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A STUDY OF FERTILITY IN
A HERD OF SOWS

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INTRODUCTION

The productivity of the pig ranks high when compared with other classes of farm mammals. Reproductive potential is the most important factor contributing to total meat production from the species, and one which is markedly influenced by husbandry practice.

Although many consider the pig not to be a seasonal breeder due mainly to its many years of domestication, it has recently become apparent from several overseas reports that this may not be so, a reduction in fertility having been noted to occur during the hot season of the year.

A lack of comparable data for New Zealand conditions, where the recent movement of the industry towards larger and more intensive enterprises has created the need for more efficient production, stimulated the conduct of this study. It was undertaken with the objective of determining whether a seasonal trend in pig production existed in New Zealand, and if so, likely causal factors of the variation. The study comprised an analysis of records collected over a seven year period in one herd.

CHAPTER ONE

REVIEW OF LITERATURE

FACTORS INFLUENCING SEASONAL VARIATION IN REPRODUCTIVE PERFORMANCE WITH PARTICULAR REFERENCE TO THE PIG

Introduction.

Environmental factors are known to influence seasonal variation in reproductive performance both directly and indirectly. Light, ambient temperature and other biotic factors are considered to have a direct effect. Indirect effects on seasonal variation of reproductive performance are assumed possible through variation in the activity of disease producing organisms and immunity to disease and in the activity of certain dietary components.

A. Light.

(1) Basic Aspects.

(a) General. Reproductive periodicity is largely determined by light; notably photoperiod. The timing of the breeding season, termed macroperiodicity, is influenced by photoperiod through changes in the sexual receptivity of both male and female members of many domestic species. These include the sheep, goat and horse. Pigs and cattle are less liable to exhibit seasonal variation in parturition dates (Dutt, 1960).

Seasonality of reproduction in the male is much less marked than in the female. Nevertheless, a great deal of information on this subject of the mammalian male has been reported by Asdell (1964) and presented in reviews by Ortavant, Mauleon and Thibault (1964), Thibault et al. (1966) and Lodge and Salisbury (1970).

The oestrus cycle of many domestic species is also influenced by photoperiod. Such changes are often termed macroperiodicity. Comprehensive reviews on the seasonality of oestrous activity and the mating behaviour of domestic animals have been compiled by several authors (Ortavant et al., 1964; Thibault et al., 1966 and Fraser, 1968).

The precise mechanisms by which the annual changes in photoperiod throughout the year act to synchronise breeding cycles remain largely unknown. In a study of photoperiodic regulation of the breeding cycle in hamsters, Stetson, Elliot and Menaker (1975) listed four possible methods of photoperiodic regulation. Thus the animal may measure the absolute length of either the light period or the dark period to which it is exposed or the ratio of light : dark period. Again, it may be governed in the response to photoperiod by a circadian oscillation of photosensitivity.

Bünning (1967) postulated a mechanism to explain what might be required if mere perception of light did not provide sufficient information. He proposed that the mechanism is dependant on the existence of a circadian rhythm, on which the annual seasonal change acts as an entraining agent - often termed a Zeitgeber. Menaker (1971), in summarizing information on this subject considered that, "in most of the photoperiodic systems which have been investigated in some

detail, the organism appears to measure daylength not by either the light or dark period or the ratio between them. Rather, they distinguish between inductive and noninductive daylengths by assessing whether or not light is present at a particular phase point on an endogenous circadian rhythm of sensitivity to its inductive effects".

Recent support for the mechanism postulated by Bünning (1967), as an explanation for the control of annual rhythms of reproductive activity in birds, has come from Farner and Lewis (1973); Follett (1973); Gwinner (1973) and Lofts and Lam (1973).

(b) Mechanisms of photoperiodic control. Whilst the photoperiodic effect is known to be important in the control and timing of sexual and breeding cycles, it is not yet clear how the external photogenic information is mediated to the animal's brain.

The integrity of the retinal ganglionic layer of the eye, is fundamental for light to influence reproductive activity in the ferret (Thomson, 1951). Such integrity is considered non-essential for the mediation of the photoperiodic effect in some animals. A claim by Critchlow (1963) for the existence of direct rectino-hypothalamic tracts is disputed by Hayhow et al. (1960) and Nauta (1963). Ganong et al. (1963) proposed that light may penetrate the skull of the dog, sheep, rabbit and rat, thereby activating the central nervous system.

The pineal gland may possess the ability to control or modulate seasonal reproductive rhythms in photosensitive animals (Reiter, 1973, 1974, 1976). The mode of action of this gland, as a possible modifier of the hypothalmo - hypophyseal - gonadal axis in the mediation of reproductive responses to photoperiodic stimuli is considered to be by the secretion of antigonadal compounds.

In reviews by Amoroso and Marshall (1960) and Farner (1961), it is suggested that, although the reproductive system of the ferret responded when it had received sufficient light exposure, the intervening periods of darkness were equally important in the photic control of annual endocrine rhythms. A more comprehensive review of the possible mechanisms for photic control of annual endocrine rhythms in mammals is given by Wurtman (1967).

Despite numerous investigations by different workers, many questions relating to the mechanism of light action on variations in reproductive activity in animals still remain unanswered. These have been outlined by Bowman (1973) and include the question of whether photoperiodic changes are stimulatory, inhibitory or both. No explanation has yet been agreed upon as to why, many animals, following exposure to either continuous light or dark treatment, exhibit a refractory period in their re-establishment of normal cyclical activity.

In reviews by Amoroso and Marshall (1960) and Wurtman (1967) experiments are cited where direct influences on endocrine function arise from light per se and not from indirect influences such as muscular activity, wakefulness and feeding habits. Nevertheless, indirect influences must be borne in mind when experiments involving lighting effects are being evaluated.

(c) Photoperiodic effect on hormonal cycles. The annual cycle of pituitary gonadotrophin hormone released and the gonadal development of numerous mammalian species, is dependant upon photoperiodic information (van Tienhoven, 1968; Lodge and Salisbury, 1970, Davis and Meyer, 1972; Berndtson and Desjardins, 1974; Turek et al., 1975).

The many investigations conducted with sheep to study changes in gonadotrophin levels have involved comparisons between anoestrous ewes and cycling ewes, rather than between ewes during the breeding and non-breeding seasons. Results from such experiments have been conflicting. Kammlade et al. (1952) reported higher pituitary gonadotrophin levels during the non-breeding season in ewes, while Lammond, Radford and Wallace (1959) were unable to duplicate this result. Jackson et al. (1971) reported that anoestrus in the ewe is not related to an absence of gonadotrophin releasing hormone in the hypothalamus, but to the absence of a signal for its release.

Definite seasonal changes in pituitary lutenizing hormone (LH) levels occur in Ile-de-France rams; with peak levels occurring during summer and lower levels in winter months (Thibault et al., 1966). In the same study these authors reported similar patterns for follicle stimulating hormone (FSH) levels, with an extra peak during the winter months. The increase in LH output observed in rams at the onset of the breeding season is considered by Short (1973) to be due to an increase in the frequency of discharge rather than any change in the amplitude of the peaks. Using different breed of rams, other workers have provided evidence to support the theory; they include Sanford, Palmer and Howland, (1974a); Katongale et al. (1974) and Hocherean-de Reviers, Loir and Pelletier (1976). The magnitude of seasonal fluctuations in serum LH levels may be influenced by the breed of ram (Sanford et al., 1974a).

Many workers have reported elevations of plasma androgen levels in males of a number of different species during their breeding season (Berndtson, Pickett and Nett, 1974; McMillin et al., 1974; Plant et al., 1974; Giménez et al., 1975 and Mirarchi et al., 1975).

Plasma testosterone levels in rams, increase during, or shortly before the breeding season to exceed the levels during the remainder of the year (Gomes and Joyce, 1973; Sandford et al., 1974a; Sandford et al., 1974b).

(d) Summary. Photoperiodicity has a direct role in the induction of reproductive activity in many livestock species. The onset of breeding in sheep is the most notably affected by photoperiod; lengthened hours of daylight initiates its reproductive cycle. Despite knowledge of the importance of photoperiod in the regulation of breeding patterns, much controversy remains as to the explanation of the mechanisms involved in creating the changes that are brought about with changes in photoperiod.

(2) Breeding Pig Performance.

(a) General. Ortavant et al. (1964) in their review on seasonality of reproduction in domestic species categorized pigs along with cattle, buffalo and rabbits into a group whose long domestication had caused their sensitivity to photoperiodic stimulation to lessen. It has been suggested that short daylength associated with higher latitudes, especially during winter, may influence the reproductive performance of the sow (Hanbikov, 1968). Numerous studies (Urban et al., 1966; Strang, 1970 and Randall and Penny, 1970) conducted to investigate such suggestions have produced conflicting and inconclusive results in the sow where clear seasonal fluctuation in reproductive performance was found, however, this appears to be associated with other factors such as ambient temperature.

(b) Attainment of puberty. Reports on lighting and onset of puberty in the gilt tend to conflict; in some cases darkness is reported

to be associated with a delay in attainment of puberty and in others an advancement (Table 1.1). Extended daylength decreased age at puberty in the trials of Martinat et al. (1970) and Hacker et al. (1976), whereas Dufour and Bernard (1968) have reported that gilts raised in total darkness attained puberty significantly earlier than those kept under normal daylight conditions. This is in contrast to the findings of Hacker et al. (1974) where gilts maintained under conditions of normal daylight attained puberty earlier than those kept under 24 hours of darkness.

Clearly there being no agreement between the results of the above mentioned studies, it is impossible to come to a decision on the "ideal" lighting regime for attainment of sexual maturity. In view of the fact that it is the changing photoperiodic interval which plays such a dominant part in stimulating the onset of oestrus in the ewe, further work on this aspect would seem desirable.

(c) Oestrous behaviour. There is little information on the influence of lighting regime on the oestrous cycle. An increase in the proportion of sows exhibiting prolonged oestrus was observed by Beljaev, Kločkov and Kočkova (1968) in a group of sows exposed to additional lighting periods at the time of mating, when compared to controls kept under a natural daylength regime. Klochkov et al. (1971) reported that the strength of oestrus in gilts was intensified by supplementary lighting (17 hours per day). Conversely, investigations by van Putten (1965) of factors influencing the external signs of oestrus, showed that oestrus tended to be expressed more clearly in winter than in summer. The relationship between the light period and intensity of oestrus remains questionable.

(d) Ovulation rate. Waddil, Chaney and Dutt (1968) reported that when a group of Yorkshire gilts were kept in a situation of continuous

TABLE 1.1 ATTAINMENT OF PUBERTY IN GILTS KEPT UNDER DIFFERENT LIGHTING REGIMES

TREATMENT	NUMBER OF GILTS	AGE (DAYS)	WEIGHT (KG)	REFERENCE
Normal Day Light	6	207.0 \pm 2.2	93.0 \pm 6.8	Dufour and Bernard (1968)
23hr dark + 1hr light	8	191.1 \pm 3.2	92.6 \pm 2.7	" " "
As above - light	8	219.3 \pm 8.3	110.8 \pm 5.2	" " "
As above - dark	8	208.3 \pm 7.8	106.0 \pm 2.9	" " "
As above - light	4	190.5 \pm 2.1	108.7 \pm 7.2	" " "
As above - dark	4	189.3 \pm 2.0	102.2 \pm 3.4	" " "
As above - light	4	210.8 \pm 2.4	99.0 \pm 2.0	" " "
As above - dark	3	210.0 \pm 1.0	97.8 \pm 9.2	" " "
12 hr light	16	183	-	Hacker <u>et al.</u> , 1974
24 hr dark	16	222	-	" " "
24 hr light	69	285.1 \pm 10.1	112.8 \pm 2.3	Martinat <u>et al.</u> (1970)
Daylight	53	293.2 \pm 11.0	114.2 \pm 3.1	" " "
24 hr light	19	253.0 \pm 7.4	-	" " "
Daylight	28	261.0 \pm 6.9	-	" " "
6 hr light	16	232	-	Hacker <u>et al.</u> (1976)
18 hr light	16	190	-	" " "

light for one complete oestrous cycle prior to mating, their average ovulation rate was almost identical to that of controls kept under normal, springtime daylight conditions. However, the number of pigs involved in the trial was small (10 per group), the duration short and there were significant between-year differences in ovum production. Hacker et al. (1976) also reported no significant effect of supplementary lighting on ovulation rate in gilts. Neither does there appear to be any significant effect on ovulation rate of accommodating gilts in complete darkness, compared with normal daylight (Dufour and Bernard, 1968) or 12 hour light per day (Hacker et al., 1974).

From the scant evidence available it would appear that photoperiod is unlikely to produce any significant increase in ovulation rate. More work is obviously required before definite conclusions can be drawn. In a report by Kločková, Rogov and Émme (1961), it was noted that in a group of gilts exposed to a lengthened daily photoperiod regime (18 hours) ovarian weight, the number of fresh corpora lutea and follicle number and size were greater than in a group of similarly bred gilts exposed to daily light periods of only six hours. Šurmuhin and Čeremnyh (1970) reported an increase follicle volume for young growing gilts (3.5 to 9 months of age) exposed to lengthened photoperiod (greater than natural daylength by four hours) compared with a group subject to periods of light four hours less than natural daylength. The report of increased corpora lutea weights due to increased photoperiod regimes was substantiated in a study by Beljaev et al. (1968). They reported significantly heavier corpora lutea weights by day 25 of pregnancy for sows exposed to increased lighting regimes when compared to controls. Shortened photoperiod may therefore result in reduced numbers of follicles and the size of them.

(e) Embryonic mortality. Many workers have reported a range in litter size at birth according to the lighting regime under which the pigs were housed at mating and during the initial phase of gestation.

In studies conducted over several years in Siberia (Novosibirsk - latitude 55° North), Kločkov et al. (1971) reported responses to increased lighting regimes to which gilts were exposed. Although only slight improvements in ovulation rates were reported when the gilts were subjected to the increased lighting regime for 10 to 20 days before oestrus, when the treatment was continued after mating into pregnancy, consistent increases both in the number of embryos at 25 days, and in the number of piglets born at term were found. The non-significant increase in ovulation rate was in accordance with the observations of Waddil, Chaney and Dutt (1968), although the design of their trial is subject to the reservations already mentioned. In summarizing the findings at a more recent study, Kločkov et al. (1975) stated that "litter size at birth was always less on natural daylight than on the increased lighting regimes". The earlier findings of Beljaev et al. (1968); Klockov and Klockova (1969) and Kločkov et al. (1971) substantiate this claim. However, in the trial of Beljaev, Kločkov and Kločkova (1969), the size of litters borne to older sows (3-4 years) was not increased by an increased light treatment. Age of the sow may therefore influence the effect of the lighting regime on the litter size.

