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Epidemiological analysis of reproductive performances and kitten mortality rates in 5,303 purebred queens of 45 different breeds and 28,065 kittens in France

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Contents

Reproduction management and performances are evaluated in the feline species only through a limited number of animals and studies. Our objective was to provide reference figures in purebred cats, from a large-scale sample. Data were collected from an online software dedicated to cattery management (Breeding Management System®, BMS, Royal Canin, Aimargues, France). Information was recorded on a voluntary basis by French breeders between 2011 and 2014. Data were anonymously transferred for analysis. A total of 9,063 oestrous periods (in contact with a male) from 5,303 queens (45 breeds) were recorded from 1,521 breeders. Most matings (70.1%) occurred during increasing day length periods. The mean age at mating ($\pm SD$) was 2.7 ± 1.6 years for queens and 2.9 ± 1.9 years for tomcats. Pregnancy rate (based on breeders declaration) was 85.2%. Among queens declared pregnant, 8.4% failed to maintain pregnancy. Globally, 78% of the mated females gave birth to 28,065 kittens within 7,075 L. Mean litter size was 4.0 ± 1.9 kittens among which 8.5% were stillborn. Neonatal and paediatric mortality rate was 8.2%. In total, 16.0% of kittens born died before weaning. The results of this study are based on the largest feline database ever analysed. The figures collected can thus be used as reference to define average reproductive performances in numerous breeds for cat breeders. Further analysis will identify factors influencing reproductive performances and early mortality in the feline species.

1 | INTRODUCTION

In spite of cat breeding growing in popularity, reproduction management and performances are evaluated in the feline species only through a limited number of studies and animals, for example 1,056 queens in UK (Sparkes et al., 2006) or 264 queens in Sweden (Ström Holst & Frössling, 2009). Moreover, most studies are older than 15 years and focused on the outcome (litter size and kitten mortality), whereas infertility and pregnancy loss in queens have been poorly studied (Jemmett & Evans, 1977; Johnstone, 1987; Povey, 1978; Root, Johnston, & Olson, 1995; Sparkes et al., 2006; Ström Holst &

Frössling, 2009). Our objective was to provide an update on feline reproduction with reference figures for reproductive performances and kitten survival in purebred cats, from a national-scale database.

2 | MATERIAL AND METHODS

2.1 | Data collection

Data were collected from an online software dedicated to breeding management (Breeding Management System®, BMS, Royal Canin, Aimargues, France). Information was recorded on a voluntary basis

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by French breeders from 2011 to 2014 and then anonymously transferred with the breeders' consent as a Microsoft Excel table (Microsoft corporation, Redmond, WA, USA) for analysis.

2.2 | Data management

Each line in the database corresponds to an oestrus with mating. Only purebred matings were registered. Variables included information on genitors, environment and litters. Corrections have been made to ensure the quality of the data. Every negative interval was considered as aberrant data (e.g. queening cannot occur before mating). Intervals of aberrant length according to literature lead to exclude the corresponding data: mating has to occur within 15 days after the onset of oestrus, pregnancy declaration, abortion and queening have to occur, respectively, between 15 and 80 days, 15 and 56 days, 50 and 80 days after mating (Johnston, Kustritz, & Olson, 2001; Sparkes et al., 2006). The status of the queen (pregnant, aborted or queening) as declared by breeders has been verified thanks to kitten's data (birth or not). Litter data were also checked for the coherence between the total number of kittens born, born alive, dead and the declared sex ratio.

2.3 | Definitions of variables

Variables used in the analysis were defined as follows:

Age of the queen/tomcat at mating (year): mating date subtracted by the birth date of the queen/tomcat divided by 365.25.

Origin of the tomcat: housing to the declarant or not. The females were all considered as belonging to the cattery of the declarant, as external origin was marginal (<0.01% (21/5303)).

Season: mating/queening dates were categorized as follows: spring = 21st March–21st June, summer = 21st June–21st September, autumn = 21st September–21st December and winter = 21st December–21st March.

Pregnancy rate: number of pregnant females (as declared by the breeders) divided by the number of mated females (all the females included in the database were mated)*100.

