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ORIGINAL PAPER

Reproductive parameters of the common genet *Genetta genetta* (Linnaeus, 1758) in Southwest Europe

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Abstract We used information from 148 litters belonging to 119 different wild and captive female common genets (*Genetta genetta*) in SW Europe over a period of almost 50 years to study certain reproductive parameters. Data were obtained from a combination of sources including carcasses, live captures, telemetry-based studies, captive genets, and reports in the literature. The circannual pattern of breeding was fairly similar in both wild and captive genets, with births occurring in all months except December, albeit with a large peak in spring and a secondary peak in autumn. The sex ratio at birth was near to 1:1, and mean litter size was 2.16 ± 0.76 cubs/litter with a range of 1–5 cubs. Litters of two cubs were the most frequent both in wild and captive settings. In captivity, we have observed the births of replacement litters and double litters; however, we did not find evidence of wild females that having two litters in the same year. We conclude that the possibility of breeding at any time of the year is facilitated by the continuous spermatogenesis of the males and by the ability of females to enter into estrus after losing a litter prematurely and to breed twice in the same year.

Keywords Birth · *Genetta genetta* · Litter size · Reproduction · Sex ratio

The original version of this article was revised: The article title was changed from "Reproductive parameters of the common genet (*Genetta genetta*, Linnaeus 1758) in Southwest Europe" to "Reproductive parameters of the common genet *Genetta genetta* (Linnaeus, 1758) in Southwest Europe". In Table 2, entries below "Litters" and "Total cubs" was changed to "*N*" from "*n*".

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Introduction

Knowledge of species' reproductive parameters is essential if we are to understand their population demography and propose management, conservation, or control measures (Holt et al. 2014). However, in many species, the process of reproduction has not been well studied. This is especially true of mammalian carnivores, which are difficult to study in wild settings because most are nocturnal, secretive, and occur at low densities.

The common genet (*Genetta genetta*) is a medium-sized nocturnal carnivore belonging to the family Viverridae. It is a species native to Africa, although also present in Europe, possibly due to an intentional introduction to southern Iberia via Phoenicians' commercial routes, in 800 BC (Gaubert et al. 2015a, b). Nowadays, it is a species perfectly adapted to the natural communities of SW Europe, the range of its current distribution in this continent (Jennings and Veron 2009; Fig. 1). The reproductive biology of the common genet is poorly known. A few general papers on the ecology and biology of the species in Europe provide fragmented information