The increase in litter size of young sows (less than 3 years of age) by increased lighting regimes was considered to be due to a decrease in embryonic mortality during the early stages of gestation. Litter size was increased by 1.7 - 2.0 pigs per litter, by additional

lighting (17 hours or continuous lumination) during the first 40 days of gestation and by 0.8 - 3.0 piglets per litter, by additional light from mating through to day 40 of pregnancy (Beljaev, Kločkov and Kločkova, 1969). A group of sows, in the same study, kept at a 17 hour daily photoperiod throughout gestation, had an increase of 10-20% in the number of well developed piglets in their litters, and a decreased number of still born and weak piglets.

Although confirmation and amplification of the results obtained by Beljaev, Kločkov and Kločkova (1969); Kločkov et al. (1971); Steger et al. (1971) and others is urgently needed, their findings do provide the basis for tentative recommendations; when winter days are short and/or buildings prevent a good supply of natural light reaching the pigs, then artificial light should be provided to ensure approximately 17 hours of light daily, especially for gilts and sows just prior to service, and maintained for at least the first 40 days of their pregnancies.

(f) Body weight changes. In a study with growing pigs from 3.5 to 9 months of age, Šurmuhin and Čeremnyh (1970) found no significant effect on body weight or on the weight of genitalia under light regimes of natural daylength, 4 hours less than natural daylength or 4 hours longer than natural daylength.

(g) Conception rate. In a 10 year study by Kločkov et al. (1975), gilts (North Siberian (NS), Lacombe x NS and Landrace x NS) exposed to either an increased (17 hour) or continuous lighting from weaning until puberty, exhibited an increase in farrowing rate compared with controls kept under natural daylight conditions, with the exception of one year when in fact farrowing rate was lower for gilts under the 17 hour or continuous lighting regimes.

(h) Semen characteristics and libido. To date little information exists in the literature on the effect of photoperiodicity on reproductive performance of the boar. It was suggested by Jaussiaux (1964), that daylength during summer influences boar semen production. An unfavourable interaction between increased photoperiodism and temperature, on boar semen characteristics was reported by Mazzari, du Mesnil du Buisson and Ortavant (1968). Sperm output, sperm motility and farrowing rate to such semen are severely depressed when boars are submitted to high summer temperatures (35°C) under long days (16 hours of light per day).

The reproductive performance of the boar is also thought to be affected by a reduction in daily photoperiod (Steger et al., 1971). They reported a reduction in libido, and a decline in semen quality. Ejaculate volume, sperm concentration, motility and the percentage of normal spermatozoa were all adversely affected by a reduction in daylength.

B. Ambient Temperature

(1) Basic Aspects.

(a) General. The three main climatic factors which contribute directly to the sense of environmental comfort are ambient temperature, humidity and air speed, but of these ambient temperature is the main determinant, and the most closely studied in relation to reproductive disorders. However, many other factors play a secondary role, so it must be borne in mind when evaluating experimental findings that it is seldom possible to consider air temperature in isolation.

The affect that a high ambient temperature has on seasonal

variation in reproductive performance varies according to species, period of exposure, gestation length, stage of pregnancy and the magnitude of temperature elevation (Hafez, 1964).

Elevated environmental temperatures, often below the upper critical limit of the animal's thermoneutral zone, can cause a decline in reproductive efficiency. Such reductions in reproductive efficiency may occur in either the male or female through decreased gametogenesis (Chowdhury and Steinberger, 1964), libido (Steinbach, 1972), oestrus behaviour (Steinbach, 1971), conception rate (Madžirov et al., 1973), fertilization (Alliston and Ulberg, 1961), implantation (Omtvedt et al., 1971), embryonic survival (Bellvé, 1973), gestation length and mothering ability (Steinbach, 1971) as well as increased dystocia (Brown et al., 1977).

In contrast to the effects of elevations of environmental temperature, exposure to temperatures at the lower critical thermoneutral zone has little or no direct harmful affect on reproduction in farm animals (Faulkner et al., 1967). The same workers also reported that only under extreme conditions when Canadian bulls suffered scrotal frostbite was their reproductive performance impaired.

Comprehensive reviews on the effects of air temperature on mammalian reproduction are given by Dutt (1960) and van Demark and Free (1970).

(b) Critical periods. The three critical periods in respect of the influence of ambient temperature on reproduction in the female are pre-mating, implantation and mid-gestation.

(i) Premating. From the commencement of oestrus until the ova pass

down the fallopian tubes to the utero-tubule junction, is the period considered most susceptible to heat stress prior to mating (Yeates, 1953; Alliston and Ulberg, 1961; Dutt, 1963; 1964; Thwaites, 1967; 1968). Exposure to elevations in mean daily ambient temperature during this period, often results in an increased proportion of abnormal ova shed, a decrease in fertilization rate (Alliston and Ulberg, 1961) and an increase in embryonic deaths early in gestation (Elliott and Ulberg, 1971).

Alliston and Ulberg (1961) using embryo transfer techniques with heat stressed ewes, reported a lowered fertilization rate in those subjected to elevated environmental temperatures (20 and 30°C) five days prior to oestrus. They gave no explanation of the physiological mechanism involved. The fertilization failure might for instance, be due to the inability of sperm to penetrate the ovum or to the effect of the uterus on the sperm after its deposition in the female reproductive tract. A further suggestion concerning alteration of the timing of oestrus or ovulation rate by elevated ambient temperature, is that it may result from changes in the pituitary - adrenocortical system, or from the release of adrenocorticotrophic hormone (ACTH) (Smith and Smith, 1952). The cumulative effect is thought likely to be dependant on the critical timing of the stress, and on genotype, habituation and other environmental factors such as nutritional status (Alliston and Ulberg, 1961). In the same study the workers observed no significant difference in ova and embryo morphological structure between the two temperature groups. The difference in embryonic death rate between the two groups was significant however, despite no apparent damage at the time of transfer. It was also noted that damage was not confined to the first

three days after mating; some detrimental effect of high ambient temperature can also occur after the embryo reaches the uterus (Alliston and Ulberg, 1961).

(ii) Implantation. Exposure of females to small elevations of air temperature immediately following mating has been reported to substantially increase the incidence of preimplantation embryonic mortality, in the mouse (Elliott et al., 1968; Burfening et al., 1970; Bellvé, 1972), the sheep (Edey, 1969) and the pig (Omtvedt et al., 1971).

Despite the considerable amount of research on the effect of elevated temperature on preimplantation embryonic mortality, the mechanisms remain obscure. In a study with unacclimatised heat-stressed rats, Macfarlane, Pennycuik and Thrift (1957) reported a reduction in the rate of foetal resorption (although not significant) when progesterone therapy was applied following mating. Howarth and Hawk (1968) and Yang et al. (1969) proposed that an increase in the pituitary-adrenal activity may be responsible for the depression of embryo survival in sheep. Failure of luteal function was yet another possible explanation offered for increased resorption, although many workers consider that heat stress during early pregnancy has no significant influence on the ovine corpus luteum. Instead, the regression of the corpus luteum occurs after the death of the embryo.

The period of greatest temperature sensitivity is considered by Cribblez and Alliston (1974), to be confined to the one-cell stage of embryonic development, even though in some species the arrest in cleavage may not occur until a later stage. However, Bellvé (1973), proposed that maternal hyperthermia arrested the development

of the embryo at the two-cell stage. He postulated that maternal hyperthermia causes three discrete, but apparently related forms of embryonic mortality; they are firstly, an arrest in development at the two-cell stage, associated with failure of incorporation of uridine into RNA, secondly a partial effect in which one blastomere is arrested and the remaining blastomere may undergo further cleavage divisions, and thirdly continued, but, retarded cleavage of both blastomeres.

In their recent studies, Biggers and Bellvé (1974) and Barbehenn et al. (1974) considered it feasible that the effect on RNA synthesis may be secondary to some imbalance in energy metabolism at the early cleavage stages.

(iii) Mid-gestation. In early studies (Yeates, 1949, 1953 and 1958), in which ewes were subjected to thermal challenges during the second and/or final third of gestation, an impairment in foetal development was reported. Further evidence in support of this observation has come from workers using many different species including the rat (Benson and Morris, 1971), the sheep (Goode, 1964; Morris, 1966; Shelton, 1964a,b; Alexander and Williams, 1971; Brown et al., 1977) and the pig (Omtvedt et al., 1971).

When heat stress is applied to the ewe during the last month of pregnancy, foetal growth is impaired, irrespective of the level of nutrition (Brown et al., 1977). However, a lowered plane of nutrition may also lead to reduced birth weights and in cases of severe feed restriction, the reduction in litter weights at birth is additive to that of heat stress (Alexander and Williams, 1971).

Shelton and Huston (1968) suggested that heat stress may

also lengthen the gestation length. Yeates (1953) reported full term pregnancies of ewes kept in hot rooms for either the last two thirds or one third of pregnancy. In contrast lambs from ewes subjected to heat stress during the second half of pregnancy, delivered by caesarian section between days 142 and 146, exhibited dwarf characteristics (Alexander and Williams, 1971).

A summary of results to date, reveals that nutrition, breed of ewe and effective environmental temperature may all contribute to retardation of foetal lamb growth during heat stress of the pregnant ewe, but their exact roles are not known. It has been reported that the frequency of still-births and problems of dystocia in cattle have often been observed to be increased during relatively hot periods late in gestation.

(c) Reproduction in the male. Although sperm are produced all year round, high temperatures may reduce the quantity, concentration and viability of the cells, and increase the percentage of abnormal spermatozoa (McKenzie and Berliner, 1937; Gunn et al., 1942; Bogart and Mayer, 1946).

Despite a reduction in libido associated with high temperatures (McKenzie and Berliner, 1937), the males of many species are capable of mating throughout the year. The level of the fertility of the ejaculates does, however, fluctuate according to the climatic conditions to which the animal is subjected. This has been reported in the ram (Amir and Volcani, 1965; Lincoln and Davidson, 1977), the bull (Rhymes and Ewing, 1973) and the boar (Wetterman et al., 1976). The extent of the influence of high temperatures is compounded by growth and development of the individual however.

The male members of all mammalian species, with the exception of the whale and elephant, possess an anatomical structure, the scrotum, in which their testicles are contained. Continuation of the normal spermatogenic cycle in the male is dependant on the existence of an abdomino-testicular temperature gradient. The magnitude of this gradient is of evolutionary significance (Cowles, 1958).

The structure of the scrotum is characterized by features which enable it to actively control its own temperature. The skin is thin, often hairless, lacks subcutaneous fat and has a distal underlying sheet of smooth muscle, termed the tunica dartos (Schweizer, 1929; Gutzschebauch, 1935). Movement of the scrotum by the tunica dartos muscle affords the mammalian male a natural protective process for spermatogenesis in situations of moderate changes in ambient temperature. Contraction of this muscle, induced by cold temperatures, throws the skin into folds, increasing its insulation, while at the same time drawing the testes towards the warmer abdomen. In high temperatures the muscle is relaxed, giving an effectively larger scrotal surface, therefore increasing heat loss. A comprehensive review is given by Waites and Setchell (1969).

Despite the anatomical characteristics of the scrotum described previously, the spermatogenic cycle of many male animals is altered in their natural environment, due to extremes in temperature, especially elevations.

The progression of the events of the spermatogenic cycle are thought not to be effected by exposure to cold. However, it has been reported that low ambient temperatures do alter semen characteristics, sperm production and epididymal sperm numbers. Swierstra (1970)

reported that exposure of boars to the cold for long periods, increased the testicular size, and therefore epididymal capacity. Characteristics he considered to be due to either a direct response to the cold, or a result of the associated increase in energy intake due to the cold. The increased semen volume reported by Swierstra (1970) in these boars exposed to cold, was attributed to either a direct response to the cold or in association with increased libido. Sperm output per unit time was similar for both control and low temperature boars, but, epididymal reserve sperm numbers for the low temperature boars was larger than for the controls; a factor considered due to the greater size of the low temperature boar testes (Swierstra, 1970).

The process of spermatogenesis in most animals proceeds through a number of well defined stages within the seminiferous epithelium (Leblond and Clermont, 1952). Definition of the spermatogenic stages, within the seminiferous epithelium has enabled the degeneration of different stages at spermatogenesis to be predicted, if the time interval between exposure and autopsy is known. The rate of degeneration of susceptible cells varies greatly (Chowdhury and Steinberger, 1964). Heat susceptible cells in the spermatogenic process of the rat have been divided into three separate categories by Chowdhury and Steinberger (1964), (i) cells which degenerate and disappear from the seminiferous tubule within two days following heat exposure, (ii) cells apparently capable of some differentiation into more advanced stages before degeneration and disappearance and (iii) cells capable of considerable development and differentiation, including division and formation of spermatids. These spermatids disappear within 8 to 26 days after exposure.

In the spermatocycle, the earliest detectable change is an abnormal cytochemical reaction in the cytoplasm. Changes in the nucleus of the spermatid do not become obvious until cytoplasmic changes are intense. As morphological abnormalities are absent immediately, or shortly after exposure, it appears that the effect of elevated temperature may be via some metabolic activity in the susceptible cell, which only brings about visible morphological damage on reaching a certain stage in its development (Chowdhury and Steinberger 1964).

The young spermatid, a cell not undergoing division, nor preparing to do so, is also highly susceptible to elevations in scrotal temperature. Initial changes occur within the nucleus, where the chromatin granules accumulate around the nuclear membrane. This subsequently thickens and a vacuole forms in the centre of the nucleus. Chromatin material accumulates more at one pole of the nucleus than the other. The pole about which accumulation occurs is invariably near the golgi zone, the area of further development of the acrosomic granule. With time, the entire nucleus shrinks to form a compact mass around the vacuole to result in the classic ring formation of the spermatid.

