Original Research Article

Staying alive: a questionnaire study on pregnancy outcome and pre-weaning puppy health in Swedish dogs

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ABSTRACT

Pre-weaning mortality and stillbirth rates in dogs are relatively high. Hypoxia during prolonged parturition is the main cause of neonatal death, followed by septic infection, predominantly caused by opportunistic bacteria. Several viruses also contribute to neonate mortality. Good breeding management and vaccination are important in improving newborn survival. The purpose of the study was to establish pregnancy outcome rates in a large cohort of Swedish breeding dogs, information that had not been previously documented. Further, we aimed to identify risk factors associated with abortion, congenital anomalies, and puppy mortality. Last, we wanted to investigate potential risk for transmission of *Brucella canis* or other zoonoses related to parturition. To achieve this, a web-based questionnaire was distributed to dog breeders in the Swedish Kennel Club.

The results comprise data from 1879 breeders on 10,124 puppies from 1791 litters. Abortion rate was 1.5 %, stillbirth rate 4.8 %, and pre-weaning mortality 3.7 %. Disease in the pregnant bitch was associated with spontaneous abortion or resorption. Stillbirth was associated with the bitch having her first litter, dystocia, increased litter size and presence of congenital anomalies in the litter. Pre-weaning mortality was associated with dystocia and increased litter size. Having seven or more dogs less than one year old together with the bitch during the last weeks of pregnancy was a risk factor for both stillbirth and pre-weaning mortality, an association not previously shown. Thirty per cent of respondents reported having used mouth-to-nose resuscitation on newborn puppies, a potential transmit route for *Brucella canis* and other zoonotic agents.

1. Introduction

Successful breeding programs are essential to ensure healthy, well-adapted dogs. Abortions, stillbirths and deaths of young puppies are not only a threat to successful breeding work, but also to animal health and welfare. Furthermore, it may lead to significant emotional stress for the breeder, as well as financial losses.

Previous studies have found high mortality rates in newborn dogs, ranging from 6 % to 24 % [1–8]. The risk is highest during parturition, with stillbirth rates from 4.3 % to 15.4 % [2,3,6,9–11], and during the first days of life [10,12–15]. Hypoxia is the main cause of mortality during parturition, particularly in cases of prolonged expulsion and dystocia, situations that are associated to the breed, body conformation,

age and parity of the bitch, numerically small or large litters and other factors [13,16]. Infections are the main cause of death during the first weeks of life, with bacterial infections causing up to 61 % of newborn mortality [2,3,13,17–19]. The most common pathogens identified associated to neonatal septicaemia and mortality are *Escherichia coli*, *Staphylococcus* species and *Streptococcus* species, originating from the bitch or from the environment [2,13,19]. Newborn puppies are sensitive to hypothermia, hypoglycaemia and dehydration, conditions that may arise as a consequence of hypoxia, low birth weights, delayed food intake postpartum, faulty mothering ability or other causes, predisposing to infections [13,19–22]. Inadequate management of the breeding facility, including high population density, insufficient nutritional supply, and poor hygienic standards, may facilitate pathogen transmission

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within a kennel and further increase the risk of infections in newborns [23,24].

Brucella canis is reported as an emerging zoonotic pathogen in several European countries [28], so far only described in a few imported cases in Sweden [26,27]. Typical clinical signs are abortion, stillbirths, or newborn puppy mortality [25], and handling infected dogs during parturition has been associated with human infections [29–31].

Canine herpesvirus-1 (CHV-1) is widespread in dog populations all over the world and can cause severe systemic disease with high mortality in puppies up to three weeks of age [19,32–34]. A vaccine for pre-partum usage in the bitch to decrease the risk of CHV-1 in neonates is available. Other viruses that are associated with puppy mortality include canine parvovirus types 1 and 2 (CPV), canine distemper virus (CDV), and canine adenovirus type 1 (CAV-1) [19]. These are included in vaccinations with a high coverage in Sweden and clinical disease caused by these viruses is rare [35]. Endoparasites can also contribute to neonatal disease and death in newborn puppies, both due to intestinal infestation and due to migrating larvae [19,36]. In addition to infectious causes, several non-infectious factors are associated with puppy mortality, including congenital anomalies, traumatic injuries, toxic milk syndrome, and non-infectious diarrhoea [13,37].

To be able to effectively improve puppy health and reduce neonatal mortality, knowledge about the breeding conditions and the health status of the general dog population, as well as of mortality risk factors, is necessary. Overall studies on the Swedish dog population are lacking, and detailed data on these reproductive parameters cannot be achieved through breeding registers. To fill knowledge gaps, a population-based questionnaire study was conducted aiming at characterizing reproductive outcomes, identifying risk factors for abortion, congenital anomalies, and neonatal mortality among Swedish breeding dogs, and investigating potential risks for transmission of *B. canis* or other zoonotic agents.

2. Material and methods

2.1. Study design and questionnaire

The study was designed as a web-based questionnaire distributed through an online provider, Netigate (Netigate AB, Stockholm, Sweden), and the target population was Swedish dog breeders. The sampling frame consisted of dog breeders registered with the Swedish Kennel Club (SKK) whose e-mail address were available, roughly 76 % of all registered breeders. The questionnaire items were formulated in Swedish by the research team. Conditional branching logic was applied to tailor question flow according to responses, ensuring relevance and reducing redundancy. After technical testing, a pilot study with six breeders was performed to ensure that the questions were clear and not open to multiple interpretations. The items were modified based on their perception of the questions before launching the final version of the questionnaire.