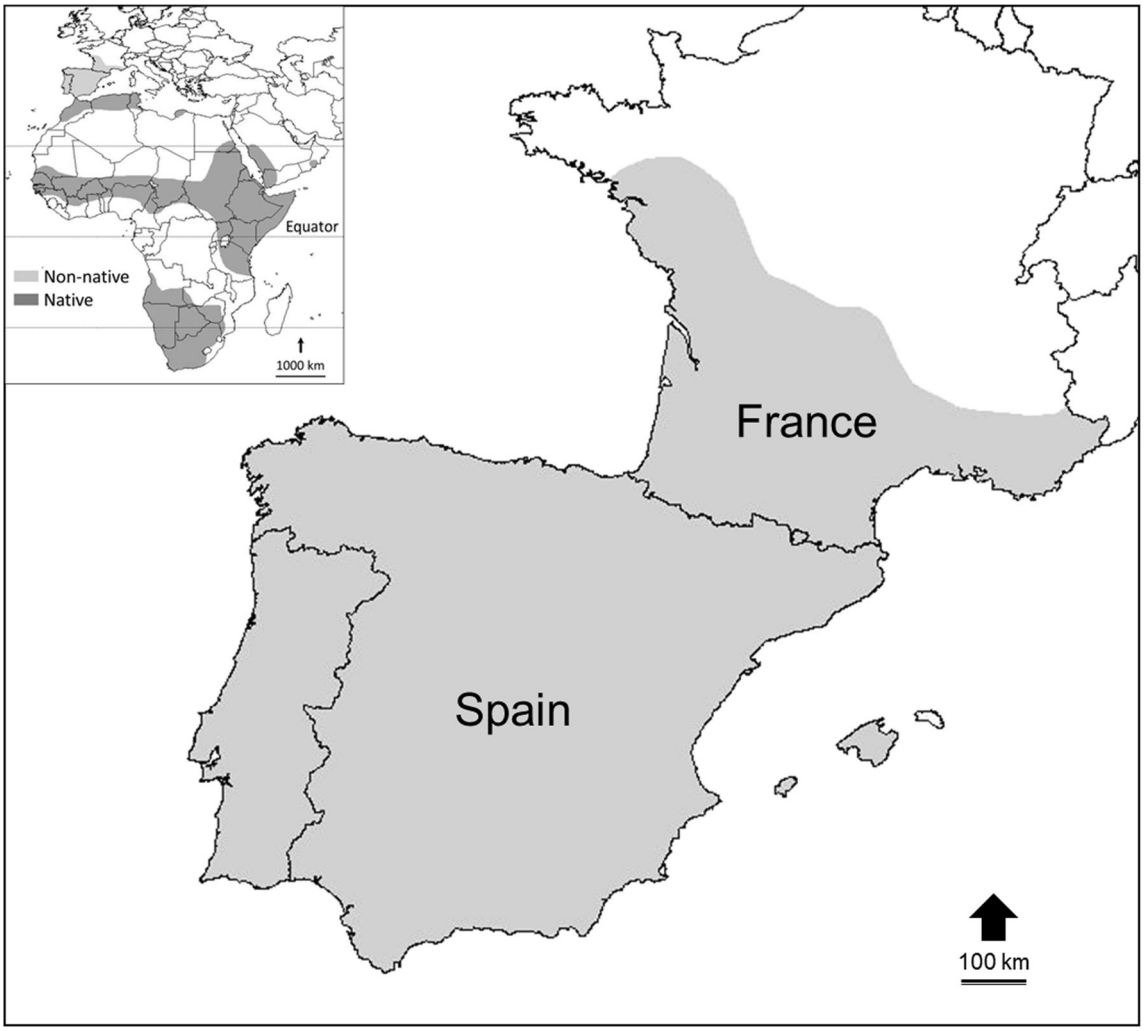

Fig. 1 Worldwide distribution (*small box*) of the common genet (*Genetta genetta*) and study area of the breeding parameters in SW Europe: France and Spain. In *gray*, the habitual distribution of the species is represented (author's work based on Jennings and Veron 2009 and Gaubert et al. 2015a, b)

on its reproduction in the wild; these sources include data on matings, parturitions, and descriptions of breeding dens, but usually based on small sample sizes (Delibes 1974). Other studies have dealt with this species' breeding habits on a broad level, but lack data for reaching conclusive results (e.g., Aymerich 1982). Finally, several studies have discussed breeding in captivity (Roeder 1979; Livet and Roeder 1987).

Adult genets are basically solitary animals, and males and females only interact during the period of estrus. Gestation of the female lasts about 10–11 weeks (Roeder 1979) and the implantation of the blastocyst is normal (Ruiz-Olmo 1997). Only the female will raise her cubs, and for parturition, she seeks a quiet place to locate the den, preferably in elevated places and cavities (Delibes 1974; Delibes and Gaubert 2013). Cubs leave their mother after the fourth or fifth month. At this point, the dispersal period can begin, although in the first movements, the cubs usually accompany their mother, a contact that can last a few more months, until they are forced to look for a free area (Roeder and Pallaud 1980). By the 15th month, they are already the size of an adult and reach sexual maturity around 2 years of age (Krapp and Delibes 1993). The few available data about reproduction of common genet indicate that in W, E, and S Africa, breeding seems to be associated with wet seasons, while it occurs in spring and autumn in Mediterranean N Africa and SW Europe (Delibes and Gaubert 2013).

Here, we analyze data collected over a period of almost 50 years in SW Europe (the European range of the species) from a combination of sources including carcasses, live captures, telemetry-based studies, captive genets, and reports in the literature. This sample provides the widest and most accurate information on breeding ever assembled for this species in this area. Compiling data from multiple sources in this portion of the species' range allows us to determine with some accuracy certain reproductive parameters in both wild and captive common genets such as dates of births, the number of paturitions per year, litter size, and the sex ratio at birth. We then compare our findings with existing information in the literature as a step towards a more rigorous approach to the management of this species.