Abortion rate: number of females declared pregnant that failed to maintain pregnancy divided by the number of pregnant females, multiplied by 100. The number of females who failed to maintain pregnancy was obtained by subtracting the number of queened females from the number of pregnant females.

Queening rate: number of females who gave birth to a litter divided by the number of mated females, multiplied by 100.

Litter size: total number of kittens born by litter.

Sex ratio: number of male kittens divided by the number of female kittens.

Stillbirth rate: stillborn kittens were kittens recorded dead at birth by the breeder. Stillbirth rate was calculated as the number of stillborn kittens divided by the total number of kittens born, multiplied by 100.

Neonatal and paediatric mortality rate: number of kittens born alive but having died within the first 60 days of life divided by the total number of kittens alive at birth (obtained by subtracting the number

of stillborn kittens from the total number of kittens born), multiplied by 100.

Global kitten mortality rate: the kitten mortality included stillbirth and neonatal–paediatric mortality. Global kitten mortality rate was calculated by adding the number of stillborn kittens, and the number of kittens born alive but having died within the first 60 days of life then by dividing by the total number of born kittens (multiplied by 100).

2.4 | Statistical analysis

Descriptive statistics were performed on gestation length, pregnancy rate, abortion rate, queening rate, pre-weaning mortality, stillbirth, neonatal and paediatric mortality rates thanks to Microsoft Excel software (Microsoft corporation) and SAS software (SAS-PC system, Version 9.3 for Windows; SAS Institute, Cary, NC, USA) in the general population with 95% confidence intervals (calculated thanks to Exact binomial) and for each breed represented by a sufficient number of oestrus ($n > 10$).

3 | RESULTS

3.1 | Study population

A total 5,303 queens (45 breeds) gave birth to 28,065 kittens divided into 7,075 L. Forty-five breeds were included in the study. A total of 9,063 oestrous periods (all with contact with a male) were recorded by 1,521 breeders. Catteries were either small or did not practise intensive reproduction, as 71% ($n = 1,076$) of them registered only 1–5 oestrus and 70% ($n = 1,062$), five or less litters over the 4 years. Eighty per cent of queens had <2 oestrus registered over this period. The two most represented breeds were Persian and Maine Coon (21.4% and 20.3% of oestrous periods, $n = 1,940$ and $n = 1,838$, respectively).

3.2 | Mating

The mean age at mating ($\pm SD$) was 2.7 ± 1.6 years (from 4 months to 11.5 years, $n = 7,699$) for queens and 2.9 ± 1.9 years (from 4 months to 18 years, $n = 7,696$) for tomcats. The majority (93.3%, $n = 8,455$) of tomcats belonged to the same owner than the mated female. Most matings (70.2%, $n = 5,434/7,738$) occurred during increasing day length periods (winter and spring). Seventy-five per cent ($n = 4,779/6,321$) of matings happened during the first 3 days of heats.

3.3 | Reproductive performances

Pregnancy rate was 85.1% ($n = 7,710$). Among pregnant queens, 8.2% ($n = 637$) failed to maintain pregnancy. Globally, 78.1% ($n = 7,075$) of the mated females gave birth to 28,065 kittens within 7,075 L (Table 1). Sex ratio of born kittens (male:female) was 1:1.1. Mean litter size was 4.0 ± 1.9 kittens. Most of the queens (58%, $n = 4,126$) delivered between three and four kittens and <10% ($n = 586$) delivered four kittens or more. Table 2 provides pregnancy and queening rates

TABLE 1 Reproductive performances (means and 95% confidence intervals (CI)). $n = 7,075$ L including 28,065 kittens from 5,303 queens (45 breeds)

	%	IC95% inf	IC95% sup
Pregnancy rate ^a	85.1	84.3	85.8
Abortion rate ^b	8.2	7.6	8.9
Queening rate ^c	78.1	77.2	78.9

Number of mated females: 9,063.

^anb of pregnant females/nb of mated females $\times 100$.