The breeders were invited by email, containing a web link to the questionnaire. Only one answer per link (i.e. breeder) was accepted. The responders were anonymized to the research group. Data collection started on the 24th of June 2024, and finished on the 25th of July 2024. Two reminders were sent after 6 and 19 days, respectively. The survey length depended on the respondent's answers, with 55 questions as the maximum. The items focused on one bitch mated between the 1st of January 2020, and the 31st of December 2023. If the breeder had several bitches mated during this period, they were asked to contribute information for the one most recently mated.

All questions were close-ended and mandatory. The initial questions focused on the respondent's experience of dog breeding, the characteristics of the bitch and the male, as well as breeding management and preventive measures. The respondents were asked whether they had ever used their own mouth to resuscitate a newborn puppy, a potential transmission route for zoonotic agents. Further inquiries focused on

details about the mating or artificial insemination, fertilization rate, estimation of resorptions and abortion rate, followed by aspects related to parturition. Questions concerning stillbirth rate and pre-weaning mortality were included, as were questions regarding the health of the bitch during pregnancy and of both bitch and puppies during post-partum period. The remaining questions covered additional reasons for puppy mortality, including congenital anomalies and trauma. One answer per question was allowed, except for questions about illnesses in the bitch or puppies, medication of bitch, type of congenital deformity, and type of feed, where several answers were possible. The full questionnaire, translated into English, is available as a Supplementary file (Appendix A).

Responses were excluded if the respondent replied 'no' to having mated a bitch in 2020–2023 (n = 100), if the bitch was mated before 2020 (n = 63), or if the response was incomplete (n = 278). Results for bitches that were not pregnant after mating (n = 88) are included in the descriptive data but excluded from the regression analysis.

2.2. Data analysis

The statistical analysis was performed in R version 4.2.1 [39]. Categorical variables are presented as numbers and percentages per category, and continuous variables as medians (ranges) or means (standard deviations). Histograms were used to evaluate the normality of continuous variables. The Kruskal–Wallis test was used to compare continuous variables between groups. Based on the association between breed size and dystocia [13,16], the breeds were categorized by size, according to the classification of the Swedish Kennel Club [38].

The associations between predictors and outcomes were evaluated by logistic regression models, using the "stats" package. The analyses were exploratory, without pre-specification of a main predictor variable and potential confounders in each regression model. Four separate models were built with the outcomes: abortion/resorption, stillbirth, congenital anomalies, and death of puppies during the first eight weeks of life. Variables examined for association with outcomes of pregnancy and puppy health are presented in Table 1. In addition, two separate, univariable logistic regression models were built exploring the association between becoming pregnant and the vaccination status of the bitch (Appendix B).

Univariable analyses were performed, and variables with p-values <0.2 were included in the multivariable model-building process together with biologically plausible interactions. Manual stepwise backwards elimination was used for variable selection, and p-values <0.05 were considered statistically significant. The significance of multilevel categorical predictors was evaluated via the Wald test from the "lmtest" package [40]. Model selection was guided using the likelihood ratio test from the "lmtest" package and the Akaike information criterion [40]. The variance inflation factor was used to assess multicollinearity in the final models, using the "car" package [41]. Coefficients, standard errors, odds ratios (ORs) with 95 % confidence intervals (CI) and p-values were presented for the final models. The full list of variables tested in each model can be found as a Supplementary file (Appendix C).

3. Results

Out of the 21,717 breeders who were invited to participate, 2320 (11 %) responded to the survey. Of these, 441 did not meet the inclusion criteria, leaving 1879 questionnaires for analysis.

3.1. Characteristics of breeders and dogs, and breeding management

Key parameters of breeder demographics and husbandry practices are summarized in this subsection. Less than 1 % (n = 11/1879) of breeders had their first litter before 1970, 10 % (n = 197) between 1970 and 1989, 59 % (n = 1100) between 1990 and 2019, and 30 % (n = 571)

Table 1

Variables related to bitch, puppy and environment examined for association with outcomes of pregnancy and puppy health during the first eight weeks of age in a web-based questionnaire study on outcome of pregnancy and pre-weaning puppy health in Swedish dogs.

VARIABLES	DEFINITIONS	CATEGORIES
Vaccination parvovirus and distemper virus	Within 3 years before mating/insemination	Yes/no/do not know
Vaccination kennel cough	Within 1 year before mating/insemination	Yes/no/do not know
Age at mating/insemination		In years
Country of origin bitch		Sweden or Norway/Europe (other than Sweden or Norway)/outside Europe
Country of origin male		Sweden or Norway/Europe (other than Sweden or Norway)/outside Europe
Disease during pregnancy		Yes/no/do not know
Prescribed medication pregnancy		Yes/no
Type of parturition		Caesarean section (all or part of litter)/vaginal with manual or medical help/vaginal without help
Duration of parturition		<6h/6-<11h/≥11h/do not know/Caesarean section, birth was not initiated
Disease bitch postpartum		Yes/no/do not know
Vaccination herpes virus	Two injections before/during pregnancy	Yes, two injections/no/do not know
Deworming during pregnancy		Yes/no/do not know
Feeding raw food during pregnancy		Yes/no
Feeding raw food during nursing period		Yes/no
Deworming postpartum		Yes, only the bitch/yes, bitch and puppies/yes, only puppies/no/do not know
Breed		Separate categories for breeds ≥25 individuals, the rest are combined as "other breed"
Breed size category	According to the Swedish Kennel Club	X-small/small/medium/large/giant
Litter size	Responses as "15 or more pups" were calculated as 15	Numerical 1–14/15 or more/do not know
Congential anomalies in litter		Yes/no/do not know/was not assessed
Disease within 8 weeks postpartum		Yes/no/do not know
Dogs older than 1 year housed with the bitch in the last two weeks of pregnancy		0/1–3/4-6/≥7/not applicable
Dogs younger or equal to 1 year housed with the bitch in the last two weeks of pregnancy		0/1–3/4-6/≥7/not applicable

between 2020 and 2024. The number of litters raised per breeder is presented in Fig. 1. The question assessing the risk of zoonotic transmission to the owner revealed that 31 % (n = 590) of the breeders had at one or more occasions resuscitated a puppy by placing their mouth directly on the puppy's nose/mouth.