Methods

Data collection

We used information from 148 litters belonging to 119 different wild and captive female genets born between 1970 and 2014 in Spain and France. Data from 77 litters were previously unpublished, the remaining 71 litters being obtained from the literature (Faugier and Condé 1973; Delibes 1974; Roeder 1979; Aymerich 1982; Camacho 1993). The data corresponded to 50 litters born to 50 different wild females (unpublished information in 11 cases), while captive genets represented 98 litters (66 unpublished) corresponding to 69 females. Our data were obtained throughout the whole study area from (a) taxidermists and trappers in the period 1970–1989 when the capture of genets was still legally permitted in Spain (Camps 2015), (b) road-killed individuals collected by ourselves or by collaborators, (c) individuals trapped for several studies on presence, morphometry, radio-tracking, etc. (e.g., Camps and Llimona 2004), and (d) records contributed by individual observers. Data on captive genets came from recovery and captive breeding centers and from a number of private owners. Other than three cases in which one male and two females lived together as part of a project analyzing potential female communal breeding, all captive genets were caged in pairs. In several cases, the cubs were removed from the cage to avoid that they were killed by their parents.

Reproductive parameters

The following reproductive parameters were estimated: date and seasonality of breeding, litter size, cub sex ratio and viability, and the time interval between consecutive deliveries by individual females in the same year (for captive individuals that bred more than once in a year). Where appropriate, data were considered separately by month of the year and for wild or captive individuals.

Carcasses were necropsied by ourselves or by collaborators to determine the number and sex of fetuses (if present). Given a gestation period of 70 days (Roeder 1979) and the growth pattern compiled by Camps (2015), conception and birth dates were estimated. Adult live-captured females were examined to assess their reproductive status (inactive, pregnant, or lactating). Radio-tracked females provided data on the location of breeding dens, the number and sex of cubs, and their estimated birth dates (e.g., Camps and Llimona 2004). Captive genets also provided information on cub survival (viability) and provided evidence for the existence of "second litters" in the same year (as previously suggested; see Delibes 1974; Aymerich 1982; Livet and Roeder 1987), either because the first litter was lost or because some females bred more than once a year.

Not all litters provided all the above information, so the sample sizes used in analyses varied. Chi-squared contingency tests were used to compare frequencies. As the assumptions of normality (evaluated using the Kolmogorov-Smirnov test) of the data were not satisfied, we used a nonparametric Spearman's rank correlation to relate variables and nonparametric tests to compare means (Zar 2010). Mean values are given with standard deviations.

Results

Breeding seasonality

The circannual pattern of breeding was fairly similar in both wild (50 births) and captive (98 births) genets, with births occurring in all months except December. Most of the births, however, were concentrated in April–May (58.8%) and, secondarily, in August–September (20%) (Fig. 2). Overall, birth in wild genets occurred in April (38.0%) and for captive animals in May (38.8%), with statistically different frequency distributions (x^2 = 29.57, df = 10, p = 0.001). A few births occurred in October (2) and November (1) in Spain and in January (5) in France; births in February (3) took place in both countries.

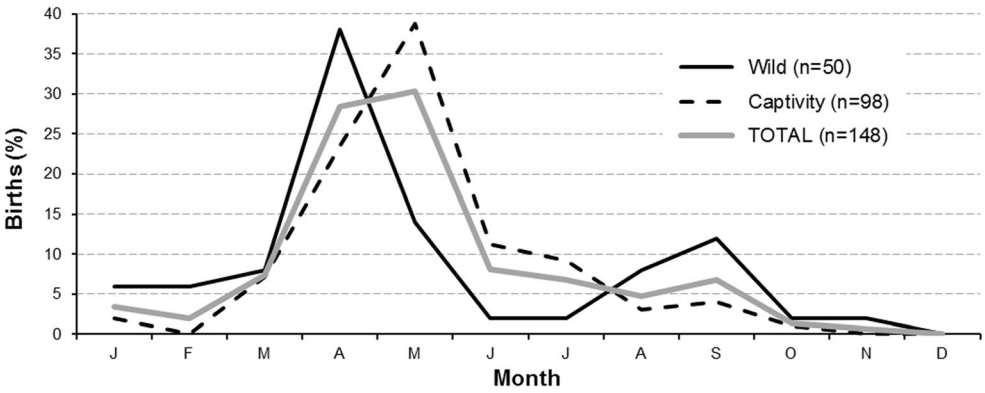

Fig. 2 Breeding frequency throughout the year in SW Europe in wild and captive genets

