

Factors Influencing Canine Reproduction and Nutritional Management of the Pregnant Bitch

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INTRODUCTION

The ultimate goal of any mating is to produce viable offspring for the propagation of the species. In the bitch, reproductive success should be defined as the generation and weaning of an adequate size litter of healthy viable puppies reflecting the genetic potential of both the dam and sire. To achieve this goal, the breeder will be required to not only select the proper breeding stock, but also to develop a plan by which the stock will be managed. While the basis of the program must be applicable to an entire kennel, it must also have some degree of flexibility to meet the needs of each individual bitch.

When developing a new program or attempting to upgrade an existing breeding program, there are several questions that should be addressed. One of the most critical questions the breeder must answer is "What are my expectations?" To answer this, the breeder must understand that several factors can influence various components of canine reproduction, including litter size. These factors include the bitch's breed, age, and health, the type and

quality of semen used for the mating, as well as her plane of nutrition. At first glance, these various influences may appear independent in nature; however, there is a common association. The breeder controls all of them to some degree. Within the breeding program, the breeder decides which bitches are bred, which sires are selected, at what age a bitch will be bred, what type of mating will be employed, and lastly, which and how much food will be fed. These are all critical questions that must be answered since the successful weaning of a litter is probably the most demanding and stressful act that the bitch will experience as an adult.

FACTORS INFLUENCING REPRODUCTION:

Breed

Although it has long been recognized that a bitch's breed will influence how many puppies she is expected to produce, there continues to be a lack of information on what is the typical litter size within a given breed. Therefore, we obtained records (728,271 litters) spanning a 3-year period for 15 popular breeds from the American Kennel Club (AKC). Each record contained the litter number, breed code, number of males born, number of males registered, number of females born, number of females registered, mating type of litter (natural, fresh semen, fresh extended semen or frozen semen) and age of bitch when bred. Unfortunately, the records do not indicate the number of puppies that the bitch weaned. Therefore, we were not able to determine if the discrepancy between the number born and the number registered was due to a failure to thrive, substandard quality, or sold with registration agreement (pet only). Practically speaking, it was probably a combination of all the factors. The breeds and the number of litters (in parenthesis) examined were the Labrador Retriever (85113), Poodle (69755), Dachshund (59935), Pomeranian (56976), Chihuahua (55513), Yorkshire Terrier (53141), Shih Tzu (48667), Rottweiler (46805), German Shepherd Dog (44537), Beagle (42823), Cocker Spaniel (39019), Golden Retriever (38233), Miniature Schnauzer (32235), Shetland Sheepdog (28421), and Boxer (27098).

The "typical" litter size for a breed is often difficult for the breeder to obtain. Numerous resources simply report the "average" litter size for a breed. While this practice provides the breeder or veterinarian with a rough number, a simple mean cannot convey the amount of variation for that breed. A good example of this would be the Labrador Retriever. The majority of publications indicate that a Labrador Retriever bitch should whelp 7 or 8 puppies per litter. While 7 to 8 puppies would be accurate with regard to the breed average (7.6), litters of 7 or 8 puppies only accounted for 30% of the Labrador Retriever records in our database.

A more practical method for determining what is a typical litter would be to define in whole numbers a range encompassing the mean \pm 1 standard deviation as “typical” and any litter outside that range as “atypical”. Using this method for the Labrador Retriever, the typical litter size would be listed as ranging from 5 to 10 with a mean of 7.6 ± 2.6 puppies. This range would account for approximately 75% of all litters and would allow for a more accurate management plan to be developed for the bitch and her whelps. The use of the mean \pm 1 standard deviation method has been found to account for at least 70% of all litters in the breeds tested to date. The typical litter sizes for each of the breeds examined are presented in **Table 1**.

