A STUDY OF LITTER SIZE IN THE AMERICAN ESKIMO DOG[1]

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In this study of 301 American Eskimo Dog litters, the average Toy litter was 2.516 puppies; the average Miniature litter was 4.011 puppies; and the average Standard litter was 5.035 puppies. It is shown through statistics with a greater than 99% confidence level that Miniature AED bitches have larger litters than Toy AED bitches and that Standard AED bitches have larger litters than Miniature AED bitches. Overall the male-female ration is approximately 50-50. From statistical calculations on 280 litters using a 95% confidence interval, the age of the dam does not appear to be a determining factor in the size of the litter.

INTRODUCTION

Breeders of American Eskimo Dogs ("AEDs" or "Eskies") have long meditated upon those questions which confound all dog breeders regarding their litters of puppies: How many puppies will she have? How many males? Females? Will my bitch's age be a factor in the size of the litter? Unfortunately, in the past no one has ever performed any type of statistical study on the breed and its litters.

Since so few breeds have the range of size of the AED, it is easy to understand why this question of litter size remains foremost in the minds of Eskie breeders. The old adage among dog breeders is that the larger the breed, the larger the litter; therefore, the smaller the breed, the smaller the litter. AED breeders wonder if this holds true for the Eskie: do Toys really have smaller litters than Miniatures or than Standards?

Statistics predict that a puppy has a 50% chance of being male or female because that determination is random and only two possibilities exist for sex. Although logic predicts that overall the sexes will split 50-50, breeders want to know about their litter.

Some breeders believe that a major factor in litter size is the age of the dam. Common belief is that younger bitches are more fertile than older bitches. Is this true for the Eskie?

This study attempts to provide answers to help breeders understand American Eskimo Dog litters.

ACKNOWLEDGMENTS

Appreciation is sincerely expressed to the American Eskimo Dog Club of America, Inc., ("AEDCA") for allowing access to its Stud Book and Litter Registration Forms. Appreciation is also extended to my colleagues at the Texas Natural Resource Conservation Commission (TNRCC), Mr. Jeff Corbin and Ms. Patricia Allen, who reviewed this paper for technical soundness.

METHODOLOGY

The data used as the basis for this study were taken from the Stud Book and Litter

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Registration Forms which were kept as a supplement to the Stud Book of the AEDCA, the National Parent Club for the American Kennel Club-("AKC") registered Eskie. The AEDCA maintained its Stud Book from 1986 through August 31, 1993.

Eskies which were Single-Registered into the Stud Book were entered based upon the presentation of United Kennel Club ("UKC") papers from the owner. Other requirements were also met before each AED could be assigned a number and placed into the Stud Book.

AEDs produced from the mating of two AEDCA-registered Eskies were also placed in the Stud Book. During the first few years, the AEDCA automatically entered each puppy from such a breeding directly into the Stud Book at birth. Litters are found as multiple entries from the same sire and dam grouped together in continuous Registration Numbers without the "S-" prefix of Single-Registered Eskies.

Later, the AEDCA changed its registration procedure and started using Litter Registration Applications. Each puppy listed on the Application was issued a "green slip" (similar to the AKC blue puppy registration form, or "blue slip"), from which the owner could individually register the pup into the Stud Book.

The limitations of litter data include:

1. Registries, including the AEDCA's, only list live pups; and they do not typically list pups lost shortly before, during, or shortly after birth. Questions regarding the loss of such pups and their significance are still debated by genetic and veterinary experts.

2. An owner could withhold information on a puppy if it had a disqualifying fault(s). Since no one knows if or how often this happens, its effect upon any study is unknown.

A total of 301 litters were included in this study. Of these, 126 were produced by Toy bitches; 91 were produced by Miniature bitches; and 84 were produced by Standard bitches. The summarized data regarding frequency of litter size and totals are presented in Table 1.

Figure 1 presents a histogram (graph of frequency) of all AED litters used in this study. The number of pups in the individual litter is found on the x-axis, and the frequency of that size litter is found on the y-axis. Figure 2 presents the same graph for litters produced by Toy bitches; Figure 3 for litters produced by Miniature bitches; and Figure 4 for litters produced by Standard bitches.

As seen in Figure 1, the data for all 301 litters taken at one time appear to be normally-distributed. Litters ranged in size from 1 to 8 pups.