Exposure of male animals to elevated ambient temperatures, may not only alter the process of spermatogenesis, but may also influence hormonal characteristics of the animal.

(2) Breeding Pig Performance.

A number of adverse effects have been attributed to elevated environmental temperatures on sow reproduction.

(a) Attainment of puberty. Information on the effect of air temperature on the attainment of sexual maturity in the gilt is scant. Schmidt and Breitscheider (1954) observed that gilts born in the cold season attained sexual maturity earlier (3-7 months) than those born in the warm season (5-13 months). This phenomenon was attributed to ambient temperature, but a daylight effect cannot be ruled out. That moderately cold temperatures may enhance the onset of puberty in gilts has received limited support (Burger 1952).

There does not appear to be any information available as to the direct effect of high temperatures on the attainment of puberty.

(b) Oestrous cycle. Warnick et al. (1965) and Teague, Roller and Grifo (1968) reported that gilts housed in climatically controlled chambers, at temperatures over 30°C were less likely to display oestrus (up to 10% failed to display oestrus at 33°C) despite exhibiting a normal cycle before and after treatment. In contrast, Edwards et al. (1968) and D'Arce et al. (1970) reported no depression in the number of gilts displaying oestrus under similar conditions.

In the tropical climate of Nigeria, Steinbach (1972) reported that about 10% of gilts became anoestrus during the hottest season of the year (mean effective temperature 26°C), whereas, less than 5% were affected in the cool season. He also observed, that the average duration of the oestrus period was negatively correlated with temperature. The proportion of periods lasting for more than two days were significantly lower in the hot season, than in the cool season.

Moderately high environmental temperatures (37°C), as reported by D'Arce et al. (1970) and Steinbach (1972) do not appear to affect the actual length of the oestrus cycle. Nevertheless, by imposing

temperatures so severe that several gilts died from "heat stress", Edwards et al. (1968) observed that the oestrous cycles of the survivors were almost two days longer before the treatment was imposed.

(c) Interval weaning-oestrus. Magnani and Casati (1966) in an analysis of data relating to 282 crossbred sows (Large White x Spotted Poland-China x Chester White) reported that the interval from farrowing to first oestrus varied significantly between months. The interval was notably longer during the summer months. To date, no evidence is available to support this observation.

(d) Ovulation rates. It has been suggested (Warnick et al., 1965; Teague et al., 1968; D'Arce et al., 1970) that ovulation rate may be slightly reduced in heat-stressed gilts. This is particularly when the period of exposure to a high temperature occurs several days prior to ovulation. With the exception of this possible effect, exposure to elevated ambient temperatures before service (as distinct from post mating) appears to have little effect on the conception rate, or the number and size of the embryos during the subsequent pregnancy.

Edwards et al. (1968) reported that the number of corpora lutea in a cool environment exceeded that in a warm one. This is in agreement with the work of Teague et al. (1968) who found that with gilts maintained at ambient temperatures of 27°C, 30°C or 33°C for one cycle prior to breeding, as the air temperature increased, ovulation rate was significantly reduced, the number of corpora lutea present being 14.2, 13.7 and 13.1 respectively. This suggests that there could be a possible interaction between temperature, feed intake and ovulation rate, with decreased feed intake possibly

explaining the reduction in ovulation rate. Warnick et al. (1965) however, found no effect on ovulation rate of an air temperature of 16°C compared to 32°C .

With respect to very low temperatures Dyck (1974) reported no effect of cold stress on ovulation rate and that in Western Canada, where winter temperatures are as low as -30°C , the absence of housing had no effect on ovulation rate.

(e) Fertilization and conception rates. Fertilization is sensitive to both hyperthermia and hypothermia (Scofield, 1972). Fertilization rate may be reduced and the occurrence of morphologically abnormal ova is more frequent during hot weather and in animals exposed to artificially high temperatures (Hafez, 1964). Whether the harmful effect results directly from hyperthermia or from an endocrine imbalance resulting in an unfavourable environment in the oviducts is uncertain.

With regard to conception rate it appears heat stress for several days immediately prior to mating may have a reduced conception rate, but if the heat stress is for only a short period (approximately 1-3 days) little or no apparent change in conception rate is found to occur (Warnick et al., 1965).

Knowledge of the effect of a low ambient temperature on conception rate in the gilt is limited. Dyck (1974) was unable to find any difference in conception rates for gilts kept in open yards at air temperatures ranging from -12°C to -22°C , as opposed to those kept in a heated piggery at a temperature of 10 to 15°C . It is possible that the minimum of shelter and bedding used in this study reduced the effects of the cold. In contrast, Swiestra and Rannefeld (1972)

found that conception rates increased significantly as ambient temperature decreased from -10°C to -25°C for gilts housed in open pens in groups of 14-20. In this study, however, all conception rates were fairly low.

Fertilization and conception rates may both be altered due to the environmental temperatures to which the animal is exposed; extreme elevations or depressions in air temperature are required to significantly alter these reproductive parameters.

(f) Embryonic mortality. The effects of ambient temperatures on embryonic mortality are well documented and have been reviewed by Scofield (1972). It is generally believed that low ambient temperatures per se have no harmful effect on reproduction in farm animals (Yeates and Parer, 1962). The most serious effects of cold stress on reproduction are usually indirect ones involving interference with mating, parturition and changes in nutritional requirements. Dyck (1974) has found no effect of cold stress on foetal survival though the same worker has found that heat stress in early pregnancy reduces embryo survival. This latter finding agrees with the work of Warnick et al. (1965) and Edwards et al. (1968) but not with Teague et al. (1968) who failed to show a significant effect.

(i) Implantation. Slight, but statistically non-significant reductions in embryonic survival were reported by Tompkins, Heidenreich and Stob (1967) in sows exposed to a temperature of 35°C from day one for 24 or 48 hours, and in another group exposed to the same temperature until day five of pregnancy. Sows subjected to a greater elevation in temperature (37°C) from the first until the fifth day of pregnancy displayed more dramatic effects; eight

out of 22 died and, embryonic survival in the remainder was reduced to 39 percent. The controls, kept at a lower temperature, had a 69 percent embryonic survival. An extension of the heat stress period (37.8°C for 17 hours and 32.2°C for seven hours from day 0 until day 8 of pregnancy) in gilts, reduced conception rates (43% returned to oestrus) and significantly reduced embryonic survival compared with controls maintained at 23.3°C (Omtvedt et al., 1971). In the same trial a further group of gilts subjected to similar heat stress at 8-16 days post-implantation resulted in a smaller proportion of returns to oestrus than the 0-8 day stressed group, and the embryonic survival rate of this group was only reduced to 43 percent. In an earlier study, Edwards et al. (1968) reported a reduction, both in conception rate (36% returned to oestrus) and in embryonic survival rate (59.7%, compared with 83.2% in a control group) when gilts were subjected to a heat stress of 38.9°C and 32.2°C for 17 hours daily, during the first 15 days of pregnancy.

In summary, it appears that exposure of the sow or gilt to extreme heat during the preimplantation period (0-14 days after mating) undoubtedly has adverse effects on embryonic survival, either by partial or total litter losses. The mechanism by which the raised maternal body temperature affects egg and blastocyst development in the sow or gilt is not yet clear.

(ii) Mid-gestation. After 15-30 days of gestation, it appears that the uterus of the gilt or sow is well buffered against temperature fluctuation (Heitman et al., 1951; Edwards et al., 1968). Exposure of the sow or gilt to high air temperatures following implantation; between days 11 and 20 of pregnancy (Nalbandov, 1964), appears to have little or no direct effect on either pregnancy or foetal development and survival (Heitman, Hughes and Kelly, 1951; Tompkins et al., 1967;

Edwards et al., 1968 and Omtvedt et al., 1971) despite the fact that temperature elevation was such that many sows and gilts died of hyperthermia.

(iii) Late gestation. Steinbach (1971) reported that season of the year considerably affected the mean percentage of stillborn piglets of a herd of sows in tropical Nigeria. Sows which farrowed during March and April (when high temperatures and extremely high humidity prevails) had up to 10-12 percent stillborn piglets, compared with only 5-6 percent for sows farrowing at other times of the year. Losses of sows from heat-stroke also occurred during this March and April period, but only involved sows in the latter stages of pregnancy. In contrast to this report, Kernkamp (1965) found no significant seasonal variation in the stillbirth rate in pigs kept in a temperate climate.

Gilts exposed to high ambient temperatures (37.8°C for 17 hours and 32.2°C for 7 hours daily) for 8 days (day 102 until day 110 of pregnancy) in the study by Omtvedt et al. (1971) resulted in almost 50 percent of the piglets being dead at farrowing. However, while the authors in their report referred to the piglets dead at farrowing as stillborn, it is not clear whether they were true stillbirths. The weight of piglets born alive appeared to be very slightly lower on average than those from the controls, and postnatal survival (at 3 weeks) in litters from "heat-stressed" gilts was only 72 percent. Survival rate in the litters born by the control sows was 88.5 percent.

The mechanisms whereby heat-stress during the latter stages of pregnancy increases the loss of foetuses or piglets is unknown, and the pathological effects themselves are poorly defined. Possible reasons for these losses were considered in the earlier General section.

(g) Semen characteristics and libido. The deterioration in reproductive performance of the boar subjected to heat stress is manifested by a reduction in libido (direct) and through reduced semen quality, and/or a fall in the number of conceptions achieved per service (indirect). Steinbach (1972) reported that the reduction in libido of heat stressed boars (determined by the boars interest to mount a dummy sow and ejaculate) to be directly proportional to the environmental temperature. During the warmest month, refusals were approximately 16 percent, compared with no refusals during the cooler months. He also reported that, boars which did ejaculate, tended to take longer to do so in the heat. There was a time lag of about two months between the coolest month and the shortest ejaculation time.

The thermoregulatory mechanisms of the scrotum and testis of the boar have been studied by McNitt, Tanner and First (1972a, b). The boar, like most other male mammals, when exposed to high environmental temperatures may produce impaired semen. It has been suggested that temperature per se does not affect the fertility of the boars to such an extent as does sudden increases in temperature. This upsets the boar's body and scrotal thermoregulatory mechanisms. Boars reared and used in the tropics and therefore acclimatized to high temperatures are considered no less fertile than those in temperate areas (Ebunike and Steinbach, 1972)

By using direct application of heat to the scrotum of the boar, Mazzari, du Mesnil du Buisson and Ortavant (1968) raised the testicular temperature to 40°C for just three hours and yet reported a marked decrease in sperm concentration and motility in semen samples collected from the end of the second until the eighth week subsequent to treatment.

In a more recent study McNitt and First (1970), using boars previously acclimatized to 21.5°C , exposed their subjects to an environmental temperature of 33°C (relative humidity 50%), resulting in an elevation of rectal temperature of $2-3^{\circ}\text{C}$. Semen samples collected from these boars had reduced sperm concentration and motility, and increased proportions of morphologically abnormal and dead spermatozoa. Semen volume remained unaffected. In addition to the detrimental effects on semen quality from short term heat stressed boars, Christenson et al. (1972) reported a marked reduction in the percentage of gilts pregnant when inseminated with such semen.

The initial influence of elevations in testicular temperature on semen characteristics reported by McNitt and First (1970) was an increase in the proportion of primary spermatozoan abnormalities; mainly spermatozoa with tails tightly coiled around the midpiece, and others with abnormally formed heads. A decrease in sperm motility then occurs. By about day 24 after exposure, morphological abnormalities (mainly tail-less heads and sperms with distally coiled tails) begin to appear in appreciable numbers. The authors reported that decrease in total sperm concentration then occurred but by day 56 all semen characteristics had returned to normal. In a more recent study Wetterman et al. (1973) reported similar findings when they exposed boars to an environmental temperature of 30°C for a long duration.

An elevation in the rectal temperature of boars suffering from illness, displaying fevers, may produce spermatozoan abnormalities (particularly multiple-head spermatozoan) and infertility (Kojima, 1973).

Knowledge of spermatozoan development and maturation in the boar (described by Swierstra, 1968) enabled McNitt and First (1970) to

propose that primary spermatozoan abnormalities were mainly the result of heat damage at the late primary spermatocyte, secondary spermatocyte and early spermatid stages. Later effects, especially the reduction in sperm concentration, resulted from damage in the mid-primary spermatocyte. The same workers concluded that a general weakening of the spermatozoa throughout the entire development period, was responsible for secondary spermatozoan abnormalities apparent by day 24 after heat exposure.

C. Indirect Factors.

(a) Nutrition.

Reviews on the nutritional effects on reproduction in domestic animals have been given by Reid (1960) and Moustgaard (1969) and in pigs by Brooks and Cooper (1972), Lodge (1972) and Elsley and McPherson (1972). It is not the intention of the author to give a comprehensive account of specific patterns of feeding on reproduction in the pig (see Wrathall, 1975). Nevertheless, in contrast to most other species of domestic livestock, the pig is often hand fed on measured quantities of food which are below its voluntary energy intake. Partly for these reasons, and also because the pig is a monogastic, managerial decisions on the relative amounts of dietary constituents incorporated in a ration and the level at which it is fed, is of utmost importance.

Results obtained from numerous studies conducted, suggest that provided the energy, protein, vitamin and mineral content of a ration, along with the level fed conform to the recommendations of the Agricultural Research Council (A.R.C., 1967), there should be no

impairment of reproductive performance.

Increased ovulation rates have been reported to occur when rations of very high energy content are fed before or during oestrus (Wrathall, 1971; Anderson and Melampy, 1972) although an adverse effect on embryonic survival may result if such is fed during early pregnancy (Scofield, 1972; Anderson and Melampy, 1972). Apart from a reduction in the birth weights of piglets born to sows fed very low protein diets (Pond et al., 1969) there appears to be a very wide margin of safety in the protein content of a ration in regard to it affecting reproduction in the pig. The accepted level of crude protein in a ration fed to breeding pigs is approximately 14%. It appears the quality of protein is more important; essential amino acids such as tryptophan, lysine, methionine, isoleucine, leucine, arginine, histidine, threonine, valine and phenylalanine if limiting, will impair reproductive performance of the pig. Although current knowledge of the vitamin and mineral requirements for reproduction in pigs is based on unsatisfactory and often equivocal, evidence suggests deficiencies will reduce the reproductive performance. A detailed account of vitamin and mineral deficiency associated disorders in pigs is given by Wrathall (1975).