Table 1. Typical litter size in various canine breeds

Breed	Mean \pm SD	Typical ^a Litter Size Range	% of Litters ^b Accounted For	Most Frequent Litter Size	
				Litter Size	Percentage
Beagle	5.0 \pm 2.1	3 – 7	74.32	5	17.67
Boxer	5.8 \pm 2.4	4 – 8	68.63	6	16.17
Chihuahua	3.3 \pm 1.5	2 – 5	80.72	3	23.99
Cocker Spaniel	5.0 \pm 2.0	3 – 7	76.71	5	18.62
Dachshund	3.9 \pm 1.6	2 – 6	87.18	4	24.04
German Shepherd Dog	6.6 \pm 2.7	4 – 9	70.78	8	14.08
Golden Retriever	7.6 \pm 2.7	5 – 10	74.17	8	16.17
Labrador Retriever	7.6 \pm 2.6	5 – 10	75.55	8	16.54
Miniature Schnauzer	4.6 \pm 1.8	3 – 6	72.01	5	21.01
Pomeranian	3.0 \pm 1.4	2 – 4	71.48	3	26.90
Poodle	3.4 \pm 1.8	2 – 5	77.94	3	25.01
Rottweiler	6.6 \pm 2.9	4 – 10	73.75	7	12.44
Shetland Sheepdog	4.3 \pm 1.9	2 – 6	81.12	4	20.03
Shih Tzu	4.1 \pm 1.6	2 – 6	87.63	4	23.69
Yorkshire Terrier	3.3 \pm 1.5	2 – 5	79.20	3	24.08

^aDefined as the whole number range of the mean \pm 1 standard deviation.

^bPercentage sum of all litters within the defined typical range

FACTORS INFLUENCING REPRODUCTION: Age

One of the most commonly asked questions with regard to canine reproduction is “How long can I breed my bitch?” Theoretically, the answer is “As long as she will conceive.” However, this does not mean that the bitch should be bred or if bred that she will perform at a normal level. Past efforts have demonstrated that parity number influences litter size in the Beagle bitch.¹ Overall, the Beagle bitch was found to have her largest litters in her second and third parities, with slightly smaller litters in the first and fourth parities and significantly smaller litters beyond the fourth parity (**Figure 1**). However, the focus of that study¹ was the impact of parity number, not age. In practice, it is much easier to account for effects of age than parity since one can choose at what age to first breed a bitch, but cannot increase the parity number without also increasing age.

Analysis of the aforementioned AKC database, which was independent of parity number, demonstrated that litter size is influenced by the bitch’s age in almost all of the tested breeds. In general, larger breed bitches declined in their reproductive performance at a younger age than did the smaller breed bitches. This observation is logical, since larger breeds generally have shorter life expectancies. For reporting purposes, we defined the “apparent critical age” as the age in years where the average litter size for a breed declines at least 15% below the breed average. The findings for each breed analyzed is shown in **Table 2**.

The age at which bitches produce the largest litters ranged from as low as 1–2 years of age for the Boxer to as high as 1–7 years of age for the Yorkshire Terrier. Several of

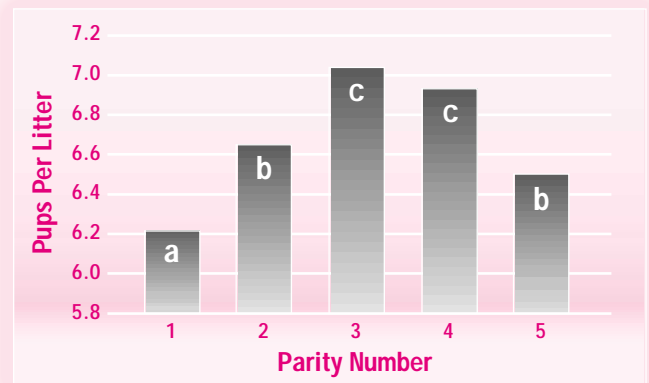


Figure 1. Effect of parity on litter size in the Beagle bitch. Bars with different superscripts significantly different ($P < .05$)

Table 2. Age-associated effects on canine reproduction across breeds^a

Breed	Age of Peak Litter Size ^b	Apparent Critical Age ^c
Beagle	2 – 3	6
Boxer	1 – 2	5
Chihuahua	1 – 4	10+
Cocker Spaniel	1 – 3	6
Dachshund	1 – 4	8
German Shepherd Dog	1 – 3	5
Golden Retriever	1 – 3	5
Labrador Retriever	1 – 3	5
Miniature Schnauzer	2 – 3	6
Pomeranian	1 – 4	10+
Poodle	1 – 5	9
Rottweiler	1 – 3	5
Shetland Sheepdog	1 – 4	8
Shih Tzu	1 – 4	8
Yorkshire Terrier	1 – 7	8