^bnb of queens who failed to maintain pregnancy/nb of pregnant queens $\times 100$.

^cnb queened females/nb of mated females $\times 100$.

together with prolificacy for the 34 breeds represented by more than 10 oestrus in the dataset.

3.4 | Neonatal and paediatric mortality

The overall pre-weaning mortality rate was 15.7% ($n = 4,408$), including 8.5% of stillborn kittens ($n = 2,380$). Sex ratio of stillborn kittens was 1.3. Among the 25,685 kittens alive at birth, 7.9% ($n = 2,028$) died before weaning (Table 3).

4 | DISCUSSION

To our best knowledge, the database analysed in the present work is the largest ever analysed for the feline species in reproduction. The process of data registration, online, by breeders for the management of their own cattery, is much more powerful than any retrospective questionnaire. It allows the collection of a large number of data, even if without any possible control of their veracity. The population included in the present study represent a large part of the French feline purebred population: according to the LOOF (Livre Officiel des Origines Félines – French Association recognized by the government to manage pedigree cats), 116,738 pedigrees were registered between 2011 and 2014. The 28,065 kittens of the present work thus represent almost a quarter (24%) of those pedigrees. As the data have been recorded in a large variety of breeding management conditions, spread over the country, they may be considered as representative of the normal general population of feline breeding population. In addition, breed distribution confirms the representativeness of our population: the 10 most represented breeds of this study were the same than registered by LOOF, and the proportions of recorded pedigrees were similar for each breed (apart from Persian and British Shorthair with a difference of 4%) over the same period. Nevertheless, it may also be speculated that the breeders that did contribute to the dataset through the breeding management software were probably among the most motivated and progressive breeders. This may have slightly skewed the results, with better results with breeding and kitten survival than the total French feline population.

Such a dataset allows to calculate key reproductive indexes for the different breeds, but offer limited opportunity to identify factors potentially impacting reproductive performances. Information such as the weight or the body condition score of the female at mating, the quantity and quality of food provided, or the place of mating (queen's or tomcat's usual room, neutral room) was not registered, because of the effective purpose of the software, that is internal cattery management and not a scientific approach of feline reproduction.

4.1 | Genitors and mating

The mean young age at mating observed in our study (2.7 years for females and 2.9 years for males) is similar to published studies ranging from 2.8 (Sparkes et al., 2006) to 3.3 years (Ström Holst & Frössling, 2009). As suggested by Sparkes et al. (2006) who reported a high proportion of primiparous females (39.6%), this may be associated with a high rate of female turnover. However, in our dataset, some queens and tomcats were observed mated as old as 11.6 and 18.1 years, respectively; in 9.4% of the matings, at least one partner was older than 6 years. The low number of queens per cattery and litters per queen registered over the 4 year study may indicate that reproduction is practised on a weak intensity, but parity and the following reproductive career of queens would be needed to conclude. Nevertheless, French cat breeding is often a familial and secondary activity, managed by highly passionate people.

An absence of anoestrus period but a peak of matings associated with increasing day length was in agreement with the cat reproductive cycle (Johnston et al., 2001), under the French natural temperate photoperiod (Faya et al., 2011; Robinson & Cox, 1970) and artificial light associated with indoor catteries.

A Swedish study (Ström Holst & Frössling, 2009) on 264 females revealed that in 58% of the matings, the tomcat belongs to the same cattery than the queen. In the present study, the proportion was far higher, reaching 93.3%. LOOF reports 70%–75% of “internal” matings. A decrease in pregnancy rate in case of “external” mating might have been anticipated, due to stress or contamination by an infectious agent, or conversely, one could expect an improvement, because of potentially lower inbreeding. Indeed, we observed similar pregnancy rates between internal and external mating (85% vs. 85.5%, respectively).