When broken out by Division, as shown in Figures 2, 3, and 4, apparent normally-distributed patterns of litter sizes also emerge. The Toys generally have the smallest litters, ranging from 1 to 7 pups; and 83% of all Toy litters have either 1, 2, or 3 pups, with a median of 2 pups. The Miniatures tend to have somewhat larger litters, ranging from 1 to 7 pups; and 66% of all Miniature litters have either 3, 4, or 5 pups, with a median of 4 pups. The Standards have the largest litters, ranging from 1 to 8 pups; and 74% of all Standard litters have either 4, 5, or 6 pups, with a median of 5 pups.

LITTER SIZE AND SIZE OF DAM

Since all male dogs release millions of sperm when they mate with any bitch, the size of the male does not significantly influence the size of the litter. Some of the primary mechanisms regulating litter size are the number of eggs produced by the bitch during ovulation as she cycles through estrus, and the ability of each egg to implant on the uterine wall and grow throughout pregnancy. These factors suggest that it is the bitch who has the most influence on litter size.

Two hypotheses regarding litter size and the size of the dam can be made: 1) the size of the dam is not a factor in determining the size of the litter (statisticians call this the "null hypothesis", or H_0); or 2) the size of the dam is a factor in determining the size of the litter (statisticians call this H_1). Please note that this is not saying that the size of the bitch is the *only* factor in determining litter size.

Statistics makes use of several mathematical terms:

1. The *mean* (μ) is the average of the sample, in this case litter size. Statisticians debate the definition of "mean", with some saying that unless every possible sample is taken, the mean can only be estimated. The estimation of the mean based upon the samples in a given study is technically known as "$\bar{x}$", pronounced "x-bar". For the purposes of this paper, "μ" is used as the mean.

2. The *variance* (s^2) measures the amount of scatter of the observations around their mean (Hogg and Ledolter, 1987). Because of its mathematical derivation, the units of the variance are in squared units; therefore, statisticians and breeders prefer to deal in real, whole units; in this case "puppies" (rather than "puppies^2").

Statisticians also debate the calculation of "s^2" in the same manner as "μ" and "$\bar{x}$". Some statisticians say that unless every possible sample is used in the calculation of the variance, the result is "s^2" rather than another symbol, "σ^2". For the purposes of this paper, "s^2" is used for variance.

3. The *standard deviation* (s) is the square root of the variance and returns to the original units, in this case "puppies". Because of the relationship between the variance and standard deviation, this paper uses "s" rather than "σ" for standard deviation.

4. The *sample size* (n) is the number of samples taken, in this case "litters".

Table 2 presents the mean (μ), variance (s^2), standard deviation (s), and sample size (n) for the litter sizes of each of the three Divisions, Toy, Miniature, and Standard.

The H_0 and H_1 hypotheses can be written:

$$H_0: \ \mu_{Toy} = \mu_{Miniature} = \mu_{Standard}$$
$$H_1: \ \mu_{Toy} \neq \mu_{Miniature} \neq \mu_{Standard}$$

From Table 2 it can be seen that 2.516 (the mean of the Toy litter size) does not equal 4.011 (the mean of the Miniature litter size), which does not equal 5.035 (the mean of the Standard litter size). But while these numbers are true for a sample population of 301 litters, of which 126 were produced by Toy bitches, 91 by Miniature bitches, and 84 by Standard bitches, could they simply be the result of random variety within a population? Is a larger sample size of 500 or 1,000 litters required to prove the hypothesis regarding the size of the dam?

Statistics provides a method to quantify the *confidence level*, or the probability that these data reflect the real world of Eskie litters. Hogg and Ledolter (1987) provide the following formula for use to test the H_0, H_1 hypotheses:

$$z = \frac{\mu_2 - \mu_1}{\sqrt{\frac{s_2^2}{n_2} + \frac{s_1^2}{n_1}}}$$

Comparing Miniatures to Toys yields $z = 7.952$; comparing Standards to Miniatures yields $z = 4.511$; and comparing Standards to Toys yields $z = 13.052$.

A Standard Normal Distribution Function table (Pearson and Hartley, 1954) will provide the value of z below which H_0, or that the size of the dam is not a factor in litter size, is accepted. If the calculated z value is greater than the table value of z, then H_0 is rejected, and H_1, or the hypothesis that the size of the dam is a factor in litter size, is accepted.