Two-hundred and forty-five breeds were represented in the study; the most common were Golden Retriever (n = 68), Labrador Retriever (n = 67), Cocker Spaniel (n = 47), and Shetland Sheepdog (n = 42). The distribution of bitches within each breed size category is presented in Table 2.

Most bitches, 56 % (n = 1061/1879), had not had any litter previously, 23 % (n = 439) had previously had one litter, and 20 % (n = 376)

had previously had two or more litters. The majority of dogs, 86 % (n = 1609/1879) of the bitches and 66 % (n = 1245/1879) of the males, originated from Sweden as seen in Table 3, showing countries of origin.

Vaccination against CPV, CDV, and CAV-1 had been administered to 86 % (n = 1625/1879) of the bitches within three years before mating/artificial insemination, and 69 % (n = 1297) were vaccinated against kennel cough within one year before mating/insemination. Two doses of the CHV-1 vaccine had been administered to 16 % (n = 288) of the pregnant bitches.

In total, 44 % (n = 790) of the bitches were dewormed during pregnancy. From another 1.2 % (n = 21) of the pregnant bitches, faecal samples were analyzed for endoparasites, but deworming treatment was not administered. During the first eight weeks postpartum, 86 % (n = 1474/1718) of breeders dewormed both the bitch and the puppies, 13 % (n = 231) dewormed only the puppies, and 1.0 % (n = 18) dewormed only the bitch. As seen in Table 4, 89 % (n = 1592/1791) of breeders housed adult dogs and 29 % (527/1791) of the breeders housed dogs one year or younger together with pregnant bitch during the last two weeks of pregnancy.

Commercial dry food was fed to 94 % (n = 1687/1791) of bitches during pregnancy and to 94 % (n = 1613/1711) during the nursing period. Commercial canned food was fed to 20 % (n = 365) of bitches during pregnancy and to 23 % (n = 400) during the nursing period. Biological Appropriate Raw Food (BARF)/fresh food/raw food was fed to 38 % (n = 686) of bitches during pregnancy and to 40 % (n = 684) during the nursing period. Homemade heated food was given to 8.4 % (n = 151) of bitches during pregnancy and to 8.9 % (n = 153) during the nursing period. Other types of food, including leftovers, were given to 32 % (n = 582) of bitches during pregnancy and to 34 % (n = 578) during the nursing period.

3.2. Mating and pregnancy outcome

Details about mating and the result of pregnancy are summarized.

The mean age of bitches at the time of mating or artificial insemination was 4.2 ± 1.5 years. Progesterone was analyzed before mating or artificial insemination in 49 % (n = 916/1879) of the bitches. Artificial insemination was performed in 4.7 % (n = 88) of the bitches, using fresh (n = 51), frozen (n = 32), or chilled (n = 4) semen. Out of the 1879 mated or artificial inseminated bitches, 1791 became pregnant, resulting in a pregnancy rate of 95 %. There was no significant difference in vaccination status between bitches that became pregnant and those that did not (P = 0.860, OR 1.07 (CI 0.54–2.44) for CPV, CDV, and CAV-1 vaccination; P = 0.930, OR 1.02 (CI 0.64–1.69) for kennel cough).

In 2.8 % (n = 51/1791) of the bitches, foetal resorption of all foetuses (n = 10 bitches) or at least one foetus (n = 41 bitches) was confirmed by a veterinarian. Twenty-six bitches aborted at least one foetus, resulting in an abortion rate of 1.5 %. In 77 % (n = 20) of these cases, the abortion was partial, with at least one live puppy born at full-term. One breeder reported congenital anomalies in the aborted foetuses, with a deformed skull and another, non-defined deformity. The other breeders reported no anomalies, or that the aborted foetuses were not investigated for defects.

As presented in Table 5, 2.1 % (n = 37/1791) of the bitches were reported as unhealthy during pregnancy, with signs of gastrointestinal disease (n = 9), uterine disease (n = 4), and trauma (n = 4) listed as the most common conditions. Veterinary care was sought for 76 % (n = 28) of these bitches, with antibiotics being prescribed to 36 % (n = 10), analgesics to 21 % (n = 6), and a medication unknown to the breeder to 7.1 % (n = 2).

3.3. Parturition

This subsection includes the type and duration of the parturitions. On average, parturition started on day 61 from the last mating or insemination, with 9.2 % (n = 164/1791) starting on day 58 or earlier, 86 % (n
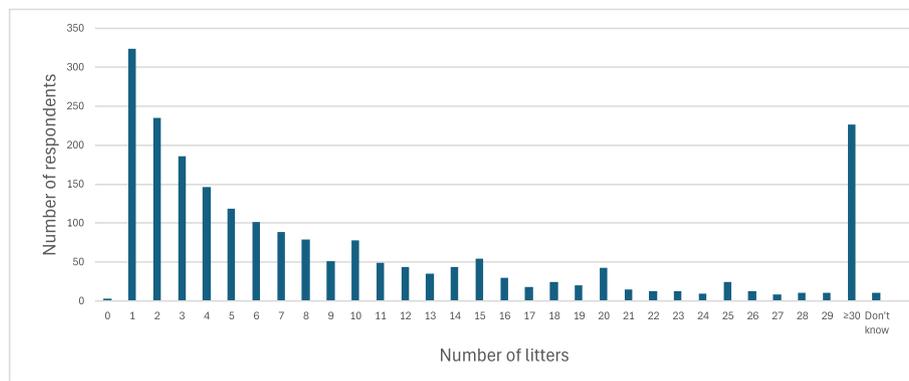
Fig. 1. Distribution of number of litters each breeder had raised, as reported in a web-based questionnaire study on outcome of pregnancy and pre-weaning pup health in Swedish dogs.