Ingestion of harmful chemical substances by pigs will often seriously effect their reproductive performance. It is beyond the scope of the present review to give a detailed account of the effects; such a review is also given by Wrathall (1975).

(b) Health status

The basic immune status of an animal is established by a combination of many factors. These include genetic, anatomical,

physiological, humoral and cellular elements. In addition, further influence on the animals immunity is from its past and present exposure to parasites, to toxins and to pathogenic organisms distributed throughout the biosphere. Climatic, dietary and stress factors also play an influential role. It is not the intention of the author to give a detailed account of the mechanisms by which the environment are thought to effect the immunity to disease of an animal.

Although the mechanisms by which diet influences immunity to disease remain to be determined fully, it appears that if adequate levels of a balanced diet (energy, protein, vitamins and minerals) are fed, immunity of the recipient will be enhanced.

The disease defence systems of the respiratory and gastrointestinal tracts are directly affected by housing and animals in situations of low relative humidity, high temperatures and sudden changes in temperature (Schaedler and Dubos, 1962). Lower winter temperatures and associated air movements may create a tendency towards an increased incidence of weak piglets and mortality from respiratory diseases (Mount, 1968).

(c) Other biotic factors.

Communication between animals within a species via sensory organs by visual, tactile, olfactory and auditory stimuli, frequently occurs. Such stimuli are often termed the social component of the environment. The cumulative effect of such stimuli may give rise to both immediate and delayed responses manifest either physiologically, behaviourally or both. Evaluation of the relative importance of such stimuli in variations of reproductive performance has therefore been difficult.

The role of biotic stimuli in the manipulation of the reproductive processes in domestic animals has been reviewed by Clegg and Doyle (1967) and in ungulates by Fraser (1968). Summaries of these topics with special reference to the pig have been given by Baldwin (1969), Signoret (1971, 1972) and Wrathall (1975). The authors concluded that although the evidence for a role seem irrefutable, these senses involved were inter-related, but not one of them was absolutely essential.

On the evidence available, it is assumed that the factors mentioned in this section are less important than light and temperature in most species. However, the role of social and behavioural factors in the normal reproductive processes of the pig, although a relatively recent topic of study, is assuming greater importance.

CHAPTER TWO

MATERIALS AND METHODS

Data for the analysis undertaken came from the records of the Massey University Pig Research Centre collected over a seven year period, commencing September 1970 and concluding August 1977.

(1) The herd and its management.

(a) Size and structure. During the relevant seven year period, the mean herd size was around 50 breeding females and four breeding males. Two breeds of females were kept, namely, purebred Large Whites (55%) and first cross Landrace x Large White sows and gilts (45%). All boars used in the herd were of Landrace origin. The sows in the herd varied in age from young gilts to 12th litter sows. All members of the herd were individually ear marked.

(b) Replacement policy. The herd numbers of Large White sows and Landrace boars were maintained by unmated gilt and boar replacements brought in on a regular (three monthly) basis from the New Zealand National Pig Breeding Centre of the Pork Industry Council, with the Research Centre herd acting as a crossbred multiplier for this nucleus herd.

Replacements for the crossbred sow herd were bred at the Massey University Pig Research Centre.

(c) Health Status. Blood samples taken periodically from breeding and growing stock during the seven year period, showed Leptospira

pomona and porcine parvovirus to be endemic. However, due to a general absence of abortion and foetal mummification, neither was considered to be of any major significance in terms of sub-fertility. All stock entering the herd were allowed contact with mature sows from the time of selection to first mating and were routinely vaccinated against leptospirosis during their first pregnancy.

(d) Housing. Following weaning from individual farrowing pens, sows were held in groups until mated, in semi-enclosed pens (Fig. 2.1), adjacent to the boars. Immediately after mating they were transferred to individual sow stalls, located in a totally enclosed insulated room (Fig. 2.2), where they remained for approximately four weeks. Subsequently, they were grouped into batches of five and transferred to covered pens incorporating individual feeding bails for a further eight weeks (Fig. 2.3), and finally for the last four weeks of pregnancy were moved to open pasture with access to shelter. Sows were transferred to the farrowing pens about one week before their anticipated farrowing date.

Unmated gilts were kept in semi-enclosed pens with individual feeding facilities, until mated at approximately 100kg liveweight, and also during their first pregnancy.

Boars were housed individually in semi-enclosed pens through their working life on the unit.

(e) Mating system. Sows were mated at least twice, under supervision, during their first oestrus following weaning. The interval between successive matings varied from about 8 to 16 hours. Gilts were similarly mated at approximately their third post-puberal oestrus.

(f) Time of weaning. During the first two years of the seven year



FIGURE 2.1



FIGURE 2.2



FIGURE 2.3

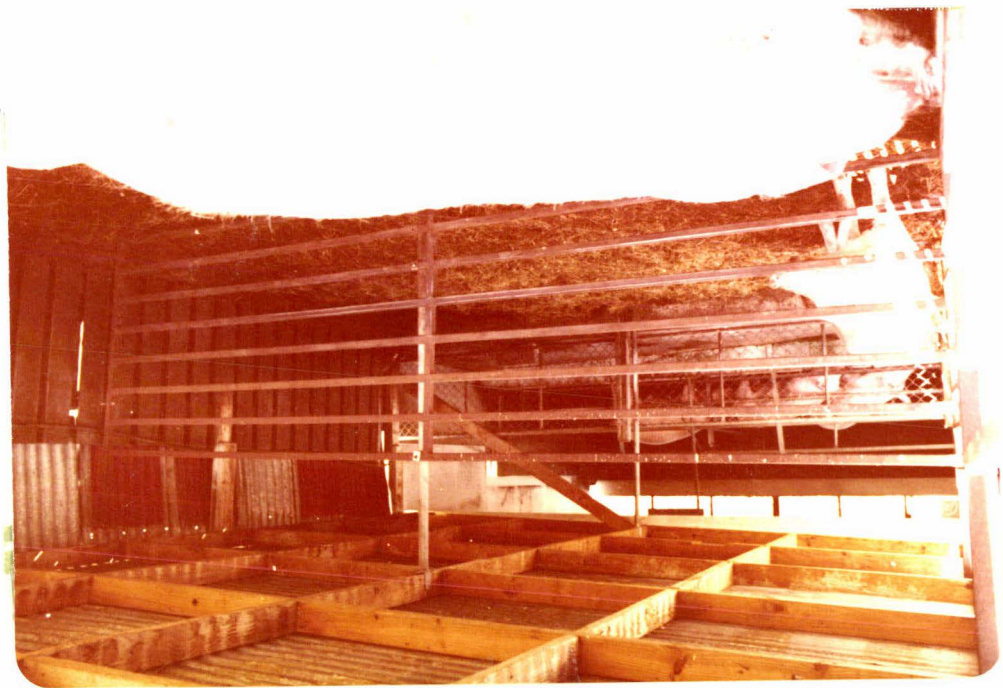


FIGURE 2.4

MONTHLY NUMBER OF SERVICES AND RESULTANT FARROWINGS AND RETURNS

FOR A HERD OF SOWS OVER A SEVEN YEAR PERIOD

Method of Service	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
YEAR : 1970												
Total No. Services									10	5	16	9
No. Farrowings									9	3	12	0
No. Returns									1	2	4	9
YEAR : 1971												
Total No. Services	21	6	7	18	5	16	8	6	25	6	16	14
No. Farrowings	16	3	5	3	3	11	6	5	14	4	13	5
No. Returns	5	3	2	2	2	5	2	1	11	2	3	9
YEAR : 1972												
Total No. Services	26	12	11	18	16	15	10	12	16	23	9	10
No. Farrowings	10	7	6	14	15	12	7	7	9	14	8	6
No. Returns	16	5	5	4	1	3	3	5	7	9	1	4
YEAR : 1973												
Total No. Services	16	23	15	18	6	10	13	14	12	14	8	12
No. Farrowings	8	13	12	16	6	9	13	13	11	12	6	7
No. Returns	8	10	3	2	0	1	0	1	1	2	2	5
YEAR : 1974												
Total No. Services	21	13	15	9	10	12	14	18	7	13	16	15
No. Farrowings	12	11	12	7	10	11	12	16	5	10	14	12
No. Returns	9	2	3	2	0	1	2	2	2	3	3	3
YEAR : 1975												
Total No. Services	11	13	13	14	13	6	17	11	12	10	11	15
No. Farrowings	7	12	12	13	11	5	13	10	9	6	4	12
No. Returns	4	1	1	1	2	1	4	1	3	4	7	3
YEAR : 1976												
Total No. Services	16	22	21	9	16	9	9	21	17	15	11	20
No. Farrowings	5	13	16	8	13	5	6	14	10	12	7	11
No. Returns	11	9	5	1	3	4	3	7	7	3	4	9
YEAR : 1977												
Total No. Services	16	19	20	14	11	13	12	17				
No. Farrowings	11	9	12	8	6	6	5	13				
No. Returns	5	10	8	6	5	7	7	4				

period, piglets were weaned at approximately three weeks of age. The length of the suckling period was extended to approximately five weeks for the rest of the period. Weanings were undertaken on the Thursday of each week in an attempt to avoid weekend services.

(g) Feeding. With the exception of pregnant sows on pasture, breeding stock, comprising gilts from the time of selection, lactating sows, gestating sows and boars were fed on the same diet during the entire seven year period. The composition of this diet, which was prepared from straights at the University Feed Centre, is given in Appendix I. Grazing sows were fed a pelleted meal as a supplement to grazing, the composition of this diet is shown in Appendix II. The daily quantities of feed allowed were as follows:

	Daily Feed Allowance (kg)
Unmated gilts	2.5
Weaned sows	3-4 (day of weaning to day of mating)
Gestating sows - housed	2-2.5 (post mating)
- grazing	1-2.5
Lactating sows	5-6 (approximately 5 weeks)
Boars	2.5-3.0 (according to body condition)

(h) Parasite control. All sows were treated routinely with an anthelmintic (dichlorvos) just prior to transfer to the farrowing quarters and again at weaning. Gilts were likewise treated at selection and boars four times yearly.

External parasites were controlled by spray (lindane) on transfer to and from the farrowing quarters and when deemed necessary at other times.

(2) Collection of data and statistical analysis. The data used for examination were those which had been collected for normal herd recording purposes during the seven years, and included individual sow, mating and farrowing records. The record of each service was taken as the prime observation. It contained (data of) the date of matings, the breed and parity of the sow (the number of litters the sow had borne prior to the service), the return or farrowing date, and where applicable, the number of piglets born alive and dead.

With regard to the number of prime observations (1,144 for the seven year period), a calendar month was chosen as the unit of time in this study. The monthly number of services and the resultant number of farrowings and returns, for each year are summarized in Table 2.1.

(3) Measures of fertility. The fertility of a breeding animal is a function of several factors. With regard to the information available, the measures of fertility used in this study were; farrowing rate, return to service pattern and litter size at birth.

Farrowing rate is defined as - number of farrowings to service
 $\times \frac{100}{1}$.

The observations of return to service (RTS) pattern were classified as either "normal" or "abnormal", on the basis of the length of the RTS interval. The observations included in the normal group, had an interval of 18-24 or 36-48 days inclusive. In these sows, implantation was considered to have failed, although in some sows with a 36-48 RTS interval, implantation may have occurred and for some reason had subsequently been followed by embryonic loss. The RTS intervals of

25-35 and greater than 49 days in length were classified as abnormal. In these cases, implantation was considered to have taken place, but had been followed by either embryonic mortality, loss of conceptus or abortion, resulting in the sow returning to oestrus. However, in some of the sows displaying oestrus 61-80 days following mating, implantation may not in fact have taken place. Although in this case oestrus may have passed undetected, it is more probable that these sows displayed silent oestrus.

The variables of litter numbers at birth chosen as a measure of the fertility of farrowings were: the total number of births born per litter and the number of live births per litter. A difference between the two may result from loss of conceptus during the latter stages of pregnancy when resorption does not occur.

(4) Statistical analyses. All analyses for examining seasonal variation in fertility were on a monthly basis (the month of mating).

The farrowing rate and the return to service pattern data were each analysed in two ways. Each service was considered an observation in the first analysis, whereas only initial observations (these included the first service of a gilt and the first post-weaning mating of older sows) were considered in the second analysis. In the latter case, any possible bias in the observations resulting from correlations between the outcome of first and subsequent matings of the same animal, was eliminated. Monthly farrowing rates were replicated across years, as were the monthly proportions of return to service intervals of abnormal length. In order to improve the normality of distribution and stabilize approximately the variance, the total number of services and the number of resultant farrowings in each month were transformed

according to the Freeman-Tukey variance stabilizing arc-sine transformation (Freeman and Tukey, 1950). The monthly total number of returns and the number of abnormal returns per month were also subject to the same transformation. The transformed data for each analysis was subjected to an analysis of variance, represented by the models below. Due to unequal subclass numbers and the existence of empty cells, the analyses of variance were conducted using the fitting constants method (Yates, 1934). The computing packages minitab and GLIM were used in performing the analyses.

The basic model is that of a two-way cross classification with interaction. The equation of the model is:

$$y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + e_{ijk}$$

where μ is the overall mean, α_i the fixed effect of breed of dam ($i = 1$ or 2), β_j the fixed effect of month of service relevant for the k^{th} observation, $(\alpha\beta)_{ij}$ the individual interaction effects of α and β , and e_{ijk} the error peculiar to the k^{th} observation.

Four of the basic two-way cross classification with interaction models were used to analyse observations for; the monthly farrowing rate to all services (Model 1), the monthly farrowing rate to initial services (Model 2), the proportion of returns to all services of abnormal length per month (Model 3) and the proportion of returns to initial services of abnormal length (Model 4). The interaction effect was excluded in Models 3 and 4 due to empty and limited numbers of observations per cell. Similarly, the fixed effect, breed (i), was excluded from Models 3 and 4 as breed was found to be non-significant in accounting for variations in the proportions of returns, of abnormal length when analysed using the two-way classification model

(Models 5 and 6).