In all three Divisions, the value of the calculated z is the greater than the table value of z at the 99% confidence level, or 2.516. Therefore, H_0 is rejected, and H_1, or that the size of the dam is a factor in litter size, is accepted. From the table, the probability that the size of the dam is a factor in litter size is over 99% whether comparing Miniatures to Toys ($z = 7.868$), Standards to Miniatures ($z = 4.491$), or Standards to Toys ($z = 12.918$).

MALE/FEMALE RATIO

Table 3 presents the summary of the total number of pups divided as to males and females for litters of the three Divisions and for all litters.

For all litters, males account for 50.8% of the litter population and females for 49.2%. The differences between the Divisions is

apparently small: Toy litters split 48.6% males to 51.4% females; Miniature litters split 49.9% males to 50.1 % females; and Standard litters split 53.2% males to 46.8% females.

Most breeders are familiar with the all-male or all-female litter, so variability at the low population range, or within one litter, is not unheard of in the American Eskimo Dog. Since one-puppy litters are always of only one sex, they were not counted in this study. Even 2-puppy litters of only one sex are not statistically uncommon; therefore they were not counted in this study.

A total of 16 3-pup litters (25% of all 3-pup litters) were of only one sex: 7 were all-males and 9 were all-female. A total of 7 4-pup litters (13% of all 4-pup litters) were of only one sex: 6 were all-males and 1 was all-female. Only 1 5-pup litter (20%) of all 5-pup litters) was of only one sex: all-male. And only 1 6-pup litter (17%) of all 6-pup litters) was of only one sex: all-female.

Breeders can rest assured that the overall male/female ratio of pups from all litters is roughly 50-50. However, the variability within any given litter is difficult to predict.

AGE OF DAM

Breeders often question whether the age of the dam influences the size of her litter. Table 4 shows the number of litters for the bitches of each of the three Divisions broken out by age of the dam (in months) at the birth of the litter. It is important to note that the total number of litters in this table is only 280, rather than 301. From AEDCA records, it was not possible to ascertain the ages of the dams of 21 litters.

Table 5 shows the statistical data for the litters within each Division broken out by age of the dam at the birth of the litter: 1-36 months (1 month to 3 years); 37-72 months (over 3 to 6 years); and 73 months and older (over 6 years).

If a bitch's fertility decreased with her age, then the young and middle-aged bitches should have larger litters than older bitches. However, this is not the case in this study. In Toys, the largest litter size is found in the youngest bitches, with the middle-aged bitches having the smallest litters; and the older bitches in between. In Miniatures, the middle-aged bitches have the largest litter size, with the smallest litters belonging to the oldest bitches. In Standards, the oldest bitches average the largest litters, with the middle-aged bitches averaging the smallest.

Statistics again will hold the key in sorting out this apparent puzzle. With only 6 Miniature bitches over the age of six having litters and only 7 Standard bitches over the age of six having litters, the problem is to put confidence in any conclusion from the study.

The H_0 and H_1 hypotheses can be written:

$$H_0: \mu_{Young} = \mu_{Middle} = \mu_{Old}$$
$$H_1: \mu_{Young} \neq \mu_{Middle} \neq \mu_{Old}$$

In the case of the Toys, the oldest bitches have neither the smallest nor the largest litters. Using a confidence level of 95%, the critical z value from the table is 1.960. The calculated z value comparing the younger bitches, who have the largest litters, to the older bitches is 1.387, which is less than the critical z; therefore the H_0 hypothesis, that no difference between the two groups of bitches exists, is accepted.

In the case of the Miniatures, the oldest bitches have the smallest litters and the middle-aged bitches have the largest litters. The calculated z value comparing the middle-aged bitches to the older bitches is 1.591, which is less than the critical z; therefore the H_0 hypothesis, that no difference between the two groups of bitches exists, is accepted.

In the case of the Standards, the oldest bitches have the largest litters and the middle-aged bitches have the smallest litters. The calculated z value comparing the oldest bitches to the middle-aged bitches is 0.586, which is less than the critical z; therefore the H_0 hypothesis, that no difference between the two groups of bitches exists, is accepted.

Therefore, from this study, it can be concluded that the age of the dam does not have an influence on litter size. However, this may be

due to the limited time that the AEDCA maintained its Stud Book and the fact that many breeders did not register their breeding stock until the final year before the closure of the Stud Book. Only through continued, long-term study can the AEDCA establish whether younger bitches are bred more often than older ones.

