) of feral goats sighting, thus enhancing the efficiency of municipal services provided (Tsakmakidou *et al.,* 2022).

4. Conclusions and further directions

Currently, distribution maps of feral goat populations are only available within a regional level (García-Serrano *et al.,* 2021). There is still absence of global distribution maps for this species (Papaioannou & Lovari, 2020).

There are abundant studies supporting feral goat eradication fundamentally due to their impact on vegetation. However, their role as nutrients and food supply for endangered fauna taxa is not sufficiently understood (Gangoso *et al.,* 2006; Margalida *et al.,* 2009). Similarly, further investigation is recommended regarding feral goat biology, ecology, and their potential biosecurity risks (Barton *et al.,* 2022). Additionally, there is a contradiction amongst the scientific community on how to proceed with hybrid individuals (Iacolina *et al.,* 2018).

Countries in Oceania are the main promoters of feral goat eradication and it has been occurring at least since the early 20th century (Williams & Rudge, 1969; Rocamora, 2015) gaining popularity and momentum in the last years. Nowadays, it is the most widespread approach when it comes to dealing with these herbivores, particularly favoured in insular ecosystems. However, there is still a lack of updated numeric data available on the efficiency and efficacy of eradication interventions. In spite of an adaptive management approach being suggested, there has been a paradigm change from a conservation approach to an eradication; and even exploitation (Tsakmakidou *et al.,* 2022); approach in the Mediterranean Basin (Capó *et al.,* 2022).

It is encouraged that the role played by the feral goat is investigated further, as good understanding of the population's life-history characteristics is essential for decision-making. This further research could provide useful insights for the optimal management of the species and the conservation of the remarkably diverse ecosystems it inhabits.

References

Alemayehu, K., Gizaw, S., Mekasha, Y., Haile, A., Dessie, T. (2011). The probable genetic introgression between Walia ibex (*Capra walie*) and domestic goats (*Capra hircus*) at Simien Mountains National Park (SMNP) in Ethiopia. African Journal of Agricultural Research 6(4):856-865. Available from: https://hdl.handle.net/10568/35288

Barton D.P., Shackelford B., Shamsi S., Jenkins D. (2022) Are feral goats intermediate hosts for *Linguatula* (Pentastomida) in Australia? International Journal for Parasitology: Parasites and Wildlife, (18): 283–286. Available from: https://doi.org/10.1016/j.ijppaw.2022.07.004

Brennan M., Moller H., Parkes J.P. (1993) Indices of density of Feral Goats in a Grassland/Forest habitat. Marlborough, New Zealand. New Zealand Journal of Ecology 17 (2): 103-106

Capó M., Cursach J., Picorelli V., Baraza E., Rita J. (2022) Eradication of feral goats, not population control, as a strategy to conserve plant communities on Mediterranean islets. Journal for Nature Conservation 65, 126108. Available from: https://doi.org/10.1016/j.jnc.2021.126108

Carrion V., Donlan C.J., Campbell K.J., Lavoie C., Cruz F. (2011) Archipelago-Wide Island Restoration in the Galapagos Islands: Reducing Costs of Invasive Mammal Eradication Programs and Reinvasion Risk. PLoS ONE 6(5): e18835. Available from: https://doi.org/10.1371/journal.pone.0018835

Campbell K., Donlan C.J., Cruz F., Carrion V. (2004). Eradication of feral goats *Capra hircus* from Pinta Island, Galapagos, Ecuador. Oryx (38):328–333.

Campbell K. and Donlan C.J. (2005). Feral goat eradication on islands. Conservation Biology, 19 (5): 1362-1374.

Chynoweth M., Litton C., Lepczyk C., Hess S., Cordell S. (2013) Biology and Impacts of Pacific Island Invasive Species. 9. *Capra hircus,* the Feral Goat (Mammalia: Bovidae). Pacific Science 67(2): 141-156. Available from: https://doi.org/10.2984/67.2.1

Chynoweth M., Lepczyk C., Litton C., Hess S., Kellner J., Cordell S. (2015) Home Range Use and Movement Patterns of Non-Native Feral Goats in a Tropical Island Montane Dry Landscape. PLoS ONE 10(3): e0119231. Available from: https://doi.org/10.1371/journal.pone.0119231

Coblentz, B. (1977). Some range relationships of feral goats on Santa Catalina Island, California. J. Range Manage. 30:415– 419.