The data on litter numbers at birth; total number of piglets born per litter (Model 7) and the number of piglets born alive per litter (Model 8), were each subjected to an analysis of variance according to the model

$$y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + (\beta\gamma)_{jk} + e_{ijkl}$$

where y_{ijkl} is the observation on the l^{th} sow of k^{th} parity, mated in i^{th} month and, of the j^{th} breed, μ is the overall mean β the fixed effect of breed of sow ($j = 1$ or 2), α the fixed effect of the month of service from which the farrowing resulted, γ the fixed effect of parity (0 represents gilts and first litter sows, 1 represents sows that have borne two or more litters), $(\alpha\beta)_{ij}$ the individual interaction effects of α_i and β_j , $(\alpha\gamma)_{ik}$ the individual interaction effects of α_i and γ_k , $(\beta\gamma)_{jk}$ the individual interaction effects of β_j and γ_k and e_{ijkl} the residual error unique to e_{ijk} (All e_{ijk} were assumed $N = 0$ As both variables are discrete, normality cannot be assumed likely. Examination of the data on both litter size at birth variables indicated that a transformation was unnecessary.)

Multiple comparison test

Differences between the various levels of the fixed effect month of service, for the farrowing rate and return to service data were tested for significance using the least significant differences test.

TABLE 3.1

MONTHLY DIFFERENCES (%) IN FARROWING RATE TO ALL SERVICES
RECORDED DURING EACH MONTH (RELATIVE TO MONTH SHOWN IN
LEFT HAND COLUMN)

[illegible]

CHAPTER THREE

RESULTS

(A) Farrowing Rates.

Overall, 801 services recorded over the seven year period were successful : a farrowing rate of 70%.

(1) Influence of month of mating. When all services recorded during each month of the year were taken into consideration, month of service significantly influenced ($P < 0.05$) the farrowing rate of sows and gilts in the herd (Appendix III).

Figures given in Table 3.1, which summarize the monthly differences in farrowing rate, show that matings which occurred during December resulted in a significantly lower farrowing rate than matings that took place during the remaining months of the year except those in January and February. The farrowing rate for both January and February matings were also significantly lower than that for some months of the year.

The depressed farrowing rate of matings during December, January and February are shown in Figure 3.1 where actual farrowing rates to all services recorded on a monthly basis are given.

When initial services only, recorded during each month, were taken into consideration, subsequent farrowing rates were again significantly influenced by the month of mating ($P < 0.01$) (Appendix IV). Reference to Table 3.2, in which the monthly differences in farrowing rate to initial services are summarized, the matings of December resulted in

FIGURE 3.1 Mean effect of month of service
on farrowing rate to all recorded
services.

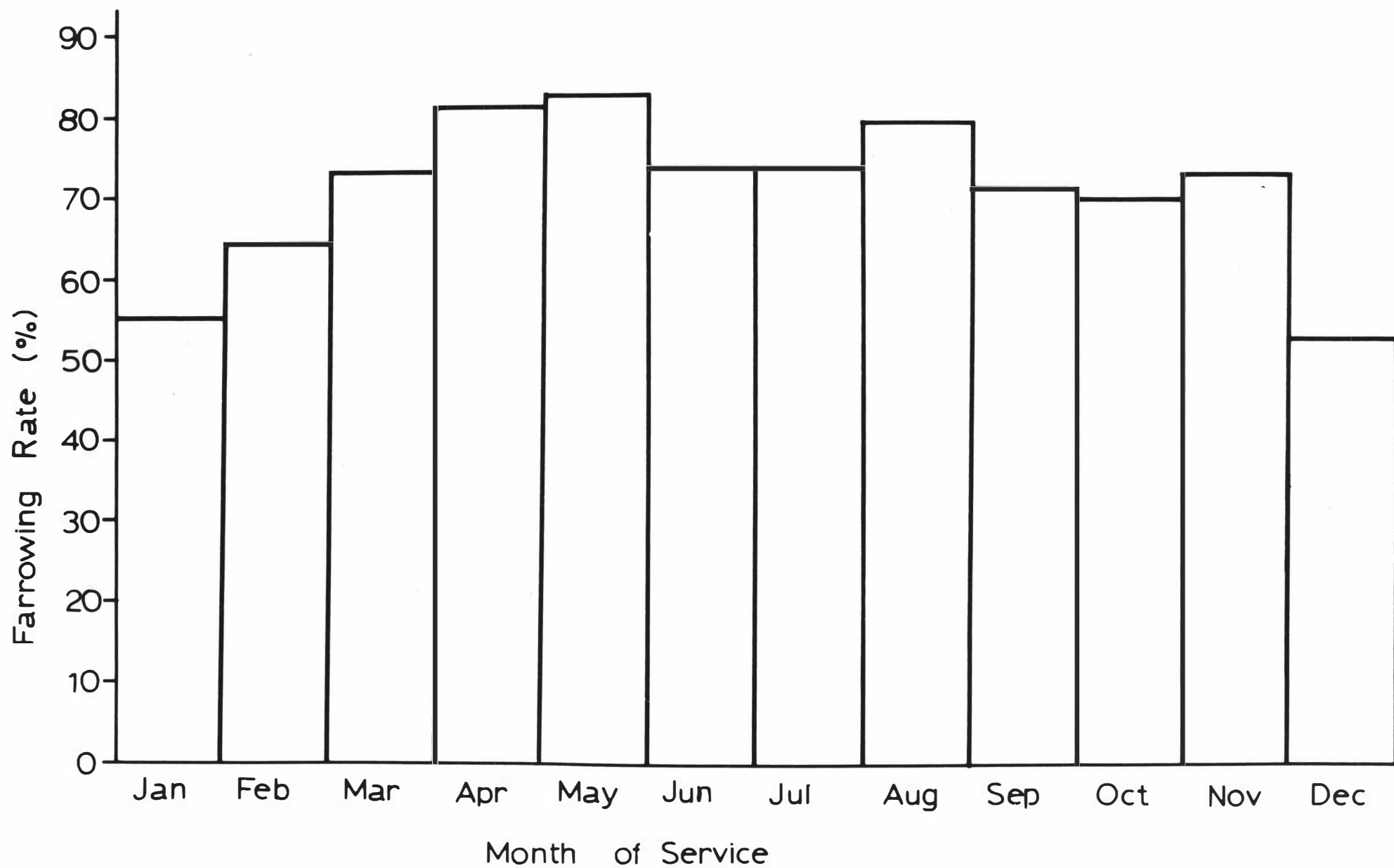


TABLE 3.2

MONTHLY DIFFERENCES (%) IN FARROWING RATE TO INITIAL SERVICES
ONLY RECORDED DURING EACH MONTH (RELATIVE TO MONTH SHOWN IN
LEFT HAND COLUMN)

[illegible]

significantly depressed farrowing rates when compared to other months of the year. January and February matings too resulted in significantly lower farrowing rates than for some matings in other months of the year. The farrowing rate of September matings was significantly lower than April matings. Figure 3.2 is a graphical representation.

(2) Influence of breed. In respect of all services recorded each month, Landrace x Large White sows and gilts had a higher farrowing rate overall than did purebred Large White breeding females ($P < 0.05$) (Appendix III). Reference to Figure 3.3 shows that the breed difference in favour of the crossbred dams was 5 % units.

The first order breed x month of mating interaction was not significant ($P > 0.05$) indicating that the effect of month of mating (all services) on farrowing rate was similar for the crossbred and purebred sows and gilts.

With reference to initial services only, recorded on a monthly basis, the farrowing rate for the crossbred Landrace x Large White and purebred Large White sows and gilts was not significant ($P > 0.05$) (Appendix IV). Figure 3.3 depicts the farrowing rates to initial service for both purebred and crossbred sows and gilts.

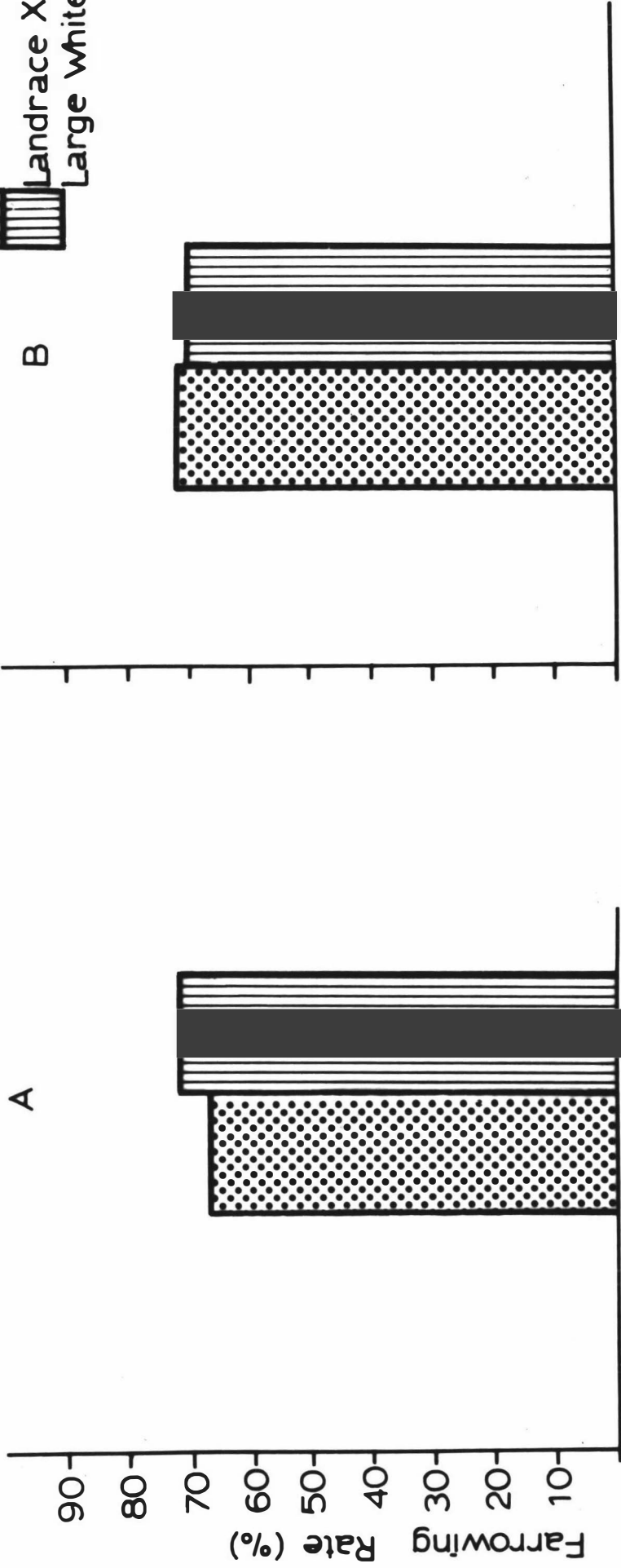
(B) Return to Service Pattern.

Overall, the proportion of returns to service which were of abnormal length, i.e. 25-35 and greater than 49 days post mating, was 44.9%. This figure was significantly influenced by month of service ($P < 0.05$) but not by the breed of the dam (purebred or crossbred) (Appendix V).

Figures given in Table 3.3 show the months in which the proportion

FIGURE 3.2 Mean farrowing rate of purebred and crossbred
sows

A = all services B = initial services only



Large White
Landrace X
Large White
B

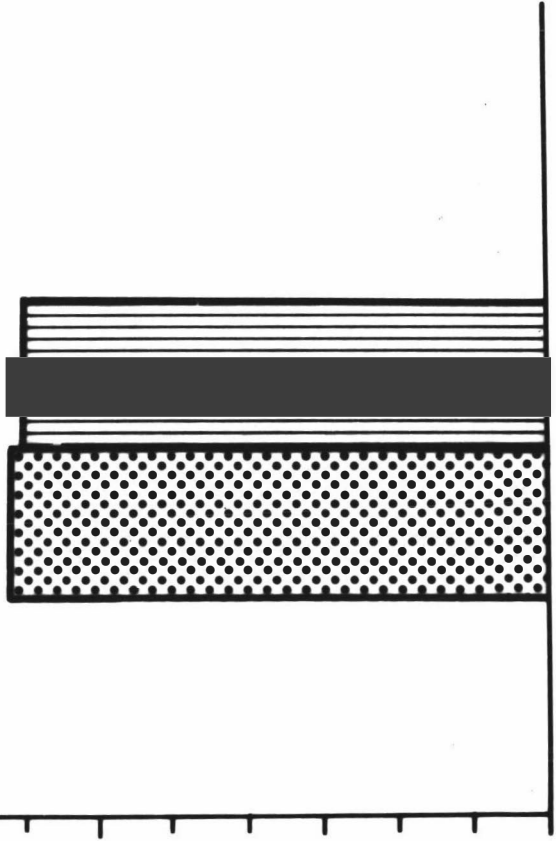
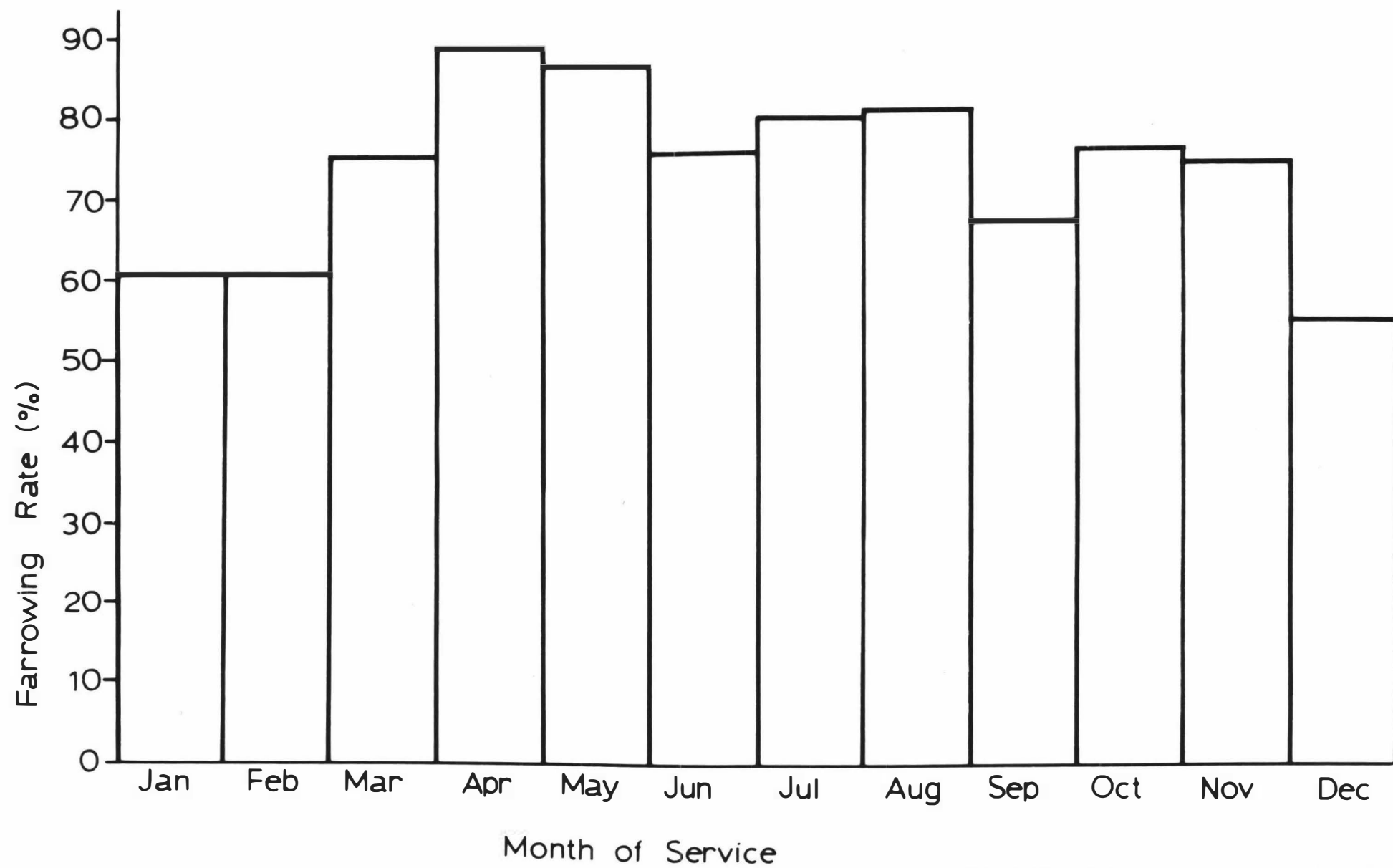