Table 2
Number of bitches within each breed size category, with distribution of litter size and the stillbirth rate, as reported by owners in a web-based questionnaire study on outcome of pregnancy and pre-weaning puppy health in Swedish dogs.

BREED SIZE[a]	BITCHES n (%)		LITTER SIZE			LITTERS WITH STILLBIRTH n (%)	
			Median (range)		Mean $\pm$ SD		
X-small	232	(13)	4	(1–8)	3.9 $\pm$ 1.45	34	(15)
Small	514	(29)	5	(1–14)	5.2 $\pm$ 2.02	90	(18)
Medium	492	(28)	6	(1–14)	5.9 $\pm$ 2.19	73	(15)
Large	500	(28)	7	(1–15)	7.3 $\pm$ 2.47	128	(26)
Giant	53	(3.0)	8	(1–13)	7.5 $\pm$ 2.69	14	(26)

[a] Classification from the Swedish Kennel Club.

$= 1543$) on day 59–68, and 0.3 % (n $= 6$) on day 69 or later. Parturition lasted <6 h for 57 % (n $= 1016$) of the bitches, 6 to <11 h for 26 % (n $= 462$), and ≥ 11 h for 8.0 % (n $= 143$). Most bitches, 74 % (n $= 1334$), whelped without assistance, 10 % (n $= 184$) required some mechanical and/or medical assistance, and caesarean section was required for 11 % (n $= 202$) of bitches, for the entire litter (n $= 125$) or for parts of the litter (n $= 77$).

3.4. The postpartum period

Health status of bitches after birth is visualized in Table 5. During the first eight weeks postpartum, 7.9 % (n $= 136/1719$) of the bitches were reported as being unhealthy, and 54 % of these had conditions related to pregnancy and nursing, such as mastitis (n $= 37$), uterine disease (n $= 29$), and eclampsia (n $= 8$). Gastrointestinal disease was reported in 22 % (n $= 30$) of the unhealthy bitches, as seen in Table 6. Veterinary care was sought for 86 % (n $= 117$) of the unhealthy bitches, with antibiotics being prescribed to 68 % (n $= 80$), analgesia to 41 % (n $= 48$), medication against eclampsia to 4.3 % (n $= 5$), anti-pruritic medication to 1.7 % (n $= 2$), and a medication unknown to the breeder to 15 % (n $= 17$).

3.5. Puppy morbidity and mortality

The study includes 10,124 puppies, of whom 9640 were liveborn, from 1791 litters. As seen in Table 2, the mean litter size was 5.9 $\pm$ 2.4 puppies and varied significantly with the size of the bitch (P < 0.001).

Stillbirth was reported in 19 % (n $= 339$) of the litters, with 4.8 % (n $= 484$) of all puppies being stillborn, as presented in Table 2. The mean number of stillborn puppies per litter was 0.28 $\pm$ 0.70, and the mean number of stillborn puppies in litters with stillbirth was 1.43 $\pm$ 0.94. In seven litters, all puppies (n $= 1$–5) were stillborn. As shown in Fig. 2, the pre-weaning mortality was 3.7 % (n $= 361/9640$). During the first eight weeks after birth, 3.6 % (n $= 352$) of the liveborn puppies had a disease,

Table 3
Country of origin for 1879 female and 1879 male breeding dogs, as reported by owners in a web-based questionnaire study on outcome of pregnancy and pre-weaning puppy health in Swedish dogs.

COUNTRY OF ORIGIN	FEMALES	MALES
Sweden	1609	1245
Norway	46	97
Finland	33	82
Denmark	20	68
Origin Nordic countries	**1708**	**1492**
Austria	0	3
Belarus	1	4
Belgium	2	3
Bulgaria	0	1
Czech Republic	14	23
Cyprus	1	1
Estonia	5	4
France	4	14
Germany	16	45
Hungary	8	11
Iceland	2	3
Ireland	2	3
Italy	10	20
Poland	20	33
Portugal	1	3
Romania	2	2
Slovakia	0	9
Switzerland	1	0
Spain	8	13
The Netherlands	10	10
Ukraine	1	6
United Kingdom	9	42
Other European country	8	23
Origin Europe outside the Nordics	**125**	**276**
Australia	0	8
Canada	3	4
New Zeeland	0	3
Russia	26	50
USA	11	31
Other country outside of Europe	6	15
Origin countries outside of Europe	**46**	**111**

leading to death or euthanasia in 53 % of such cases (n $= 186$). The most common clinical sign was weakness/fading puppy syndrome, reported in 26 % (n $= 90$), followed by gastrointestinal disease in 10 % (n $= 35$), and respiratory disease in 6.3 % (n $= 22$). In the liveborn puppies, 0.61 % (n $= 59$) had a traumatic injury, and 29 % (n $= 17$) of these died or were euthanized due to the trauma. Congenital anomalies were reported in 1.5 % (n $= 152$) of all liveborn puppies, leading to death or euthanasia in 82 % (n $= 124$). The types of anomalies are presented in Table 6. In addition, 0.4 % (n $= 34$) of all liveborn puppies were

Table 4

Number of adult and young dogs kept together with the pregnant bitch during the last two weeks of pregnancy, as reported by breeders in a web-based questionnaire study on outcome of pregnancy and pre-weaning puppy health in Swedish dogs.