Coblentz, B. (1978). The effects of feral goats (*Capra hircus*) on island ecosystems. Biological Conservation, 13: 279–285

Cowan D., Waal Z., Pidcock S., Gomm M., Stephans N., Brash M., White P., Mair L., Mill A. (2020) Adaptive management of an iconic invasive goat *Capra hircus* population. Mammal Review (50): 180–186. Available from: https://doi.org/10.1111/mam.12176

Department of Agriculture and Fisheries - DAF (2020). Feral goat fact sheet. State of Queensland, Australia. Available from: https://www.daf.qld.gov.au/

Ellerman J., Morrison-Scott T. (1966). Checklist of Palaearctic and Indian mammals 1758 to 1946, 2nd edition. pp: 404-409. British Museum (Natural History), London. Available from: https://www.biodiversitylibrary.org/item/35421#page/421/mode/1up

Gangoso, L., Donázar, J. A., Scholz, S., Palacios, C. J., & Hiraldo, F. (2006). Contradiction in Conservation of Island Ecosystems: Plants, Introduced Herbivores and Avian Scavengers in the Canary Islands. Biodiversity and Conservation, 15(7): 2231–2248. doi:10.1007/s10531-004-7181-4

García-Serrano A., Prada C., Herrero J. (2021) Seguimiento de la cabra montés y cabra doméstica asilvestrada en el Prepirineo aragonés (2006-2021). Aragon Government internal report.

Gortázar, C., Ferreres J., Marco J., Fernández de Luco D., Garin I., Aldezabal A. (1997). The feral goat in Guara (Aragón, Spain): Conservation or eradication? BIPAS, 17: 73-79.

Gortázar, C., Herrero, J., Villafuerte, R. & Marco, J. (2000). Historical examination of the status of large mammals in Aragon, Spain. Mammalia *64*(4): 411-422. Available from: https://doi.org/10.1515/mamm.2000.64.4.411

Gortázar, C., Barroso, P., Nova, R., & Cáceres, G. (2021). The role of wildlife in the epidemiology and control of Foot-and-mouth-disease And Similar Transboundary (FAST) animal diseases: A review. Transboundary and Emerging Diseases: 1-12. Available from: https://doi.org/10.1111/tbed.14235

Grubb, P. (2005) Order Artiodactyla in: D.E. Wilson & D.M. Reeder (ed.), Mammal Species of the World. A Taxonomic and Geographic Reference (3rd ed): 637-722. Johns Hopkins University Press. Available from: https://books.google.es/books?id=JgAMbNSt8ikC&printsec=frontcover&redir_esc=y#v=onepage&q=capra%20hircus&f=false

Hata, K., Suzuki J.I., Kachi N. (2007) Vegetation changes between 1978, 1991 and 2003 in the Nakoudojima Island that had been disturbed by feral goats. In: Kawakami, K., Okochi, I.

(eds) Restoring the Oceanic Island Ecosystem. Springer: 85-91. Available from: https://doi.org/10.1007/978-4-431-53859-2_14

Herrero J., O. Fernández-Arberas, C. Prada, A. García-Serrano (2013). Size and density of a feral goat *Capra hircus* population in a protected area in the Pyrenees. Wildlife Biology in Practice (9): 1-6

Herrero J., L. Rossi, L., A. García-Serrano, R. García-González, G. Meneguz, J. Navas, R. Vidaller (2021) What leucism may reflect in Iberian wild goat Capra pyrenaica and in Alpine ibex Capra ibex. Caprinae News 2021: 20-23

Hunter, E. A., & Gibbs, J. P. (2013). Densities of Ecological Replacement Herbivores Required to Restore Plant Communities: A Case Study of Giant Tortoises on Pinta Island, Galapagos. Restoration Ecology, 22(2): 248–256. Available from: https://doi.org/10.1111/rec.12055

Hunnam, J., Duff, K., Wingett, M., Brayley, E., & Williamson, G. (2018). Effect of carcase decomposition on the inactivation of foot-and-mouth disease virus under northern Australian conditions. Australian Veterinary Journal, 96(9): 332–340. Available from: https://doi.org/10.1111/avj.12731

Iacolina, L., Corlatti, L., Bužan, E., Safner, T., & Šprem, N. (2018). Hybridisation in European ungulates: an overview of the current status, causes, and consequences. Mammal Review, 49: 45-49. Available from: https://doi.org/10.1111/mam.12140

International Trust for Zoological Nomenclature (2003). Opinion 27, Case 3010 (2003). Bulletin of Zoological Nomenclature 60 (1): 81-84

Joshi, M.B., Rout, P.K., Mandal, A.K., Tyler Smith, C., Singh, L., Thangaraj, K. (2004). Phylogeography and origin of Indian domestic goats. Molecular Biology and Evolution, 21 (3): 454-462

Kessler, C. C. (2002). Eradication of feral goats and pigs and consequences for other biota on Sarigan Island, Commonwealth of the Northern Mariana Islands. In: Veitch C. R. and Clout M.N (eds.). Turning the tide: the eradication of invasive species. IUCN SSC Invasive Species Specialist Group: 132–140.