FIGURE 3.3 Mean effect of month of service on
farrowing rate to initial services only

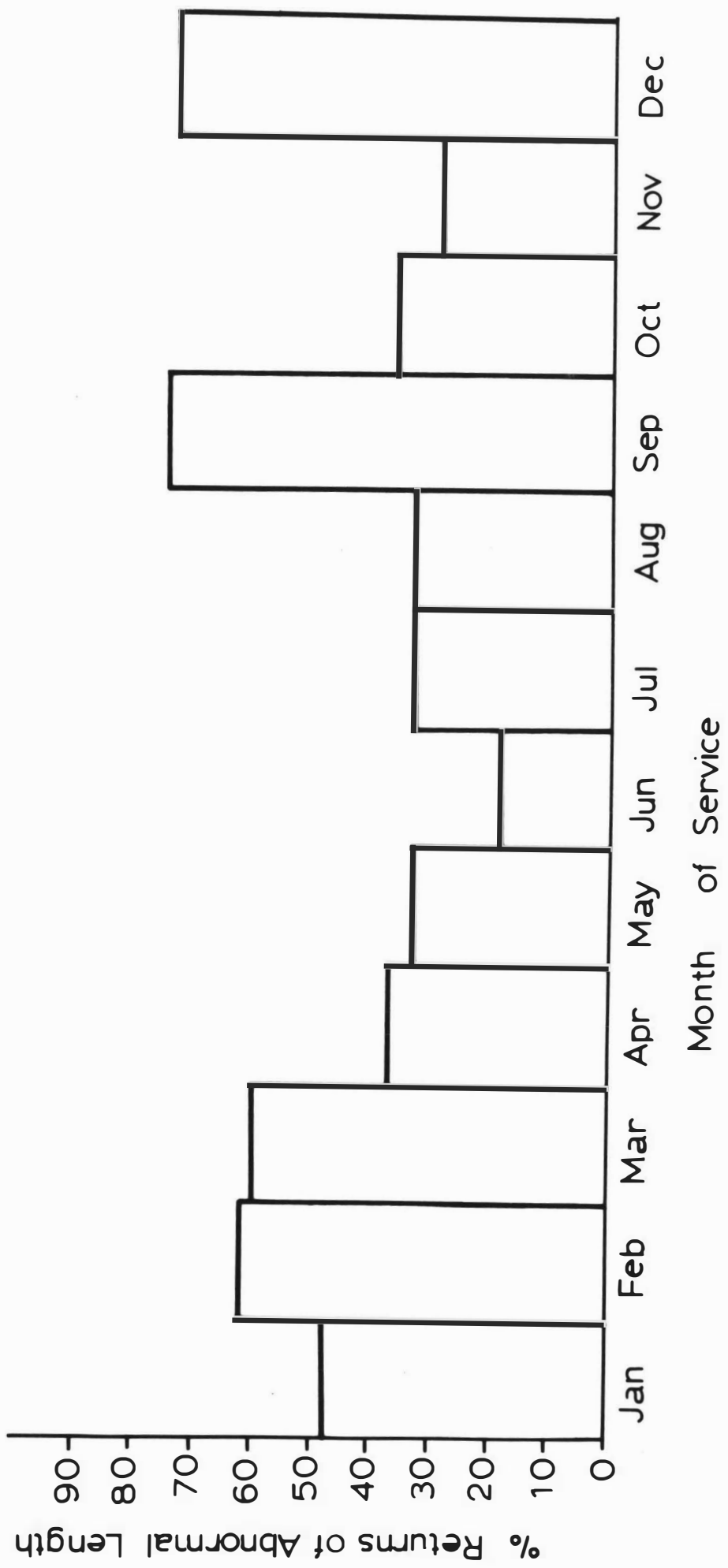


of returns of abnormal length to all services are significantly different. The proportion of abnormal length returns that resulted from the December matings was significantly higher than the proportion that occurred from matings during many other months of the year. Matings which took place during September also resulted in a significantly greater proportion of returns of abnormal length. During September, the proportion of abnormal returns was greater for some years than others but, nevertheless, the magnitude of abnormal returns during this particular month was in general larger than for most months of the year. A significant difference was also apparent for the months of February and March when compared with June, a month in which very few matings resulted in returns of abnormal length. However, analyses of the influence of the month of mating on the proportion of returns of abnormal length excluding breed in the Model (Model 5) showed no significant difference between the months ($P > 0.05$).

The overall effect of month of mating on the actual percentage of returns of abnormal length to all services is shown in Figure 3.4. In the months December, February, March and September, the relative proportion of returns abnormal in length were higher than those for the remainder of the year.

The month of service significantly affected the proportion of returns to service abnormal in length ($P < 0.01$), according to Model 4. Breed of sow, a fixed effect of Model 4, was not significant (Appendix VII). Significant differences between the monthly proportion of returns to service of abnormal length ($P > 0.05$) remained when breed was excluded as a main effect (Model 6). From the summary given of the influence of month on the proportion of returns abnormal in

FIGURE 3.4 Mean effect of month of service on the
proportion of returns of abnormal length
to all services.



length (Table 3.4), the months of December, June and September were significantly different than the proportion of abnormal returns to matings in other months. With the exception of June, there was a significant increase when compared with other months of the year. The similarity of the influence of month on the proportion of abnormal returns for both situations (all matings considered (Table 3.3) and only initial matings (Table 3.4)), the return sows appear not to excentuate the problem.

Figure 3.5 shows the influence of month on the proportion of abnormal returns to initial service graphically.

(C) Litter Numbers at Birth.

Total births - the mean number of total births per litter on a yearly basis is shown in Figure 3.6. The gradual decline in the mean number of total births per litter that occurred until 1973 reflected the changes in the herd structure that took place at this time. Many sows were culled, due to poor reproductive performance and replaced by Large White gilts which too had comparatively poor levels of performance. The low value for the 1973 born litters was not a reflection of performance over the whole herd but was confined to two fractions. Firstly, conception and litter size declined for sows involved in experimental work which necessitated surgical operation. These were subsequently culled. Secondly, the young Large White sows with which poor performance problems had been experienced earlier as gilts, remained in the herd. Gilt management changes were to occur to rectify the problems.

The coefficient of determination for each yearly analysis, according to Model 7, are given in Appendix IX. The comparatively

FIGURE 3.5 Mean effect of month of service on the
proportion of returns of abnormal length
to initial services only.

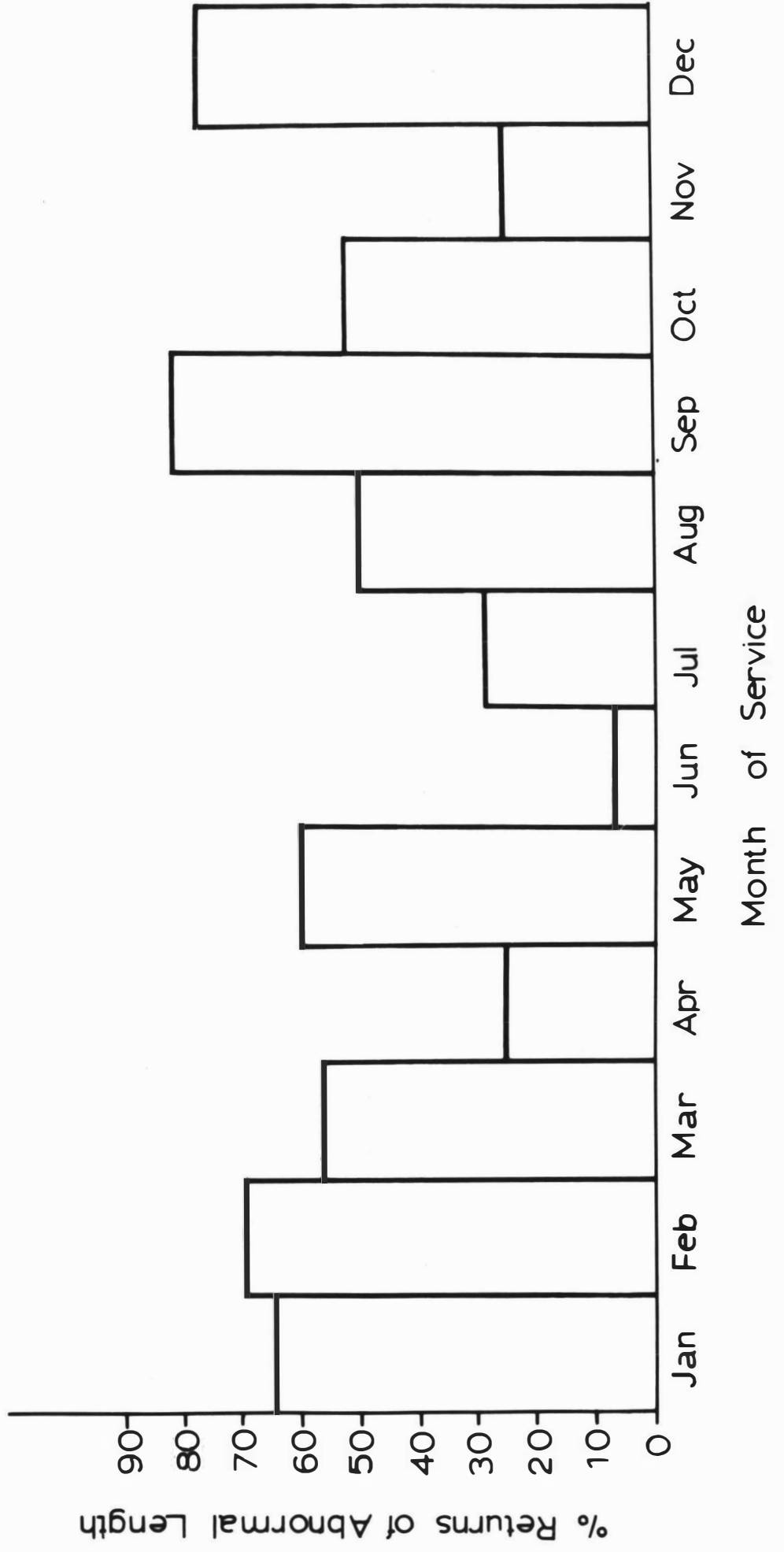
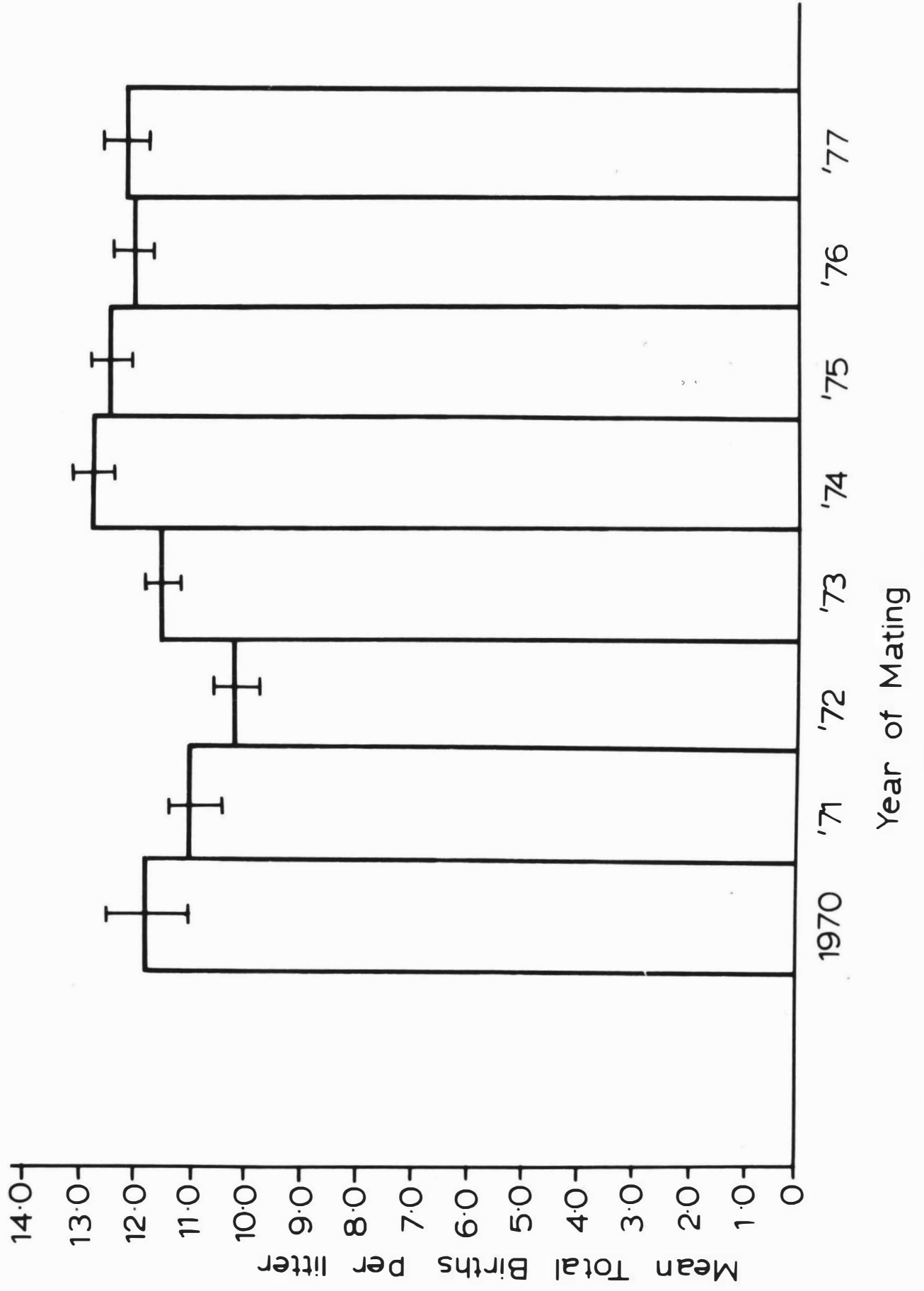