^aAge reported in years

^bBased on the reported number of puppies born

^cCritical age defined as year when litter size declines $\geq 15\%$ below breed average

the larger breeds were found to have an apparent critical breeding age of 5 years, including the Labrador Retriever, Rottweiler, German Shepherd Dog, and Golden Retriever. In contrast, an apparent critical age was not detected for the Pomeranian and Chihuahua breeds, reported as 10+ years since only bitches 10 years and younger were included in the analysis (>99.5% of the total records). An interesting point of this observation was that the Pomeranian and Chihuahua were found to produce some of the smallest litter size averages at 3.0 ± 1.4 and 3.3 ± 1.5 pups per litter, respectively. The lack of an observed apparent critical age for these breeds does not imply that Pomeranian and Chihuahua bitches should be bred at 7 to 10 years of age. Both breeds were found to produce their largest litters between 1 and 4 years of age. Beyond 4 years of age, litter size did numerically decline, however, never achieved the qualifying level of $\geq 15\%$. It remains unknown how the age of the bitch at breeding will affect the health of the bitch and her puppies. Although the reason remains unknown, it should be noted that the percentage of puppies registered for a litter from a bitch older than 7 years old was dramatically reduced in almost all the breeds examined.

FACTORS INFLUENCING REPRODUCTION:

Mating Type

Another key decision that a breeder must make prior to a bitch's estrus is what type of service will be used to achieve the wanted pregnancy. There are two basic choices, a natural service or the use of artificial insemination (AI).

The vast majority of canine litters are produced by natural matings. However, the use of AI has been dramatically increasing over the past few years. At present, it is unknown what the exact percentages are for natural versus AI, however, it would be safe to assume that less than 5% of all litters are produced through the use of AI. Analysis of the AKC database (described earlier) revealed that less than 0.5% of the 728,271 litters were reported as being produced by AI. The highest percentages of AI produced litters were reported in the Labrador Retriever (1.01%), Shetland Sheepdog (0.97%), and the Golden Retriever (0.93%).

Despite the increasing popularity of AI, it remains unknown if litter size is affected. To address this question, we analyzed the previously described AKC database for puppy number accounting for mating type. Depending on breed and semen type, litters produced by AI were reduced as little as 2% and as much as 49% when compared to litters produced by natural service. Across all breeds, litter size was reduced by approximately 15% when produced by fresh or chilled extended semen and by 25% when produced by frozen semen relative to natural service produced litters (**Figure 2**). While this data suggest that

litter size is reduced when AI is utilized, extreme caution must be taken with this interpretation. There are several factors that we were unable to account for including: 1) were precautions taken to predict when the bitch ovulated, 2) were all or a subpopulation of the AI litters produced by bitches with a history of reproductive complications, and 3) what percentage of the AI breedings were performed professionally versus by the novice hand. In addition, the number of observations for the two mating types was extremely unbalanced — less than 0.5% of all observations were reported as AI produced. Perhaps there will be definitive information forthcoming in the near future to resolve if the reduction in litter size by AI matings is real.

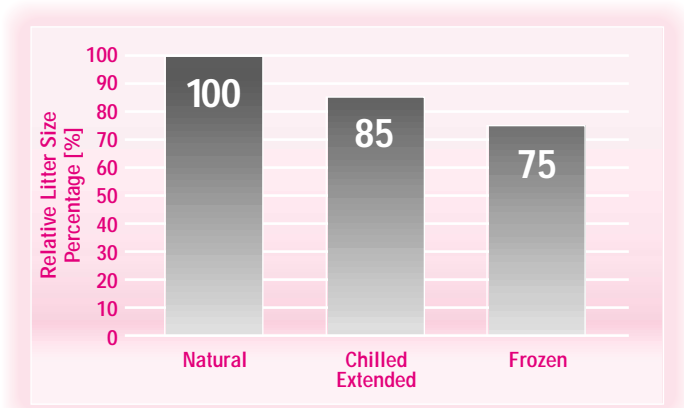


Figure 2. Effect of semen type on relative litter size in the bitch.