4.2 | Pregnancy

Queens were considered as pregnant in our dataset based on the breeder's opinion without any information on the time of diagnosis (mid or late gestation or even at queening) as well as the method used (veterinary ultrasound examination, abdominal palpation by breeder or observation of queening). The proportion of queens undergoing a veterinary diagnosis is probably very limited (Ström Holst & Frössling, 2009). So pregnancy and abortion rates have thus to be considered with caution, with our pregnancy rate being slightly higher (85%) than 73% in Swanson, Roth, and Wildt (1994) in which 52 domestic queens

TABLE 2 Reproductive performances and kitten mortality rates in the 34 most represented cat breeds (more than 10 oestrus in the database)

Breed	Number of oestrus [% of total oestrus]	Reproductive performances					Kitten mortality	
		Pregnancy rate (%)	Abortion rate (%)	Queening rate (%)	Mean litter size (nb of kittens born)	SD	Stillbirth rate (%)	Neonatal and paediatric mortality rate (%)
Persian	1,940 [21.4]	82.6	7.5	76.4	3.4	1.6	9.2	8.6
Maine Coon	1,838 [20.3]	86.6	9.1	78.7	4.5	2.2	8.1	6.0
Birman	1,077 [11.9]	88.1	7.5	81.5	3.7	1.6	8.1	6.6
British Shorthair	870 [9.6]	87.7	6.7	81.8	4.1	1.9	9.9	12.9
Chartreux	475 [5.2]	84.4	5.7	79.6	4.1	2.0	7.8	6.2
Norwegian	455 [5.0]	89.5	10.3	80.2	4.2	1.8	5.5	5.1
Bengal	444 [4.9]	81.3	11.4	72.1	4.1	1.9	7.6	10.0
Ragdoll	334 [3.7]	88.3	5.4	83.5	4.5	1.8	7.9	5.6
Exotic Shorthair	285 [3.1]	82.1	9.8	74.0	3.3	1.5	7.1	6.0
Sphynx	166 [1.8]	86.7	9.0	78.9	4.0	1.9	9.7	9.7
British Longhair	152 [1.7]	78.3	8.4	71.7	4.0	1.8	12.5	9.2
Siamese	128 [1.4]	85.2	13.8	73.4	4.2	1.9	6.6	8.2
Oriental	117 [1.3]	58.1	22.1	45.3	4.7	2.4	10.9	13.6
Scottish Fold	101 [1.1]	85.1	4.7	81.2	3.7	1.7	9.0	11.4
Siberian	89 [1.0]	91.0	3.7	87.6	4.5	1.9	4.6	3.9
Scottish Straight	76 [0.8]	93.4	0.0	93.4	3.9	1.9	3.9	9.7
Selkirk Rex	67 [0.7]	89.6	5.0	85.1	4.3	1.8	15.4	11.5
Abyssin	65 [0.7]	87.7	10.5	78.5	3.6	2.7	10.4	9.1
Turkish Angora	51 [0.6]	68.6	8.6	62.7	4.4	1.8	7.7	14.5
Somali	40 [0.4]	92.5	2.7	90.0	3.4	1.4	17.2	10.9
Highland Fold	39 [0.4]	66.7	11.5	59.0	4.1	1.9	17.0	20.5
Munchkin	29 [0.3]	86.2	24.0	65.5	4.1	2.1	16.7	0.0
Russian Blue	26 [0.3]	92.3	12.5	80.8	3.8	1.6	3.8	0.0
Devon Rex	26 [0.3]	84.6	0.0	84.6	4.1	1.4	8.8	18.1
American Curl	15 [0.2]	73.3	9.1	66.7	5.0	2.1	12.0	6.8
Burmese	15 [0.2]	100.0	6.7	93.3	4.6	2.6	24.6	2.0
Highland Straight	14 [0.2]	71.4	0.0	71.4	3.4	1.2	2.9	18.2
Burmilla	13 [0.1]	84.6	27.3	61.5	3.9	1.4	0.0	45.2
Savannah	13 [0.1]	76.9	30.0	53.8	5.0	1.7	17.1	0.0
Singapura	13 [0.1]	84.6	27.3	61.5	3.0	1.2	8.3	22.7
Nebelung	12 [0.1]	91.7	9.1	83.3	5.0	2.9	14.0	4.7
Tonkinois	11 [0.1]	72.7	0.0	72.7	3.3	1.6	11.5	8.7
Peterbalt	10 [0.1]	60.0	16.7	50.0	5.8	1.3	6.9	3.7
Thai	10 [0.1]	90.0	0.0	90.0	3.7	1.3	3.0	0.0

were ovariectomized and examined for the presence and viability of embryos between 2 and 20 days of pregnancy.