FIGURE 3.6 Mean annual total litter size at birth



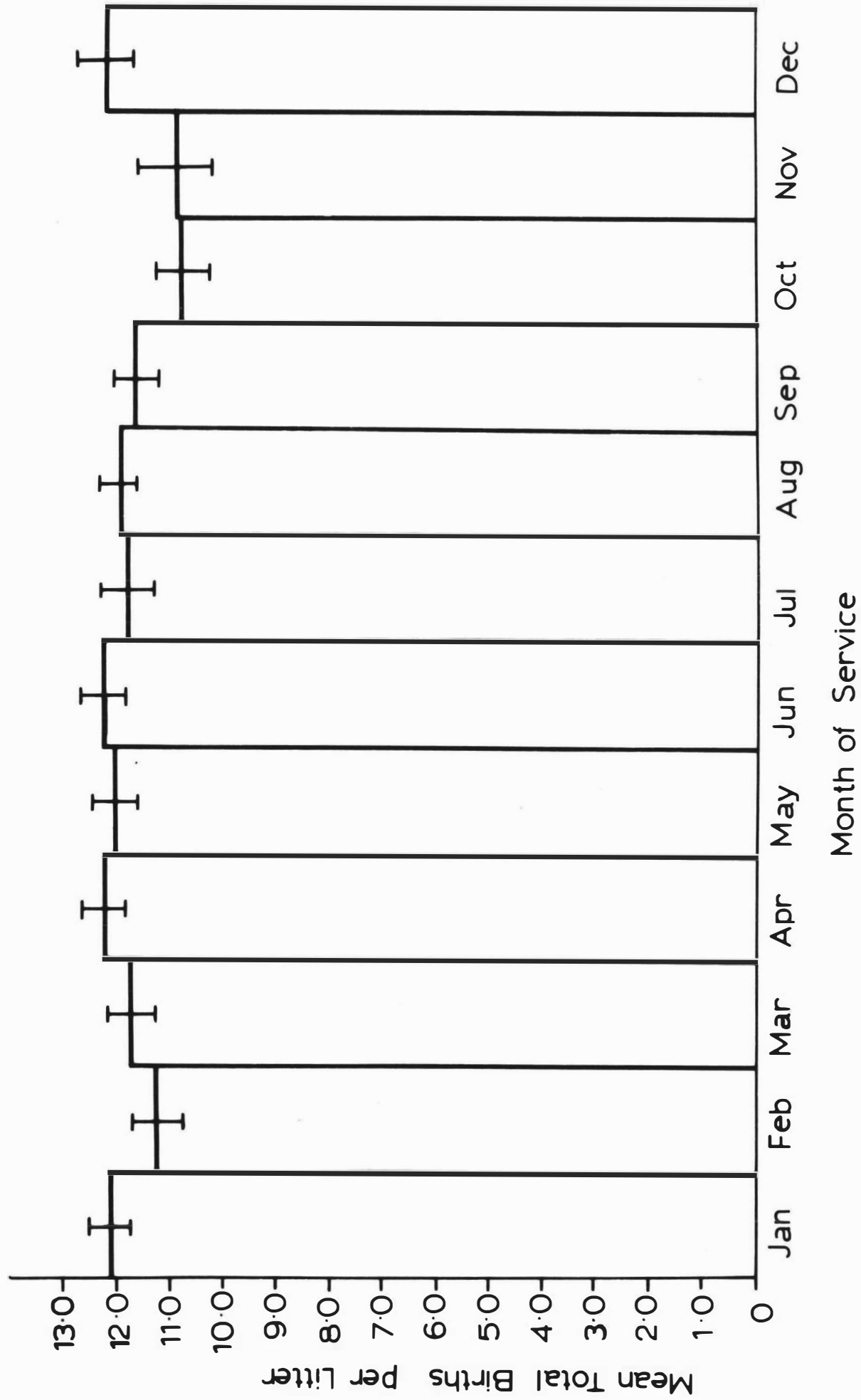
low value of the coefficient for each year indicates the possibility that the sample was not random, that total births is a poor indicator of fertility or factors not included in Model 7 accounted for much of the variation. While any of these possibilities may account for the relatively low values of the coefficient of determination, it is more likely that a combination of the possibilities offers an explanation. For these reasons, data for monthly mean total births per litter on a yearly basis, as shown in Figure 3.7, were pooled for analysis (Appendix X). The only significant effects were those of parity ($P > 0.05$) and breed x parity interaction ($P > 0.01$). These results are given in Table 3.5

TABLE 3.5 INFLUENCE OF BREED OF DAM AND PARITY OF TOTAL
NUMBER OF BIRTHS PER LITTER

	<u>Breed</u>	
	<u>Large White</u>	<u>Landrace x Large White</u>
<u>Parity</u>		
<u>First and Second</u>	10.13	9.10
<u>Third and Subsequent</u>	11.78	9.65
MEAN	10.95	9.37

The greater number of total births per litter for sows of third and subsequent litters (Large White and Landrace x Large White) when compared with gilts and first litter sows, is in accordance with the general trend; the number of total births of a sow peaks at about her fifth or sixth litter. However, the lower total number of births per litter for the Landrace x Large White sows of both parities when compared

FIGURE 3.7 Mean effect of month of service on mean number
of total births per litter.



with the purebred sows (Large White) is contrary to all previous work. The hybridisation gains in total births per litter generally obtained by crossbreeding, were not obvious in this herd. No suitable explanation could be given for this unusual observation.

Live births - the yearly mean number of live births per litter for sows in the herd are shown in Figure 3.8. The explanation for the gradual decline in the number of live births per litter is the same as for the previous section - Total births. The poor performance of Large White gilts in the herd at the time and their subsequent litters. Changes in gilt management helped rectify this problem in the later years of the study.

Analysis of variance of the yearly mean number of live births per litter data, according to Model 8, for each year, revealed none of the "main effects" nor any of the interactions had a significant effect. The "main effects" of the Model (8) in fact explained very little of the variation in the number of live births per litter as is shown by the coefficient of determination values given in Appendix XI.

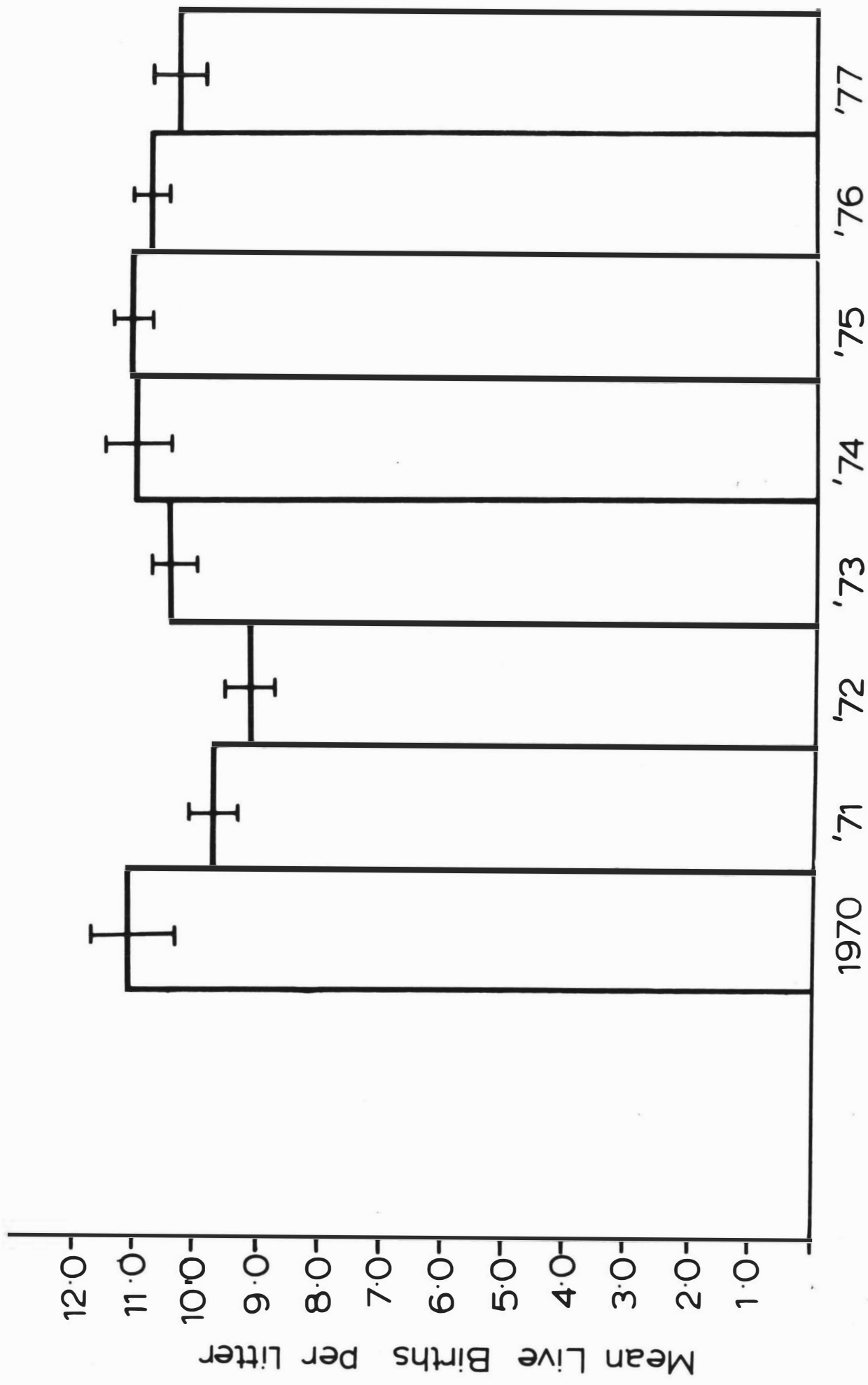
Figure 3.9 depicts the monthly mean numbers of live births per litter for the observations pooled over years. Significant differences in the number of live births per litter were due to the breed of sow ($P>0.05$) and the interaction, breed x parity ($P>0.05$) (Appendix XII). These results are summarized in Table 3.6.

TABLE 3.6 INFLUENCE OF BREED OF DAM AND PARTIY ON THE
NUMBER OF LIVE BIRTHS PER LITTER

	<u>Breed</u>	
	<u>Large White</u>	<u>Landrace x Large White</u>
<u>First and Second</u>	8.69 \pm 0.36	8.33 \pm 0.40
<u>Parity</u> <u>Third and Subsequent</u>	10.51 + 0.39	9.20 + 0.39
MEAN	9.60	8.76