CONCLUSIONS

This brief study concludes:

1. The smallest Eskie litter for each Division was one pup. The largest litter in the 301 litters studied was eight pups. The largest litters for Toys and Miniatures were seven pups, and the largest Standard litter was eight pups.

2. For all 301 AED litters in this study, the average litter size was 3.617 pups. The average size of the 127 Toy litters was 2.516 pups. The average size of the 91 Miniature litters was 4.011 pups. The average of the 84 Standard litters was 5.035 pups.

3. The size of the bitch is a factor in the size of the litter- Toys have smaller litters than Miniatures, who have smaller litters than Standards. This study calculated the confidence level of this conclusion at over 99%.

4. The overall sex ratio of males to females for the breed is approximately 50-50. However, individual litters can vary to all-male or all-female.

5. Based upon the litter data in this study and using a 95% confidence level, this study concludes that the age of the bitch is not a factor in determining litter size.

Obviously more work remains to be done in the study of the size of American Eskimo Dog litters. The AEDCA should appoint a committee to devise, record, and maintain a voluntary database to track breeding and litter data. Especially important should be tracking neonatal deaths and stillbirths and their causes. Breeders should be educated on the importance of understanding these deaths.

The question of whether younger bitches are really bred more often than older bitches remains to be answered. The AEDCA can only do so through a continued, long-term study.

Another factor which should be tracked over many generations is the role of inbreeding. Breeders concentrate the genes of their Eskies as they develop their lines, and they may be risking the future fertility of the breed. Unless the AEDCA begins tracking trends now, breeders risk losing valuable knowledge and experience. All data should be kept anonymous unless the individual breeder approves their release.

REFERENCES

Hogg, Robert V., and Ledolter, Johannes (1987). *Engineering Statistics*. Macmillan Publishing Company: New York.

Pearson, E.S. and Hartley, H.O. (1954). *Biometrika Tables for Statisticians*, Volume 1. Cambridge University Press: Cambridge.

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Size	Frequency of No. of Pups in Litter										Total
	1	2	3	4	5	6	7	8	9	10	
Toy	25	41	39	15	4	1	1	0	0	0	126
Miniature	5	11	17	21	22	12	3	0	0	0	91
Standard	1	3	8	18	20	24	4	6	0	0	84
Total	31	55	64	64	46	37	8	6	0	0	301

Table 1. Frequency of litter size by Toy, Miniature, and Standard Divisions.

	Mean (μ)	Standard Deviation (s)	Variance (s^2)	Sample Size (n)
Toy	2.516	1.157	1.339	126
Miniature	4.011	1.502	2.256	91
Standard	5.035	1.501	2.253	84

Table 2. Mean, standard deviation, variance, and sample size for litter size by Division.

Size	No. Litters	Total No. Pups	No. Males	Percent Males	No. Females	Percent Females
Toy	126	317	154	48.6%	163	51.4%
Miniature	91	365	182	49.9%	183	50.1%
Standard	84	423	225	53.2%	198	46.8%
All	301	1105	561	50.8%	544	49.2%

Table 3. Number and distribution of pups by sex and Division.

	1-12 Mths	13-24 Mths	25-36 Mths	37-48 Mths	49-60 Mths	61-72 Mths	73-84 Mths	85-96 Mths	97-108 Mths	109+ Mths	Total
Toy	0	32	25	20	14	10	9	8	4	0	122
Miniature	5	23	15	14	11	9	2	1	3	0	83
Standard	2	16	24	9	12	5	4	1	2	0	75
Total	7	71	64	43	37	24	15	10	9	0	280

Table 4. Number of litters within each Division by age of the dam (in months) at the time of the birth of the litter.