NUMBER OF DOGS WITH PREGNANT BITCH	BITCHES HOUSED WITH ADULT[a] DOGS n (%)		BITCHES HOUSED WITH YOUNG[b] DOGS n (%)	
0 dogs	199	(11)	1264	(71)
1-3 dogs	1018	(57)	461	(26)
4-6 dogs	430	(24)	42	(2.3)
≥7 dogs	144	(8.0)	24	(1.3)

[a] > 1 year old.
[b] ≤ 1 year old.

Table 5

Diseases observed in unhealthy bitches during pregnancy or during postpartum period, reported by owners in a web-based questionnaire study on outcome of pregnancy and pre-weaning puppy health in Swedish dogs.

TYPE OF DISEASE	BITCHES WITH DISEASE DURING PREGNANCY[a] n	BITCHES WITH DISEASE POSTPARTUM[a] n
Gastrointestinal disease	9	30
Uterine disease	4	29
Respiratory disease	3	4
Mastitis	0	37
Eclampsia	0	8
Traumatic injury	4	2
Pruritic skin disease/otitis	2	5
Other unspecified disease	15	33

[a] More than one type of disease could be reported for each bitch.

Table 6

Type of congenital anomalies reported by breeders in a web-based questionnaire study on outcome of pregnancy and pre-weaning puppy health in Swedish dogs.

TYPE OF CONGENITAL ANOMALY	BREEDERS REPORTING CONGENITAL ANOMALY n (%)
Cleft palate	39 (26)
Open abdominal wall	17 (11)
Tail defect	18 (12)
Skull defect	13 (8.6)
Defect of extremities	9 (6.0)
Defect of distal phalanges	11 (7.2)
Cleft lip	8 (5.3)
Aplasia cutis congenita	4 (2.7)
Anal atresia	4 (2.7)
Anasarca	3 (2.0)
Spina bifida	3 (2.0)
Congenital cardiac anomaly	1 (0.7)
Non specified anomaly	36 (24)

euthanized for reasons other than deformities, disease, or injury. Survival rate at 8 weeks was 92 % of all puppies (n = 10,124) and 96 % of all liveborn puppies (n = 9640).

As seen in Table 7, bitches with disease during pregnancy was associated with increased odds of abortion or resorption (*P* < 0.001, OR 6.45 (CI 2.51–14.70)), and with higher odds of giving birth to puppies with congenital anomalies (*P* < 0.001, OR 4.81 (CI 1.98–10.60)), compared to bitches that were healthy during pregnancy.

Lower odds for stillbirth was observed in bitches with one (*P* < 0.001, OR 0.46 (CI 0.32–0.64)) or two (*P* < 0.02, OR 0.60 (CI 0.39–0.91)) previous litters compared to bitches that had their first

litter, as seen in Table 7. Further, higher odds of stillbirth were seen in bitches when assistance during parturition (*P* < 0.001, OR 3.41 (CI 2.34–4.95)) or caesarean section (*P* < 0.001, OR 4.74 (CI 3.08–7.30)) was required, compared to unassisted whelpings. Higher odds of stillbirth were seen if the duration of parturition was 6 to <11 h (*P* < 0.001, OR 1.71 (CI 1.27–2.32)) or ≥11 h (*P* < 0.001, OR 2.79 (CI 1.82–4.25)), compared to duration of <6 h. Higher odds were also observed if seven or more dogs under the age of one year were housed with the pregnant bitch (*P* < 0.006, OR 3.71 (CI1.40–9.26)), compared to none. Higher odds of stillbirth were also seen in litters with congential anomalies in one or more puppies (*P* < 0.001, OR 2.82 (CI 1.84–4.29)), compared to litters with no defected puppies. The odds of stillbirth increased with the litter size (*P* < 0.001, OR 1.18 (CI 1.11–1.24) per puppy).

There was no significant association between puppy mortality and vaccination status of the bitch, based on univariable regression results. Higher odds of puppy mortality during the first eight weeks were observed when assistance during parturition (*P* = 0.006, OR 2.04 (CI 1.20–3.34)) was required, compared to bitches that whelped without assistance, as seen in Table 7. Furthermore, higher odds of puppy mortality were seen in pregnant bitches housed with seven or more dogs less than one year old (*P* = 0.002, OR 4.62 (CI 1.61–11.7)). The odds of puppy mortality increased with the litter size (*P* < 0.001, OR 1.15 (CI 1.07–1.23) per puppy).

4. Discussion

This study is the first large-scale epidemiological analysis on breeding management, parity, housing, and perinatal death in Swedish breeding dogs, demonstrating details on population density as a risk factor for mortality that has not been shown before. Moreover, risk for zoonotic transmission when handling weak or dead newborn puppies have been identified. The study includes data on 10,124 puppies, during the period of the 1st of January 2020 to the 31st of December 2023. During the same period, 217,361 puppies were registered in the Swedish Kennel Club (personal communication, SKK). Thus, the study population covers 4.7 % of the frame population.

The stillbirth rate in the present study agrees with what has been previously reported in Sweden and Norway [5,11], however, it is lower than reported in studies on certain risk breeds, and/or from certain regions [3,6,8,14]. The increased odds of stillbirth in bitches with dystocia compared to bitches whelping unassisted aligns with the fact that stillbirth often is caused by hypoxia during the parturition [13], and this finding highlight the importance of early recognition of dystocia and prompt management to reduce puppy losses during birth. To effectively reduce dystocia, several measures are needed, including careful selection of breeding bitches regarding body conformation, body size and genetics. Knowledge about the present rate of dystocia is important to follow up results of implemented measures. Our results, that 10 % of bitches required assistance and 11 % required delivery by caesarean section, can be compared to 6.25 %–32 % in other studies [7–9], however the variation between studies is large and can partly be explained by the varying incidence of dystocia between breeds [6–8], indicating that breed specific studies on dystocia might be more important to reduce mortality. Variation between studies may also be influenced by differences in the definition of dystocia, and by differences in legislation and practice regarding elective caesarean sections [9,42]. In Sweden, elective caesarean section in dogs is not allowed by legislation; hence, all caesarean sections are considered emergency cases. Result of an Italian study showed a significantly higher risk of stillbirth in litters delivered by emergency caesarean section compared to elective caesarean section [42].