Lowe S., Browne M., Boudjelas S., De Poorter M. (2004) One Hundred of the World's Worst Invasive Alien Species. Global Invasive Species Database. Species profile *Capra hircus.* Invasive Species Specialist Group (ISSG) of the International Union for Conservation of Nature (IUCN). Available from: http://www.iucngisd.org/gisd/species.php?sc=40

Luikart, G., Gielly, L., Excoffier, L., Vigne, J.D., Bouvet, J., Taberlet, P. (2001). Multiple maternal origins and weak phylogeographic structure in domestic goats. Proceedings of the National Academy of Sciences, 98 (10): 5927-5932

Luna-Mendoza L., Aguirre-Muñoz A., Hernández-Montoya, J.C., Torres-Aguilar M., García-Carreón J., Hernández O., Luvianos-Colin S., Cárdenas, A., Méndez Sánchez, F. (2019). Ten years after feral goat eradication: the active restoration of plant communities on Guadalupe Island, Mexico. Available from: https://www.researchgate.net/publication/331939753_Ten_years_after_feral_goat_eradication_the_active_restoration_of_plant_communities_on_Guadalupe_Island_Mexico

Margalida A., Bertran J., Heredia R. (2009). Diet and food preferences of the endangered Bearded Vulture *Gypaetus barbatus*: a basis for their conservation. Ibis, 151(2): 235–243. Available from: doi:10.1111/j.1474-919x.2008. 00904.x

Masseti M. (2009a) The wild goats *Capra aegagrus* Erxleben, 1777 of the Mediterranean Sea and the Eastern Atlantic Ocean islands. Mammal Review, 39(2): 141–157. Available from: https://doi.org/10.1111/j.1365-2907.2009.00141.x

Masseti M. (2009b) A possible approach to the "conservation" of the mammalian populations of ancient anthropochorous origin of the Mediterranean islands. Folia Zoologica, 58(3): 303–308

Masters P., Markopoulos N., Florance B., Southgate R. (2018) The eradication of fallow deer (*Dama dama*) and feral goats (*Capra hircus)* from Kangaroo Island, South Australia. Australasian Journal of Environmental Management 25(1): 86-98. Available from: https://doi.org/10.1080/14486563.2017.1417166

Moroni B., Brambilla A., Rossi L., Meneguz P.G., Bassano B., Tizzani P. (2022) Hybridization between Alpine Ibex and Domestic Goat in the Alps: A Sporadic and Localised Phenomenon? Animals, 12(6): 751. Available from: https://doi.org/10.3390/ani12060751

Nogales M. Rodríguez-Luengo J.L., Marrero P. (2006) Ecological effects and distribution of invasive non-native mammals on the Canary Islands. Mammal Review, 36(1): 49–65.

NSW Department of Primary Industries (2021). Goat Industry Data Collation and Tracking. Industry update 2020/21. NSW Government, Australia. Available from: https://www.dpi.nsw.gov.au/

Papaioannou, H., Lovari, S. (2020) Mediterranean Feral Goat *Capra hircus* Linnaeus, 1758. Hackländer, K., Zachos, F.E. (eds) Handbook of the Mammals of Europe. Handbook of

the Mammals of Europe. Springer, Cham. Available from: https://doi.org/10.1007/978-3-319-65038-8_161-1

Parkes, J. P. (1984). Feral goats on Raoul Island. II. Diet and notes on flora. New Zealand Journal of Ecology, (7): 95–101.

Parkes, J. P. (1993). Feral goats: Designing solutions for a designer pest. New Zealand Journal of Ecology, 17(2): 71–83. http://www.jstor.org/stable/44945333

Parkes, J.P., Henzell, R., Pickles, G. (1996). Managing Vertebrate Pests: Feral Goats. Australian Government Publishing Service, Canberra. Available from: https://www.researchgate.net/publication/265101007_Managing_Vertebrate_Pests_Feral_Goats

Pejchar L., Lepczyk C., Fantle-Lepczyk J., Hess S., Johnson T., Leopold C., Marchetti M., McClure K., Shiels A. (2020). Hawaii as a Microcosm: Advancing the Science and Practice of Managing Introduced and Invasive Species. BioScience, 70 (2): 184–193. Available from: https://doi.org/10.1093/biosci/biz154

Rocamora G. & Henriette E. (2015). Invasive alien species in Seychelles: Why and how to eliminate them? Identification management of priority species. Island Biodiversity and Conservation centre, University of Seychelles. Biotope, Mèze; Muséum national d'Histoire naturelle (Inventaires & biodiversité series), 384p.