	1-36 Months	37-72 Months	73+ Months
Toys	No. litters = 57 Range: 1 - 7 Average (μ) no. of pups/litter = 2.684 s = 1.055 s^2 = 1.113 ***Largest Litters***	No. litters = 44 Range: 1 - 7 Average (μ) no. of pups/litter = 2.295 s = 1.304 s^2 = 1.700 ***Smallest Litters***	No. litters = 21 Range: 1 - 4 Average (μ) no. of pups/litter = 2.333 s = 0.966 s^2 = 0.933
Miniatures	No. litters = 43 Range: 1 - 6 Average (μ) no. of pups/litter = 3.767 s = 1.342 s^2 = 1.801	No. litters= 34 Range: 1 - 7 Average (μ) no. of pups/litter = 4.500 s = 1.581 s^2 = 2.500 ***Largest Litters***	No. litters = 6 Range: 1 - 6 Average (μ) no. of pups/litter = 3.167 s = 1.941 s^2 = 3.767 ***Smallest Litters***
Standards	No. litters = 42 Range: 1 - 8 Average (μ) no. pups/litter = 5.048 s = 1.834 s^2 = 3.364	No. litters = 26 Range: 3 - 7 Average (μ) no. of pups/litter = 5.038 s = 1.148 s^2 = 1.312 ***Smallest Litters***	No. litters = 7 Range: 4 - 7 Average (μ) no. of pups/litter = 5.286 s = 0.951 s^2 = 0.904 ***Largest Litters***

Table 5. Statistical data for litters within each Division showing number of litters, range of litter size, average litter size, the standard deviation of the litter size, and the variance of the litter size. Range of months at the top of the table indicate the age of the dam at the time of the birth of the litter.