The parity of the bitch was also associated with stillbirth, with decreased odds of stillbirth in bitches with one or two previous pregnancies, compared to nulliparous bitches, an association that has also been observed in a Norwegian study [11].

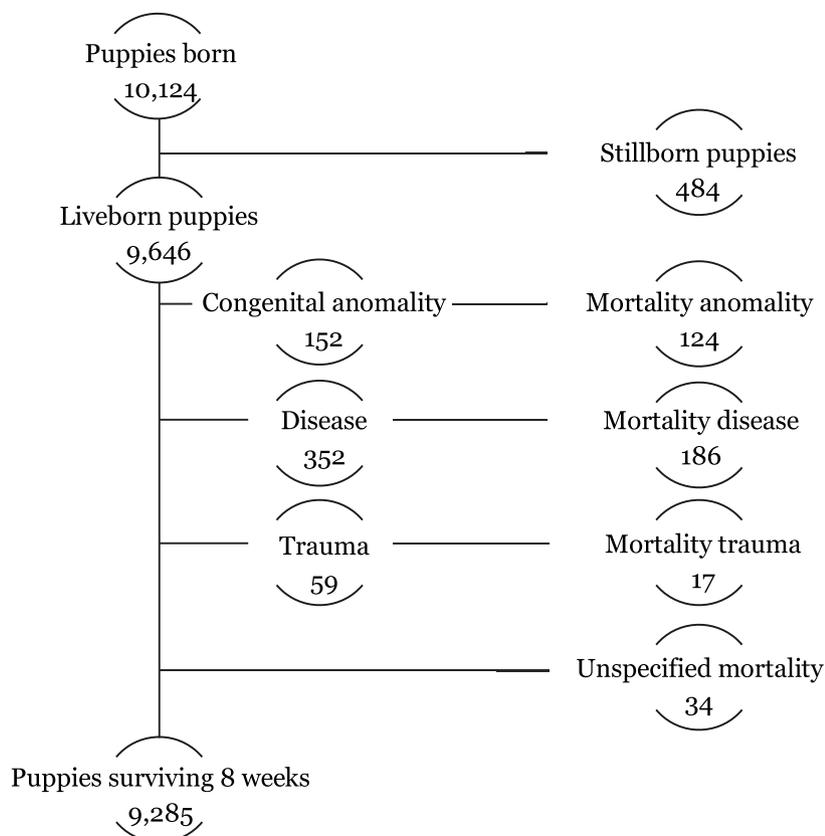It would be beneficial to further explore the associations of stillbirths

Fig. 2. Stillbirths, morbidity and mortality during the pre-weaning period for 10,124 pups, based on data reported by breeders in a web-based questionnaire study on outcome of pregnancy and puppy health in Swedish dogs.

with parity and litter size to better clarify definitions for dystocia in special situations, such as large litter size or nulliparous bitch. Such investigation could render recommendations, for example reduce the interpup interval that is considered as normal parturition, to make breeders and veterinarians more cautious for signs of dystocia and facilitate rapid interventions. Stillbirth associated with increased litter size has also been observed in other studies [1,6,9,11,37,43]. We found that the litter size was higher in large and giant breeds, with a mean litter size of 7.3 and 7.5 pups, respectively. This is similar to the mean litter size of 7.6 in a Norwegian study of four large breeds, with a stillbirth rate of 10.9 % [10]. In the present study, stillbirth in large breeds seems to be correlated with the increased litter size, rather than the size of the breed. Descriptions of breed-specific exemptions have been reported, for example studies on the Bernese Mountain dog and Dogue de Bordeaux, where over 50 % of bitches had one or more stillborn neonate (s), despite the mean litter size being only 6.0 and 6.1, respectively [6, 11], indicating other causes for stillbirth than size of breed.

The association between stillbirth and the presence of congenital anomalies in the litter has previously been shown in cats [44]. In our study, it was not clear whether the defected neonate(s) were stillborn or whether there were littermates without visible anomalies. Considering the possibility of lethal anomalies, this would at least partly explain this association.

Our finding that housing seven or more young dogs together with the pregnant bitch increased the odds for both stillbirth and postpartum mortality has not previously been described. One experimental study describes a high perinatal mortality (31.3 %) in a kennel, when 39 bitches gave birth during the same period [45], which can also indicate the impact of high population of young dogs on mortality. There are several possible explanations for this, including kennel density, bacterial load, and maternal factors. Keeping many dogs together may have a significant impact on both the load and the transmission rate of

pathogens, especially pronounced in young individuals, since they are at higher risk of infections [23,24]. For newborn puppies, the bitch and the environment are the main sources of bacteria, and bacterial infections are the second most common cause of neonate mortality [13,19]. Apart from the risk of transferring pathogens, high-density groups might also contribute to stress both during pregnancy and nursing period. Maternal stress is associated with foetal loss during pregnancy, as well as with reduced milk production, and stress may also lead to behaviors such as lack of care for puppies [19]. Failure to ingest colostrum shortly after birth will further predispose the puppies to infections due to a lack of protective antibody transfer [19]. The health of the bitch, the mothering ability, and the hygienic standards of the kennel are hence important factors in reducing the risk of neonatal infections.