Table 1 Litter size in wild and captive genets

	Litter size % (*n*)					
	1 cub	2 cubs	3 cubs	4 cubs	5 cubs	Total (*n*)
Wild	18.6 (8)	55.8 (24)	16.3 (7)	7.0 (3)	2.3 (1)	43
Captivity	15.8 (15)	54.7 (52)	28.4 (27)	1.1 (1)	0 (0)	95
Total	16.7 (23)	55.1 (76)	24.6 (34)	2.9 (4)	0.7 (1)	138
Number of cubs	7.7 (23)	51.0 (152)	34.2 (102)	5.4 (16)	1.7 (5)	298

The number of cubs is given in each case

Litter size and sex ratio of the cubs

Mean litter size was 2.16 ± 0.76 cubs/litter (n = 138 litters and 298 cubs) with a range of 1–5 cubs (Table 1); litter size did not differ between genets in captive or wild settings (wild mothers n = 43: 2.19 ± 0.91 cubs/litter; captive mothers n = 95: 2.15 ± 0.68 cubs/litter; Mann-Whitney U test: $Z = -0.29$, $p > 0.05$). The month of birth did not affect litter size ($x^2 = 22.30$, df = 27, $p > 0.05$). Litters of two cubs were the most common in the wild (55.8%; $x^2 = 38.28$, df = 4, $p < 0.0001$) and in captivity (54.7%; $x^2 = 59.06$, df = 3, $p < 0.0001$). Although litters of three cubs were the second most frequent litter size in captivity (28.4%), litters of just one cub (18.6%) were the second most frequent size in the wild. Litter sizes of four and five were uncommon; only four litters (2.9%) had four cubs (three of them of wild females and one of captivity), and just one litter (0.7%) had five cubs, the latter corresponding to a wild genet in southern Spain. In all, litters of two cubs comprised 51.0% of all cubs, followed by litters of three cubs (34.2%) (Table 1).

We determined sexes of 78 male and 74 female cubs (1.05M:1F) that did not differ from a 1:1 distribution ($x^2 = 0.11$, df = 1, $p > 0.05$) in 72 litters (Table 2). Including only litters with >1 cub, litter size did not affect the sex ratio ($r_s = 0.877$, $n = 3$, $p > 0.05$).

Additional information on common genets in captivity

In 40 litters of captive genets, we were able to monitor the survival of the cubs and the subsequent reproductive activity of the mothers in the same year. In 21 (52.5%) cases, the entire litter was killed by the parents or removed by the caretaker some days after parturition. Nine (42.9%) of these mothers then bred again (replacement litter). In addition, two (10.5%) of the 19 mothers that successfully reared their cubs bred again in the same year. Replacement litters were born on average 99.2 ± 28.1 days (n = 6; range 84–156) after the first litter was lost. Given that the gestation period lasts about 70 days (Roeder 1979), mating presumably occurred around 20–30 days after the disappearance of the cubs. Interestingly, one litter was removed after 18 days of lactation and the mother gave birth again 142 days later; this period of time was approximately the same as for the two females that bred twice in the same year (135 and 162 days, respectively).

On three occasions, two females and one male were kept in the same cage. In two cases, only one female bred, while in the other case, both females did, giving birth with a difference of 3 days (males were always removed before paturitions to avoid that they killed the cubs). The first litter (two cubs) was suckled by both females, but the infants were killed following the birth of the second female's cub (this cub was removed by the caretaker).

Discussion

Our results suggest that in SW Europe, the genet can breed all year around, albeit with peaks in spring and autumn, a finding that has been suggested previously (Delibes 1974; Livet and Roeder 1987). This pattern contrasts sharply with other European mesocarnivores, like the red fox (*Vulpes vulpes*) or the stone marten (*Martes foina*), which tend to breed seasonally in the spring (Wilson and Mittermeier 2009). This difference is very likely due to the African origin of the genus *Genetta* (Gaubert et al. 2011). Over much of Africa, the genet breeds at the most favorable time of year, which normally coincides with the rainy seasons—of which there are two in the subtropical climates the species inhabits in preference to the permanently humid tropical jungle (Delibes and Gaubert