FIGURE 1: LITTER FREQUENCY

All Litters

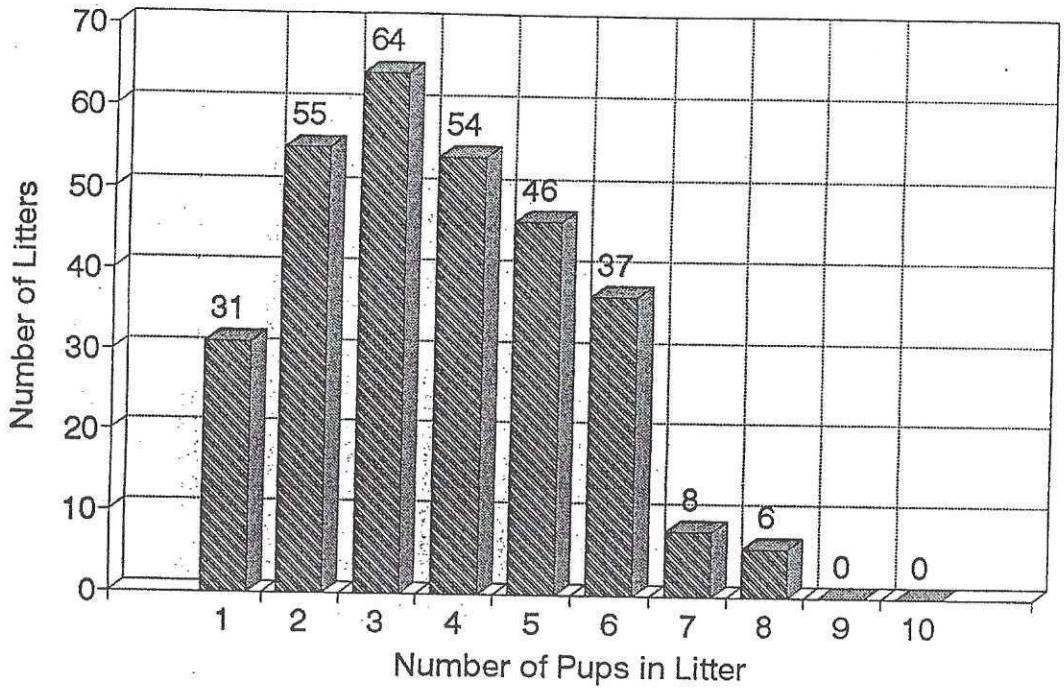

FIGURE 2: LITTER FREQUENCY

Toy Litters

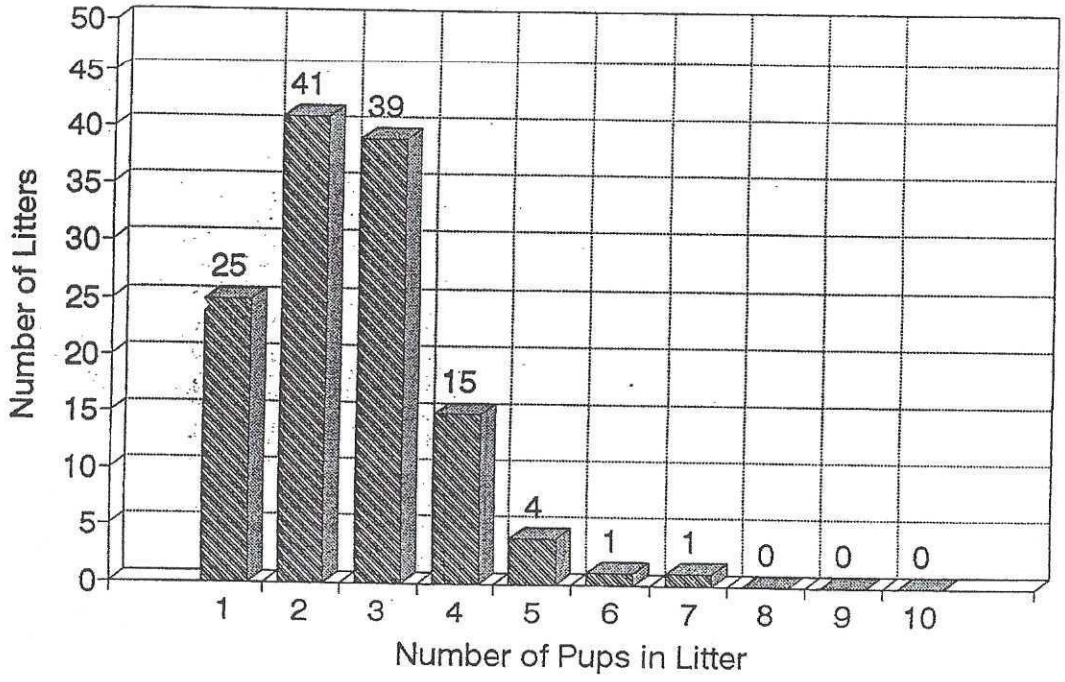

FIGURE 3: LITTER FREQUENCY

Miniature Litters

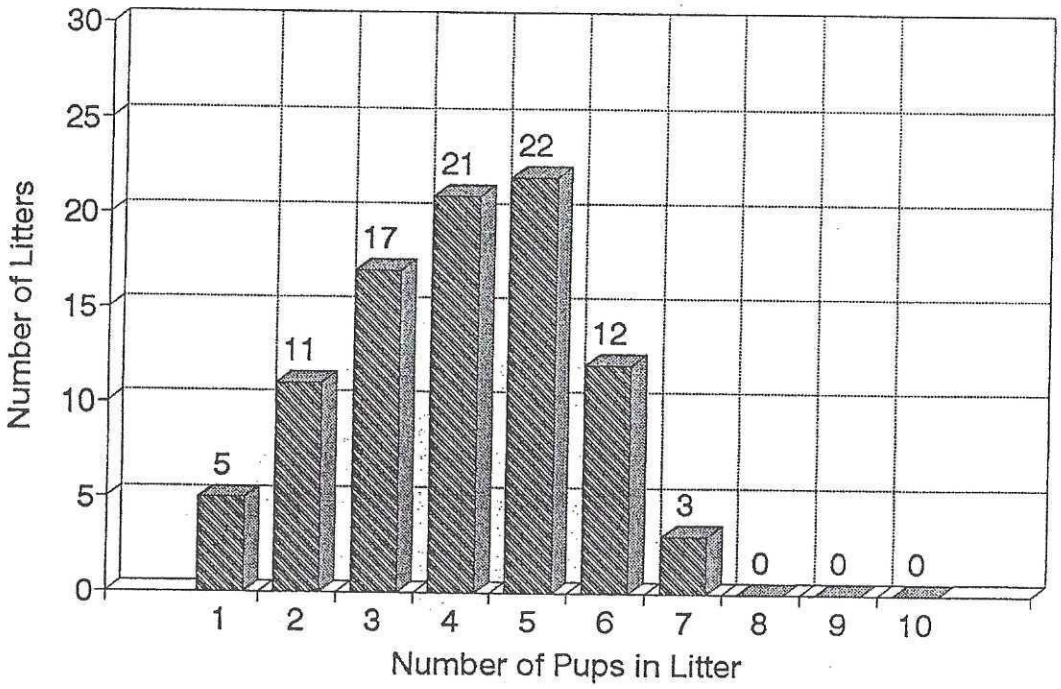

FIGURE 4: LITTER FREQUENCY

Standard Litters