Our finding that postpartum mortality was associated with increased litter size has also been reported in a Norwegian study, where perinatal mortality was more prevalent in litters with 12 or more puppies [11]. The competition for milk and maternal care among the puppies will be more intense in larger litters, leaving weak newborns behind.

Postpartum mortality was also significantly associated with dystocia. As one main factor contributing to foetal stress and consequently hypoxia, dystocia may lead to hypothermia, hypoglycaemia, or dehydration, predisposing puppies to infections and possibly death [13,19–22].

Disease in the bitch during pregnancy was the sole variable significantly associated with abortion or resorption in the present study. Abortion in dogs can be infectious, predominantly caused by *B. canis*, but also other bacteria and viruses; as well as non-infectious, for example cause by drugs, endocrine disorders, or uterine pathology. Importantly, not all of these are associated with clinical signs in the bitch [32,46–48]. The dates for abortion and parturition overlapped in the questionnaire. Hence, whether the bitch aborted or gave birth to dead, but fully developed, foetuses depended on the breeder's subjective assessment, and this might have affected the abortion rate. Our rate was

Table 7

Results from the multivariable logistic regression models evaluating associations between main outcomes and associated risk factors in a cohort of bitches mated 2020–2023, as reported by owners in a web-based questionnaire study on outcome of pregnancy and pre-weaning puppy health in Swedish dogs.

ABORTION/RESORPTION

	Coefficient[a]	OR (95 % CI)	P[b]
Intercept	−3.18	–	–
Pregnant bitch diseased			<0.001
No	Baseline	1	
Yes	1.86	6.45 (2.51–14.7)	<0.001
Do not know	3.18	24.0 (2.84–202)	0.002

STILLBIRTH

	Coefficient[a]	OR	P
Intercept	−2.96	–	–
Number of previous litters			<0.001
0	Baseline	1	
1	−0.79	0.46 (0.32–0.64)	<0.001
2	−0.50	0.60 (0.39–0.91)	0.020
3	0.13	1.14 (0.64–1.95)	0.650
4 or more	−0.15	0.86 (0.19–2.69)	0.814
Do not know	0.71	2.04 (0.07–59.4)	0.643
Type of parturition			<0.001
Vaginal without assistance	Baseline	1	
Vaginal with assistance	1.23	3.41 (2.34–4.95)	<0.001
Caesarean section	1.56	4.74 (3.08–7.30)	<0.001
Duration parturition			<0.001
0-<6h	Baseline	1	
6-<11h	0.54	1.71 (1.27–2.32)	<0.001
≥11h	1.03	2.79 (1.82–4.25)	<0.001
Do not know	−0.37	0.69 (0.21–1.87)	0.501
Caesarean section, birth was not initiated	−0.77	0.47 (0.21–0.97)	0.048
Dogs younger or equal to 1 year housed with the bitch in the last two weeks of pregnancy			0.040
0	Baseline	1	
1-3	0.01	1.01 (0.74–1.37)	0.941
4-6	−0.36	0.70 (0.26–1.65)	0.436
7 or more	1.31	3.71 (1.40–9.26)	0.006
Congenital anomalies present in the litter			<0.001
No	Baseline	1	<0.001
Yes	1.04	2.82 (1.85–4.29)	<0.001
Do not know	2.40	11.1 (1.33–238)	0.046
Number of puppies in the litter	0.16	1.18 (1.11–1.24)	<0.001

CONGENITAL ANOMALIES

	Coefficient[a]	OR	P
Intercept	−2.58	–	–
Bitch with disease during pregnancy			<0.001
No	Baseline	1	
Yes	1.57	4.81 (1.98–10.6)	<0.001
Do not know	−12.0	<0.001 (NA[a])	0.981

MORTALITY IN PUPS IN THE FIRST EIGHT WEEKS

	Coefficient[a]	OR	P
Intercept	−3.50	–	–
Type of parturition			0.022
Vaginal without assistance	Baseline	1	
Vaginal with assistance	0.71	2.04 (1.20–3.34)	0.006
Caesarean section	0.24	1.27 (0.70–2.16)	0.406
Dogs younger or equal to 1 year housed with the bitch in the last two weeks of pregnancy			0.013
0	Baseline	1	
1-3	−0.19	0.83 (0.53–1.28)	0.410
4-6	0.01	1.01 (0.24–2.89)	0.985
7 or more	1.53	4.62 (1.61–11.7)	0.002
Number of puppies in the litter	0.14	1.15 (1.07–1.23)	<0.001

CI confidence interval *STD error* Standard error *OR* Odds ratio.

***CI could not be computed due to separation, i.e. no pups with congenital defects in this group.

[a] Logistic regression coefficient (log-odds).

[b] P-values for categorical variables correspond to the comparison of each category with the reference group (OR = 1).

lower than the 6.8 % previously reported in France [1], and 8.4 % in Australia [18], but close to the abortion rate of 1.9 % described in a Norwegian study [2]. Abortion rates in dogs are rarely reported, partly because bitches often ingest the dead puppies, leading to abortions going unnoticed by the breeder [49].

The rate of congenital anomalies in liveborn puppies in this study was considerably lower than in a Brazilian study of 803 newborn puppies, where 6.7 % presented with defects [51]. The latter is, however, a prospective study, where the presence of anomalies was assessed via thorough physical examination, while in our study, the breeders did the assessment. In the present study, cleft palate was the most reported anomaly, in accordance with previous studies [51,52].