Rojas-Sandoval J., Meléndez-Ackerman E.J., Fumero-Cabán J., García-Bermúdez M. A., Sustache J., Aragón S., Morales M., Fernández D.S. (2014). Effects of hurricane disturbance and feral goat herbivory on the structure of a Caribbean dry forest. Journal of Vegetation Science. 25 (4):1069–1077. Available from: https://doi.org/10.1111/jvs.12160

Romero, R. (2010). Estructura de la población de cabras asilvestradas (*Capra hircus*) de los cantiles costeros de la Sierra de la Capelada (Galicia, NO España). Galemys (22): 207-218. Available from: https://www.researchgate.net/publication/288260229_Estructura_de_la_poblacion_de_cabras_asilvestradas_Capra_hircus_de_los_cantiles_costeros_de_la_Sierra_de_la_Capelada_Galicia_no_Espana

Saunders F.C., McElligott A.G., Safi K., Hayden T.J. (2005). Mating tactics of male feral goats (*Capra hircus*): risks and benefits. Acta Ethol (8): 103–110. Available from: https://doi.org/10.1007/s10211-005-0006-y

Shackleton D.M. (1997). Wild Sheep and Goats and their Relatives: Status Survey and Conservation Action Plan. IUCN/SSC Caprinae Specialist Group IUCN, Switzerland and Cambridge, Gland, p. 390.

Shi J., Dunbar R. I. M., Buckland D., Miller D. (2005). Dynamics of grouping patterns and social segregation in feral goats (*Capra hircus*) on the Isle of Rum, NW Scotland. Mammalia 69 (2): 185-199. Available from: https://doi.org/10.1515/mamm.2005.016

Tsakmakidou A., Stamatis P. Patta-Apostolidi E. (2022). Innovative tools for the management of feral goats.: Local authority's digital governance attempts to control and reduce the number of escaped/unattended domesticated goats on the island of Rhodes Greece. 14th International Conference on Theory and Practice of Electronic Governance (ICEGOV 2021): 503–505. Available from: https://doi.org/10.1145/3494193.3494267

United Nations (2015) The 2030 Agenda and the Sustainable Development Goals. Number 15: protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. Available from: https://sdgs.un.org/goals/goal15

Viera-Ruiz, G., Martínez Pérez M., Naranjo Suárez J. (2016). Impacto de las cabras asilvestradas. LIFE+ Inagua Project. inDiferente (22): 114-125.

Wale M. (2016) The Walia Ibex (*Capra walie*). Journal of Biodiversity & Endangered Species 4 (1): 161. Available from: DOI:10.4172/2332-2543.1000161

Weinberg, P., Lovari, S. (2020). Wild Goat *Capra aegagrus* Erxleben, 1777. Hackländer, K., Zachos, F.E. (eds) Handbook of the Mammals of Europe. Handbook of the Mammals of Europe. Springer, Cham. Available from: https://doi.org/10.1007/978-3-319-65038-8_31-1

Werdi N.M, Murray P.J., Taylor D.G. (2007). Feral goats in Australia: A study in the quality and nutritive value in their meat. Meat Science, 75 (1): 168-177. Available from: http://dx.doi.org/10.1016/j.meatsci.2006.06.026

Williams G.R., Rudge M.R. (1969). A population study of feral goats (*Capra hircus* L.) from Macauley Island, New Zealand. Proceedings of the New Zealand Ecological Society (16): 17-28

Will, D., Swinnerton, K.J., Silander, S., Keitt, B.S., Gri, R.J., Ths, Howald, G.R., Figuerola-Hernández, C.E., Herrera-Giraldo, J.L. (2019). Applying lessons learnt from tropical rodent eradications: a second attempt to remove invasive rats from Desecheo National Wildlife Refuge, Puerto Rico. Available from: https://www.researchgate.net/publication/332157512_Applying_lessons_learnt_from_tropical_rodent_eradications_a_second_attempt_to_remove_invasive_rats_from_Desecheo_National_Wildlife_Refuge_Puerto_Rico

Zheng Z., Wang X., Li M., Li Y., Yang Z., Wang X., Pan X., Gong M., Zhang Y., Guo Y., Wang Y., Liu J., Cai Y., Chen Q., Okpeku M., Colli L., Cai D., Wang K., Huang S., Sonstegard T. S., Esmailizadeh A., Zhang W., Zhang T., Xu Y., Xu N., Yang Y., Han J., Chen L., Lesur J., Daly K. G., Bradley D. G., Heller R., Zhang G., Wang W., Chen Y., Jiang Y. (2020) The origin of domestication genes in goats. Science Advances (6), eaaz5216. Available from: DOI: 10.1126/sciadv.aaz5216