4.3 | Queening

The queening rate we observed (78.1%) was similar to that of a Canadian study on 189 queens (from around 10 breeds) reporting 70%, ranging from 40% to 80% according to the breed (Povey, 1978).

Abortion and pregnancy rates were not documented. The queening rate of Persians markedly differs between our (76.4%) and Povey's study (40%), either revealing a large individual variability or a positive evolution of the breeding management of Persian.

Prolificacy was consistent with other studies, with a mean litter size ranging from three to five kittens (Jemmett & Evans, 1977; Johnstone, 1987; Povey, 1978; Prescott, 1973; Root et al., 1995; Sparkes et al., 2006; Ström Holst & Frössling, 2009). While litter size did not exceed

TABLE 3 Kitten mortality rates (means and 95% confidence intervals (CI)) $n = 7,075$ L including 28,065 kittens from 5,303 queens of 45 cat breeds

	%	IC95% inf	IC95% sup
Stillbirth ^a	8.5	8.2	8.8
Neonatal and paediatric mortality ^b	7.9	7.6	8.2
Global kitten mortality ^c	15.7	15.3	16.1

Number of kittens born: 28,065.

^anb stillborn kittens/total nb kittens born $\times 100$.

^bnb dead kittens (born alive)/nb kittens born alive $\times 100$.

^cnb dead kittens/total nb kittens born $\times 100$.

13 kittens in previous studies, 0.01% of our litters included over 10 kittens and 5 queens gave birth between 15 and 20 kittens.

Stillbirth rate (8.5%) was consistent with other studies: from 4.7% to 9.7% (Jemmett & Evans, 1977; Povey, 1978; Root et al., 1995; Sparkes et al., 2006; Ström Holst & Frössling, 2009). Nevertheless, the experimental designs of these studies (including this one) may lead to an underestimation of kitten mortality rates, especially for stillbirth. Indeed, registration of kittens born dead is of no interest for breeders, neither in national kennel club files (in some countries, breeders have to pay for the registration of each newborn), nor for their own internal cattery management (those kittens will obviously not be sold). Stillbirth rate increases with litter size (Sparkes et al., 2006). The higher proportion of stillbirths observed in this study might be explained by the number of large cats (Main Coon, Norwegian Forest cats) included in the database, with larger litters (Fournier). No information was provided in our database on the duration of parturition and dystocia, both of which could impact stillbirth rate (Sparkes et al., 2006; Ström Holst & Frössling, 2009).

4.4 | Neonatal and paediatric mortality

The global kitten mortality rate in our dataset (15.7%) was lower than the rate reported in the literature, ranging from 16.3% to 29.1% (Jemmett & Evans, 1977; Povey, 1978; Root et al., 1995; Sparkes et al., 2006; Ström Holst & Frössling, 2009). Factors responsible for this high mortality rate, especially stillbirth, remain to be identified.

The neonatal and paediatric mortality rates (7.2%) are the lowest range reported in the literature (Jemmett & Evans, 1977; Povey, 1978; Root et al., 1995; Sparkes et al., 2006; Ström Holst & Frössling, 2009). While infectious status of catteries and breeding management (indoor or outdoor) were unknown, low intensive reproduction in France and

internal mating for the vast majority of queens reduce the risk of infectious diseases, maybe contributing to these low neonatal and paediatric mortality rates.

5 | CONCLUSION

The database analysed in this study is the largest feline reproduction database ever surveyed. Due to the large number of contributing breeders, the figures provided are probably a good start to assess feline reproductive performances. As inter racial variations may exist in the domestic cats, performance indexes have to be considered by breed. Further analysis will attempt to identify factors of significant influence on reproductive performances and early mortality. Management practices might then be adapted to improve feline breeding productivity.

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