The significant association between an unhealthy bitch and puppy anomalies could be explained by the potential teratogenic effect of the illness itself or by drugs administered during pregnancy. In dogs, organogenesis is most sensitive to disturbances day 14–30 of pregnancy [50]; accordingly, in bitches with late pregnancy disease, the defects are likely not a result of toxicity or infection, but rather due to other causes. There are multiple potential causes of congenital anomalies, where inherited genetic factors might be of importance in certain breeds, while teratogenic effects from drugs or other toxic agents, nutritional factors, infectious agents, or other environmental factors can occur in any breed [51].

The overall pre-weaning mortality rate is at the lower range of mortality rates reported in other studies [1–3,10,43]. Several factors influence the comparability of pre-weaning mortality rate among studies, for example; whether stillbirth is included in the overall mortality or not, which breeds are included in the studies, and during what time period postpartum mortality was studied. In one of the first studies on canine newborn mortality, a questionnaire survey in Great Britain published in 1963, the mortality rate up to 12 weeks of age was 25 %, stillbirths excluded [14]. These figures are interesting from a historical perspective; however, knowledge about neonatal care has advanced considerably since then.

The finding that 37 % of males and 18 % of bitches originated from a country other than Sweden is a reminder that dog breeding in many aspects is an international business. One possible consequence of cross-border mating or purchasing breeding dogs is the introduction of serious diseases such as brucellosis. Infections with *B. canis* have only been confirmed in a few Swedish dogs, all imported or in close contact with imported dogs [26,27]. An increase in infections with *B. canis* due to the import of dogs has been reported from other western European countries, where the infection had not been previously described, or had been only rarely described [28,53].

Further, one-third of respondents had performed mouth-to-nose resuscitation on newborn neonate(s), likely unaware of the potential risk of the exposure they might be taking on by handling parturition fluid and material without the correct use of personal protective equipment [54]. Direct contact with aborted material and newly born puppies from bitches infected with *B. canis* has been the transmission route in several described human cases of this infection [30,31,55]. Our finding emphasizes the importance of providing breeders with information about the possible risk of zoonotic disease transmission due to direct, close contact; for example, using gloves and suction device when resuscitating neonatal pups. Communication about the zoonotic risks is also relevant for veterinarians and animal health professionals, as well as for medical doctors and public health authorities.

The reported vaccination status regarding the core vaccines in the present study corresponds well with the high vaccination coverage among Swedish dogs. This widespread coverage protects newborn pups, probably contributing to the relatively low mortality rate in the present study. Vaccination against kennel cough is not considered a core vaccine, but many breeding dogs belong to the group of dogs for whom it is recommended [56]. Despite the low CHV-1 vaccination rates, neonatal mortality was low, likely due to natural exposure of the bitches supported by reported seroprevalence of CHV-1 in Europe of 46 %–82 % [57–59].

The trend of raw-meat–based diets has appeared to increase, and due to the possible presence of pathogens, this has been considered a potential public health hazard as well as a pathogen source for dogs [48,60–63]. The correlation between the type of food given to the bitch and mortality in newborn pups is poorly investigated. The present study did not reveal any significant association between raw food and abortion, stillbirth, or puppy mortality.

The high whelping rate in the current study may reflect good overall health and fertility. Another possible reason could be that breeders with a bitch that did not conceive chose not to respond to the survey, resulting in a misleadingly high whelping rate. Fertility and whelping

rates in a population with many different breeds have not been studied in Sweden before, and there are few international studies to compare with. One study encompassing 27,221 dogs reported a high whelping rate of 87.7 % [1].

A limitation of the present study is that the frame population—i.e., registered breeders in SKK—does not include all breeders in Sweden. Mixed-breeds and breeds that are not approved by SKK are not included in the register, and some breeders of approved pure-breeds might choose not to register. This could potentially influence the result on breed and breed-category levels. By including non-registered breeders, it would have been possible to decrease the discrepancy between the frame population and the target population. Due to practical distribution reasons, the survey was only sent to registered breeders. However, the great variation in the breeders' experience, together with the wide representation in breeds, suggests that the study group despite this limitation is representative of Swedish breeders.

A further limitation related to distribution of the survey was that only breeders with an available e-mail address, resulting in a selection bias due to digital access.

As in all questionnaire studies, there are limitations, such as possible recall failure, where some information might be falsely remembered by the respondent [64]. By not asking about events prior to 2020, we reduced recall bias. The register used for survey distribution did not include data on matings or artificial inseminations. Therefore, it was not possible to select breeders who had mated a bitch during the specified period prior to the distribution of the questionnaire. This probably lowered the response rate, since a number of the invited breeders had not mated a bitch within the specified time frame. Our choice to only include one bitch, regardless of if the respondent mated several bitches during the specified period, might cause recall bias towards the true outcomes and events of the bitch for whom the respondent answered. The study design might also have caused a self-selection bias, where kennel owners with healthy dogs are more likely to participate. Since the assessment of deformities were performed by the breeders, the diagnostic accuracy is limited.

In conclusion, this nationwide study identifies several modifiable risk factors for perinatal mortality in dogs, notably dystocia management and population density at kennels. The survey also emphasizes the risk for zoonotic transmission when resuscitating canine neonates without proper equipment. These results provide an evidence base for improving breeding guideline and welfare monitoring in Sweden and beyond.

CRediT authorship contribution statement

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Conflict of interest

The authors declare that they have no conflict of interest.

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Glossary

BARF: Biological Appropriate Raw Food.
CAV-1: Canine adenovirus type 1.
CDV: Canine distemper virus.
CHV-1: Canine herpesvirus-1.
CI: Confidence interval.
CPV: Canine parvovirus.
OR: Odds ratio.
SKK: Swedish Kennel Club.
SLU: Swedish University of Agricultural Sciences
STD error: Standard Error.
SVA: Swedish Veterinary Agency.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.theriogenology.2026.117814.

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