FACTORS INFLUENCING REPRODUCTION:

Nutrition

Nutrition has long been recognized to influence the reproductive success in the bitch. Campbell and Phillips² and Ontko and Phillips³ provided some of the earliest insight into the specialized nutritional requirements for the reproducing bitch. In both studies, diets known to be sufficient for canine growth and maintenance were found to be inadequate for reproduction. Collins⁴ concluded that the stress associated with reproduction would manifest even the smallest of nutrient inadequacies in diets assumed to be complete. These dietary inadequacies may not be severe enough to inhibit the bitch from reproducing, however, they most likely will prevent her from performing at her genetic potential. Should the bitch's diet fail to meet her required nutrient levels, she will respond by mobilizing nutrients from body fat, muscle, and skeletal tissue. In extreme cases, her body's only solution may be to reduce the demand by decreasing the number of offspring or aborting the pregnancy all together. Further, since deficiencies in maternal nutrition in other species have now been associated with adult disorders in progeny,⁵ it is essential that we understand and optimize maternal nutrition.

While it is often easy to recognize malnourishment, the distinction between dietary sufficiency and optimal

nutrition can be vague. It is also critical to remember that optimal nutrition for the bitch expands beyond her maintenance. In addition to her body's maintenance, optimal nutrition will supply all nutrients required for the growth of her reproductive tissues and for the growth and development of her puppies. To meet these demands, the bitch has two nutrient sources — her diet and mobilizing her body stores. Required nutrients would include all of the essential amino acids and the essential fatty acids (functional components of cellular membranes and the endocrine system) as well as various vitamins and minerals.

However, this is not to imply that one should simply switch to a diet with the highest available nutrient (protein or energy or both) content or use various dietary supplements to enhance a food. Excess nutrition can be as detrimental as nutrient deficiencies. Excess dietary energy can often contribute to extreme maternal weight gain, which dramatically increases the chance of dystocia during parturition. The use of dietary supplements can supply excessive amounts of nutrients such as minerals, thus altering the balanced dietary matrix of the diet. The key to optimal nutrition is supplying a food that has a balanced nutrient profile at levels that meet the animal's need. As Mosier⁶ stated in 1977, "only by feeding well-managed balanced diets can the health of an individual be maximized". Components within the dietary matrix that should be considered are **not only the level** of protein, fat, carbohydrate, vitamins and minerals, **but also the type** of protein and fat **and the ratio** of nutrients, such as protein to fat.

NUTRITIONAL MANAGEMENT DURING PREGNANCY

Pre-Breeding

Prior to any mating, the breeder should take every precaution to ensure that the bitch is in ideal health. This includes not only being current on all vaccinations and free from infections and parasites, but also in optimal physical condition. Animals should be exercised and maintained on a diet that matches energy needs relative to energy output. An important note to remember is that the reproductive process does not begin at mating, but several weeks prior to the mating process when ovarian follicles are being recruited for the upcoming cycle. Because of this, it is important that the breeder not confuse optimal physical condition with athletically finished. The breeding bitch should have evident muscle tone, but also have a slight degree of body fat. This body condition will help promote a healthy endocrine system that will influence the degree of reproductive success.

What to Feed?

As mentioned earlier, nutrition has long been recognized in numerous publications as an influential factor in bitch reproduction.^{4,6-13} Often, the

recommendations from these references are generally vague, suggesting only to feed a high-quality food with sufficient energy for reproduction. There are a few publications^{4,6,10} that have addressed the effect of certain nutrient classes on canine reproduction. Generally speaking, however, past research has directed little effort to defining "quality" or to the role of specific nutrients in canine reproduction. Additionally, there has been a severe lack of studies designed to separate diet sufficiency and "optimal nutrition". There are numerous diets, both commercially available and home recipes, that are sufficient for reproduction. This merely means that animals were able to reproductively perform within expected levels while consuming a defined diet. Unfortunately, these expected levels are often well below the level that the bitch is genetically capable of performing.

Again you may ask, "what should I feed?" First and foremost, select a commercially available premium food with animal-based protein sources that is recommended for gestation and lactation and manufactured by a reputable company. While there are many "home based" diet recipes circulating, it is extremely difficult to achieve a complete and balanced diet using these recipes. These diets can often be deficient in vitamins, minerals, or other nutrients and are undefined with regard to amino acid and fatty acid levels. They may also vary over time due to an inconsistent ingredient supply. Commercial formulas offer distinct advantages by allowing the breeder to feed a product of known nutrient content and type proven to support the reproductive process.

Approximately two weeks prior to breeding, the bitch should be transitioned (if necessary) from her maintenance diet to a diet comprised of approximately 30% highly digestible animal-based protein and 20% fat. The fat portion of the diet should be balanced for fatty acid content to supply an omega-6 to omega-3 fatty acid ratio in the range of between 5:1 and 10:1.