Table 2 Number of males and females in litters of 1–3 cubs

Litter size	Litters *N*	Total cubs *N*	Males % (*n*)	Females % (*n*)	Sex ratio (*m*/*f*)
1 cub	12	12	41.7 (5)	58.3 (7)	0.71
2 cubs	24	48	52.1 (25)	47.9 (23)	1.09
3 cubs	14	42	52.4 (22)	47.6 (20)	1.10
Unknown	22	50	52.0 (26)	48.0 (24)	1.08
Total	72	152	51.3 (78)	48.7 (74)	1.05

Unknown indicates those cases in which we could collect data about number and sex of cubs, but the size of litters was unknown. The value of the sex ratio is given in each case

2013). The possibility of breeding at any time of the year is facilitated by the continuous spermatogenesis of the males (Souloumiac and Audy 1979). Likewise, the capacity of females to enter into estrus after losing a litter prematurely and to breed twice in the same year also increases the probability that litters may be born throughout the year.

It is worth noting that in SW Europe, the genet also breeds chiefly in the rainy season (spring and summer) and seems to avoid (albeit only partially) breeding during summer drought periods and cold winters, although births have been recorded in January (Zabala and Zuberogoitia 2010). In the Iberian Peninsula, the peak breeding period appears to overlap with the time of year in which the genet's principal prey (small mammals) are most abundant (Moreno and Kufner 1988). This fact ensures sufficient resources for gestation and provisioning food for cubs (milk and solid food) at a time of the year when the female has high energy requirements (Kunz and Orrell 2004). As suggested by Roeder (1979), the seasonal pattern of breeding is similar in captive and wild genets, although our data shows that the peak number of births in captive females is somewhat delayed (from April to May).

The polyestrous cycle of female genets, with more than one fertile period during the breeding season, means it is possible for females to have second litters. As commented above, males are spermatologically active all year but do have phases of maximum endocrine activity in spring and autumn (Souloumiac and Audy 1979) coinciding with the reproductive peaks detected in the species. According to Roeder (1979), captive genets had one litter in their first year and two in the following years. In captivity, we have observed the births of replacement litters (nine cases) and double litters (two), but have not documented two litter in the same year for wild females (Delibes and Gaubert 2013). Indeed, the second peak in the number of births in the wild might correspond to late first litters or replacement litters. Mother genets and their offspring stay together for 5–6 months (Livet and Roeder 1987), which, if added to the gestation period of 10–11 weeks (Roeder 1979), makes it difficult to accept the idea of a second annual litter if the first has not been lost. It is worth emphasizing the fact that the female genet that suckled her cubs for 18 days did not enter into heat after her cubs were taken away. This suggests that her investment in feeding during those days caused a negative energy balance—maybe also because of the possible stress of losing her litter abruptly—that resulted in the suppression of luteinizing hormone (LH) secretion (see Tsukamura and Maeda 2001).

Litter size was not affected either by captivity or time of year. Two-cub litters were the most common, as the literature suggests; the majority of litters were composed of 1–4 cubs and most frequently between two and three (Smithers 1971; Aymerich 1982; Livet and Roeder 1987), as it has also been registered in southern Africa (Delibes and Gaubert 2013). The five-cub litter in the wild is, to our knowledge, the first such record for the genet.

The sex ratio at birth was near to 1:1, as has been reported in both Africa and Europe (Smithers 1971; Roeder 1979; Livet and Roeder 1987; Krapp and Delibes 1993). Available data on the sex ratio in adults, on the other hand, show more variation, although generally males are more common than females, with ratios of 0.81:1 to 1.9:1 (Delibes 1974; Aymerich 1982; Krapp and Delibes 1993; Rosalino et al. 2005). This greater abundance of males could be due to monitoring bias: males may be easier to catch because they have larger home ranges (Camps 2015) or because they are less wary of traps. A study carried out in Botswana, for example, suggested that males were captured three times as often as females (Smithers 1971).

In conclusion, this study clarifies certain aspects of genet reproduction in Europe that may be fundamental to understand their population demography and develop, if necessary, management measures. Nevertheless, it would be interesting to complement this information with additional details regarding the breeding parameters of the species; in particular, future research could be done to determine the species' breeding success, the lifetime reproductive output per female, mortality rates, the effect of the age and experience of the mother, and cub survival rates.

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