Findings from a recent study conducted by The Iams Company comparing three diets demonstrated positive benefits of feeding this dietary matrix (Eukanuba[®] Premium Performance Formula).¹ When fed throughout the reproductive cycle, this diet resulted in fewer misconceptions, a reduced number of stillbirths and more consistent-sized litters from breeding to breeding.¹ The exact amount of food required will vary depending on breed and metabolic rate; however, the level of intake should be closely monitored to target a caloric intake similar to maintenance levels, thus avoiding overfeeding the bitch.

Pregnancy

During the first 4 weeks of pregnancy, the breeder should continue to feed the bitch the above mentioned 30% protein / 20% fat diet at maintenance levels. It is

possible that you may observe a change in the bitch's appetite at approximately 3 weeks post-breeding, first decreasing followed by a dramatic increase. This, however, may not indicate that you are overfeeding or underfeeding the bitch. This period of pregnancy parallels maternal recognition of pregnancy and embryonic implantation that may trigger these appetite changes. It is very important that the bitch be maintained on her normal routine during this period to prevent any undue stress, which could be detrimental to the pregnancy.

At approximately 5 weeks post-breeding, the food intake of the bitch should be increased slightly each day to achieve a 50% increase in energy by the end of week 6 (Figure 3).¹⁴ For example, if the bitch is consuming 1,000 calories/day for maintenance, by the end of week 6, she should be consuming approximately 1,500 calories/day. One can generally obtain this information from the product manufacturer. It will be necessary to closely monitor the bitch for weight gain during the later stages of gestation to ensure that she is gaining sufficient weight. It is impossible to give an exact percentage of weight that a bitch should gain since the increase will vary greatly from breed to breed, even within similar adult sizes. For instance, one might expect a Golden Retriever to gain more weight than a German Shepherd on average since they typically give birth to larger litters. However, a good rule of thumb would be to target a 25% weight gain in the bitch by the end of week 8 (d 56) post-breeding (Figure 4).

Dietary Supplements

The use of dietary supplements for the gestating bitch has been the topic of many debates. Numerous publications have hinted at the benefits of nutrient supplementation.^{2,3,10} Some of the most commonly mentioned nutrients include protein, calcium, and vitamins. In practice, the only reason to utilize dietary supplements is when the diet fails to supply the needed amount of a given nutrient. However, the theory of supplementation is often much easier than putting it into practice. The majority of currently available commercial foods are formulated to provide a well-balanced supply of various nutrients, with "balanced" being the key word.

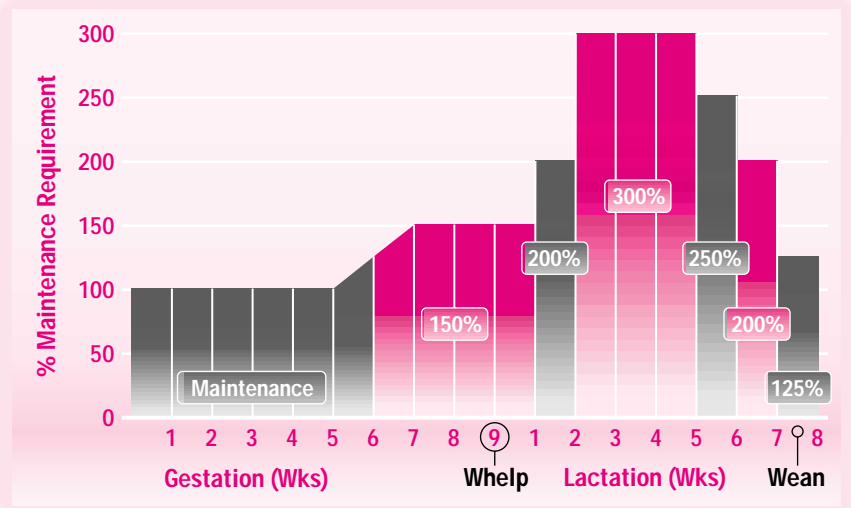


Figure 3. Metabolizable energy requirements of the bitch. Adapted from Lepine AJ. Feeding management of the reproductive cycle, in *Proceedings. Canine Reproductive Health Symposium at the 1997 North American Veterinary Conference*; 27-29.

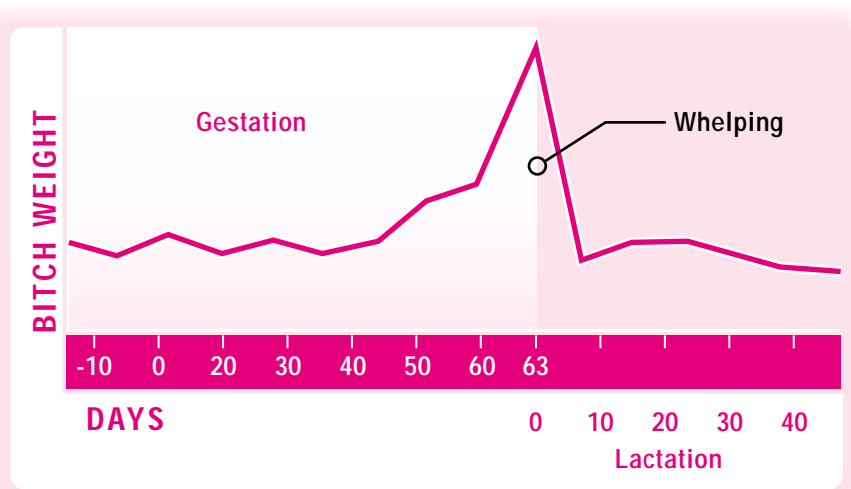


Figure 4. Weight changes during reproduction in the bitch. Adapted from Lepine AJ. Feeding management of the reproductive cycle, in *Proceedings. Canine Reproductive Health Symposium at the 1997 North American Veterinary Conference*; 27-29.

A critical point to remember is that *nothing can be added to or taken away from a diet without affecting the overall nutrient profile*. One should also remember that few supplements are pure sources of a given nutrient. For example, cottage cheese (for calcium) and liver (for protein) are two commonly used diet supplements for the breeding bitch. However, since neither of these foods is composed of a single nutrient, the net result is that more than just the desired nutrient is delivered. For example, both cottage cheese and liver add large quantities of phosphorus. In fact, cottage cheese adds more phosphorus than calcium, the targeted nutrient (Table 3). Thus if incorporated into the diet, the calcium to phosphorus ratio of the diet will be altered.

Table 3. Effect of dietary supplements on the nutrient balance of a commercial diet^a

Nutrient	Amount of Nutrient Provided By Feeding 300 grams of Dry Diet ^a	ALTERED NUTRIENT LEVEL BY ADDITION OF		
		1/2 cup Cottage Cheese	3 oz. Beef Liver	100 g Extra Dry Diet
Protein (g)	93	106	115	124
Fat (g)	63	67.5	67	84
Calcium (mg)	3500	3563	3509	4700
Phosphorus (mg)	2900	3080	3305	3850
Ca:P (ratio)	1.2:1	1.15:1	1.05:1	1.2:1

^aBased on the average analysis of Eukanuba® Premium Performance, guaranteed to contain 30% protein, 20% fat and 4452 kcal ME.

While the intention is good, it is important not to confuse an increase in the level of nutrition required with a need to change the diet profile. The bitch does require that nutrient intake be increased during the latter phase of pregnancy and lactation, however, the increase does not mean that the diet profile should be altered. It is critical to remember that during these periods, the bitch will be consuming a greater volume of food, which will increase her nutrient intake but maintain dietary balance with regard to the formulation (**Table 3**).

CONCLUSIONS

Feeding your bitch does not have to be complicated. While the science associated with nutrition and reproduction may require years to understand, the actual practice of providing nutrition can be summarized fairly simply, *feed the appropriate amount of a diet that meets the animal's needs*. While this practice still requires the breeder to make evaluations as to the exact diet that will be fed, it does eliminate questions such as to what mix of products and/or supplements must be utilized.

Based on our efforts in the area of canine reproduction, the greatest success has been achieved feeding a diet, such as Eukanuba® Premium Performance Formula, consisting of approximately 30% protein (animal-source based) and 20% fat with an omega-6:3 ratio of 5:1 to 10:1. The benefits of feeding this formula have included increased conception rate and live births and more consistent maternal productivity. While nutrition is only one component of bitch management, it is one of the most (if not the most) important. Thus by providing the proper nutrition, the breeder has taken a great step forward in achieving a successful breeding program.

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