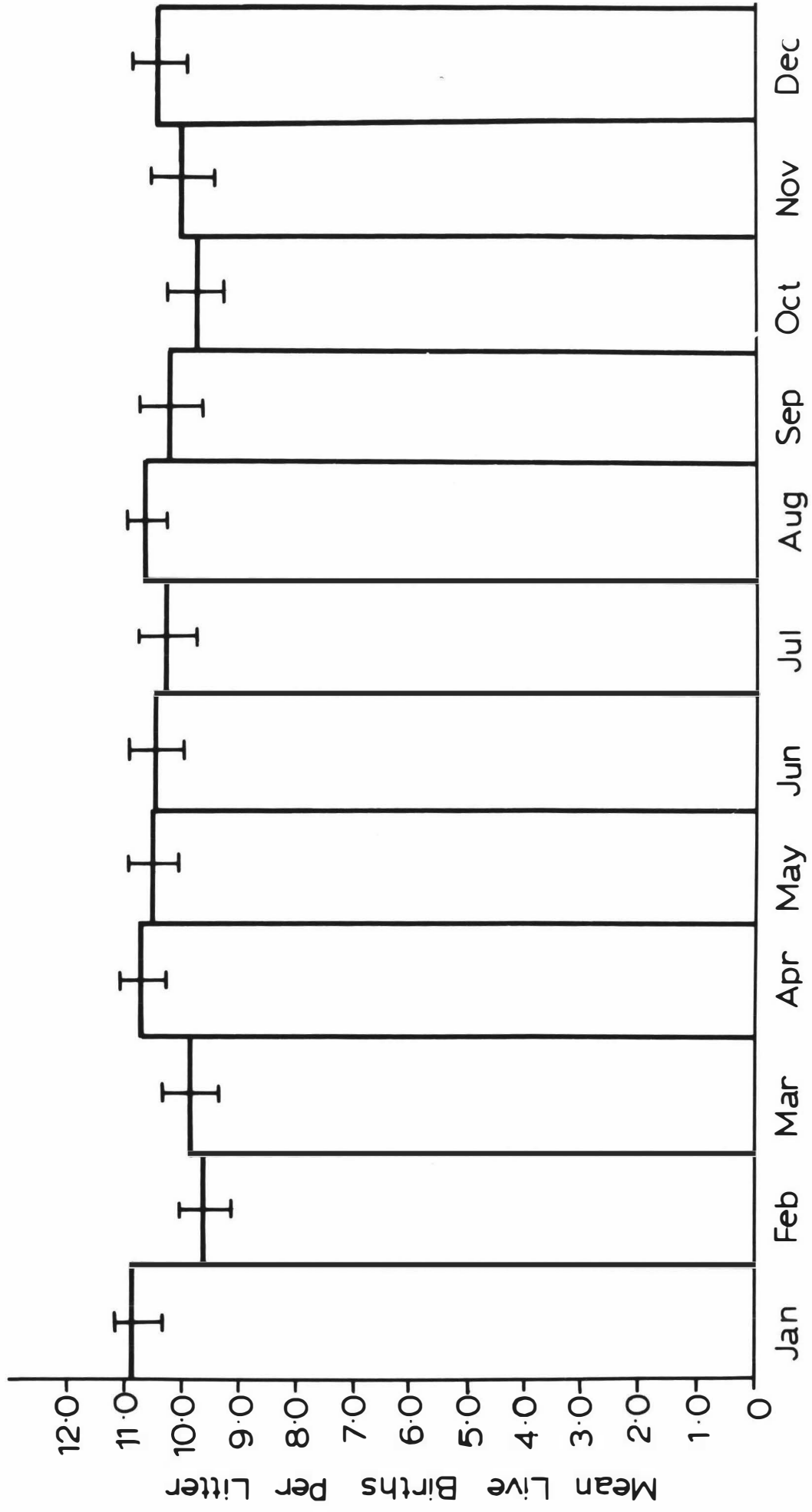
The third and subsequent litter sows (Large White and Landrace x Large White) had a greater mean number of live births per litter when compared with first and second parity sows. The significant differences in the number of live births per litter between the purebred (Large White) and crossbred (Landrace x Large White) pigs in the herd was not due to crossover effects, as the trend in the increased number of live births per litter for the older sows was similar for both breeds.

FIGURE 3.8 Mean annual number of live births per litter.



Year of Service

FIGURE 3.9 Mean effect of month of service on mean number of live births per litter.



Month of Service

CHAPTER FOUR

DISCUSSION

In contrast to the situation with many domestic animals, photoperiodic stimulation of reproduction in the pig has long been considered degenerate due to the long domestication of this species (Ortavant et al., 1964). However, with regard to the findings of this study, and several recent overseas reports (Corteel et al., 1964; Roller and Stombaugh, 1974; Love, 1978; Paterson et al., 1978 and Stork, 1979), there is increasing evidence which suggests there may be a seasonal trend in porcine reproduction when sows and boars are housed under conditions in which they are exposed to temperate, seasonal, climatic changes such as those experienced in New Zealand.

The fertility of sows in the herd varied with season; in that the farrowing rate for matings during summer months was depressed. When farrowing rate was determined from initial matings only (first service after weaning or of gilts) there was an even greater depression in this trait during the three summer months relative to the rest of the year. The summer fertility problem in this herd of sows was therefore not aggravated by the remating of sows which had been mated previously and subsequently returned to oestrus. This implies the fertility of the sows which had returned to oestrus post mating was in fact higher than post weaned sows and gilts when mated.

The depression of sow fertility evident with December, January and February matings was manifest principally by an increase in the

in the proportion of sows exhibiting a long irregular return to oestrus interval, following the post weaning service. No explanation can be given as to why there was a significant increase in the proportion of total returns to service which were abnormal in length for animals mated during September. It is noteworthy, however, that with September matings, the farrowing rate was not significantly different from that recorded for the other months of the year except June matings, where a high farrowing rate to initial service was recorded. Use of crossbred as apposed to purebred females appeared not important, as Large White and Landrace x Large White sows exhibited similar trends with regard to the seasonal influence on farrowing rate.

The total births per litter and the number of live births to sows in the herd which conceived during the summer months was not significantly different from corresponding values for those mated during the other months of the year. However, in contrast to the theoretical arguments and an abundance of data obtained on pigs to support the use of hybridisation for increased litter size (Smith and King, 1964; Hill, 1971), the Landrace x Large White crossbred dams in this study produced smaller numbers of total and live births per litter. No clear explanation of this apparent abnormality can be given. As litter traits have very low heritability values, it would seem unlikely that if a differential selection policy had occurred, which was not intentional, the superior litter traits of the purebred Large White sows would not have been obtained simply through selection.

The depressed summer fertility of the sows in the herd was apparently an all-or-none phenomenon; the sow either maintained the

pregnancy and farrowed a normal litter or lost the whole litter and at some point in time, returned to oestrus.

Shearer and Adam (1973) also reported lowered reproductive performance in summer mated sows under New Zealand conditions. They observed an increase in the proportion of sows mated during December, January and February that returned to service. In contrast to the results of the present study, these workers reported that most returns to the initial service occurred within a period of 3 to 7 weeks following mating.

Several reports of summer infertility problems in the breeding herds of overseas countries have been published (Corteel et al., 1964; Roller and Stombaugh, 1974; Love, 1978; Paterson et al., 1978 and Stork, 1979). All have recorded a depression in farrowing rate with sows mated during the summer months. With the exception of Roller and Stombaugh, (1974), the more detailed studies revealed a significant increase in the proportion of sows mated in the summer months which exhibited a prolonged irregular return to service interval. The Australian workers, Love (1978) and Paterson et al. (1978) classified sows which returned to oestrus in the period 25 days or greater after mating as an abnormally long interval, while Stork (1979) reported many sows which he observed were not pregnant 95 days post mating.

It was apparent from the findings of this study that the reproductive performance (farrowing rate) of sows following their return to oestrus after a prolonged interval, was as high as those which farrowed as a result of the first mating post weaning of the litter. Similar findings were reported by Love (1978) and Paterson et al. (1978)

Examination of the present data indicated that the fertility

problem was similar for all sows, irrespective of the previous number of litters farrowed and reared. Love (1978) on the other hand reported that gilts were more frequently affected by the infertility problem than were first parity sows which in turn, were more affected than the later parities. He attributed this differential effect to possibly be associated with the severity of stress factors other than ambient temperature. Furthermore, it was found that first parity sows which exhibited an extended weaning to oestrus interval (greater than 18 days), were apparently unaffected by the summer infertility problem when remated. It is considered possible that there was a sufficient time lapse to enable these sows to recover from the stresses imposed during their first lactation. The time factor, a critical component of this theory may suggest a hormonal change. Such a change may also offer an explanation to the normal farrowing rate of sows affected by the summer infertility problem to subsequent mating, as found in this study and by Love (1978) and Paterson et al. (1978).

The regular occurrence of the infertility problem in sows mated during the hotter months may reflect the sensitivity of the reproductive process to environmental variation. Climate, feed and disease are some of the many factors considered to have either a direct and/or indirect role in animals. Thus the interaction of these factors in combination with the complexity of each makes evaluation of the relative importance of any single factor and its role in the influencing of reproductive performance very difficult, if not impossible. This has been discussed in detail; review of literature (see pages 30 to 33).

The depressed reproductive performance of the sows in the herd, mated during the summer months could not be directly associated with

the lengthened photoperiod. In view of the summary given by Klotčkov et al. (1975) for many artificial lighting studies "litter size at birth is always less on natural daylight than under increased lighting regimes", one might have expected the longer daylength associated with the summer months to increase total births per litter for matings during this period. However, no significant difference in total or live births were recorded in this study. The expression of oestrus by sows is less well defined during summer when compared to winter according to van Putten (1965). This may possibly be a partial explanation to the abnormally long return to oestrus interval exhibited by a greater proportion of sows mated during the warmer months as found in this study; although oestrus was found to be prolonged under increased lighting regimes by Beljaev, Kločkov and Kočkova (1969). The greatest differences in the proportion of returns to service abnormal in length compared to the remainder of the year occurred for matings which took place during December.

Paterson et al. (1978) suggested an upper critical ambient temperature of around 32°C at or close to the time of mating. Exposure of the sow to such ambient temperatures were reported to influence its reproductive performance (Paterson et al., 1978). Thus, above this temperature level they found a significant increase in the proportion of total matings that resulted in sows exhibiting long and irregular intervals before returning to oestrus. The same workers also noted that sows subjected to such temperatures shortly after mating were unaffected, despite most of their pregnancy taking place under hot conditions. However, ambient temperatures during the summer months in Palmerston North, the site of the present study are lower than this level during the summer months. Daily maximum temperatures during the

three months in question ranged from 12 - 25°C. In fact, this temperature range is similar to that in which sows were kept in the studies of Corteel et al. (1964), whose results were in agreement with those of this study.

Meteorological data obtained from the Department of Scientific and Industrial Research, adjacent to the Massey Pig Research Centre was used in an attempt to investigate the relationship between farrowing rate and ambient temperature. Mean monthly farrowing rate (to all services) was found to be negatively correlated with monthly mean daily maximum temperature. The degree of association although statistically significant ($r = -0.59^*$) was not high. This is indicative that ambient temperature is not a good indicator of the "heat stress" of an animal. A lower and non-significant negative association was found to exist between farrowing rate and mean monthly diurnal temperature range ($r = -0.36^{ns}$). See Figures 4.1 and 4.2.

It is well known that the incidence of embryonic mortality increases with an elevation of ambient temperature (Tompkins et al., 1967 and Edwards et al., 1968). Tompkins et al. (1967) and Edwards et al. (1968) demonstrated experimentally that heat stress imposed on sows during the early stage of pregnancy caused increased embryonic mortality, but without complete litter loss. However, in this study despite increased ambient temperatures during the summer months, season of mating had no significant effect on litter size. On this basis there is no reason to associate embryonic mortality with the seasonal effect on reproductive performance. Love (1978) and Paterson et al. (1978) also reported no reduction in the size of litters born to sows mated during the period of lowered fertility when compared to the resultant from matings done in the remainder of the year.

FIGURE 4.2 Relationship between mean monthly farrowing rate and mean monthly diurnal temperature fluctuation at time of mating.

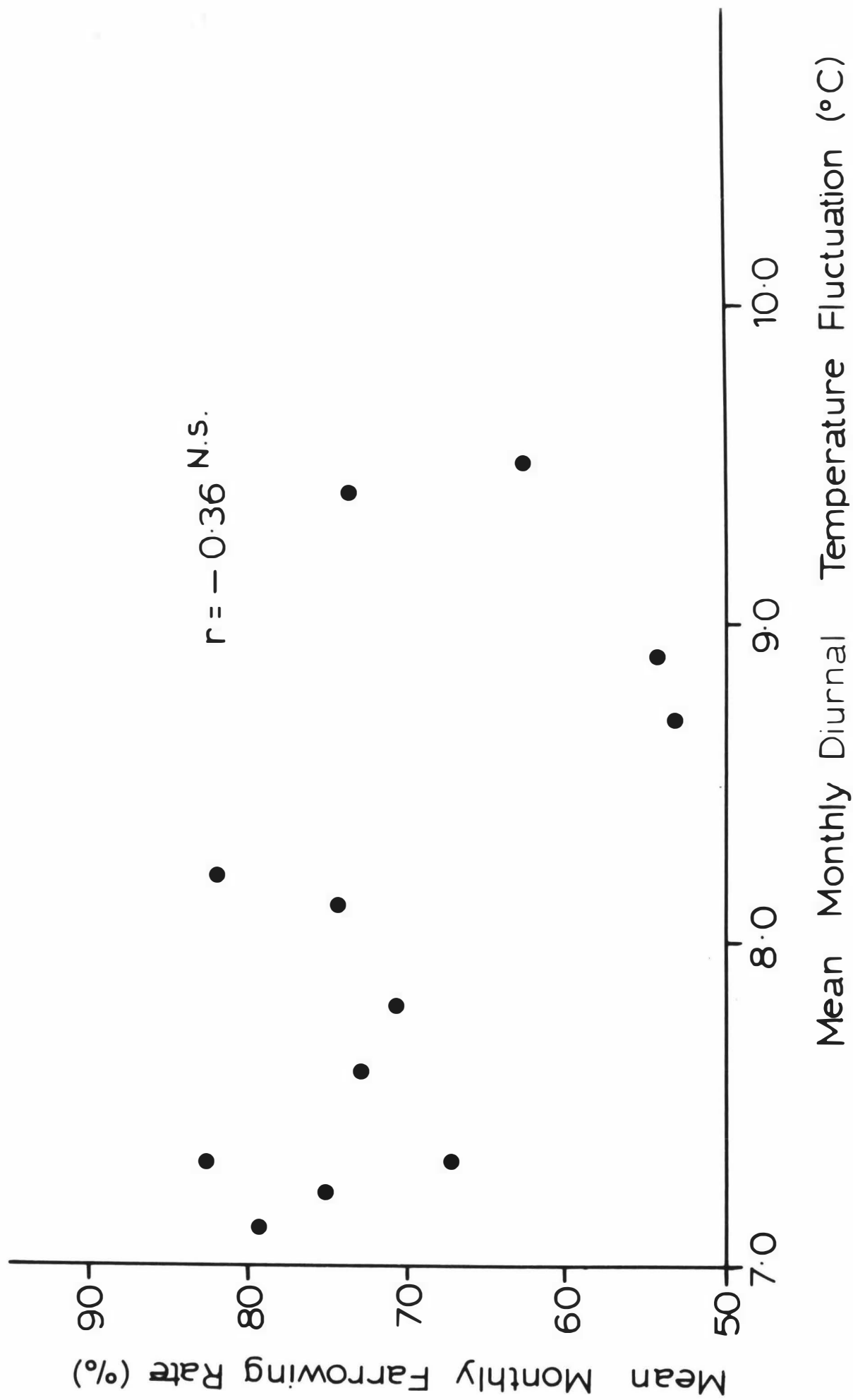
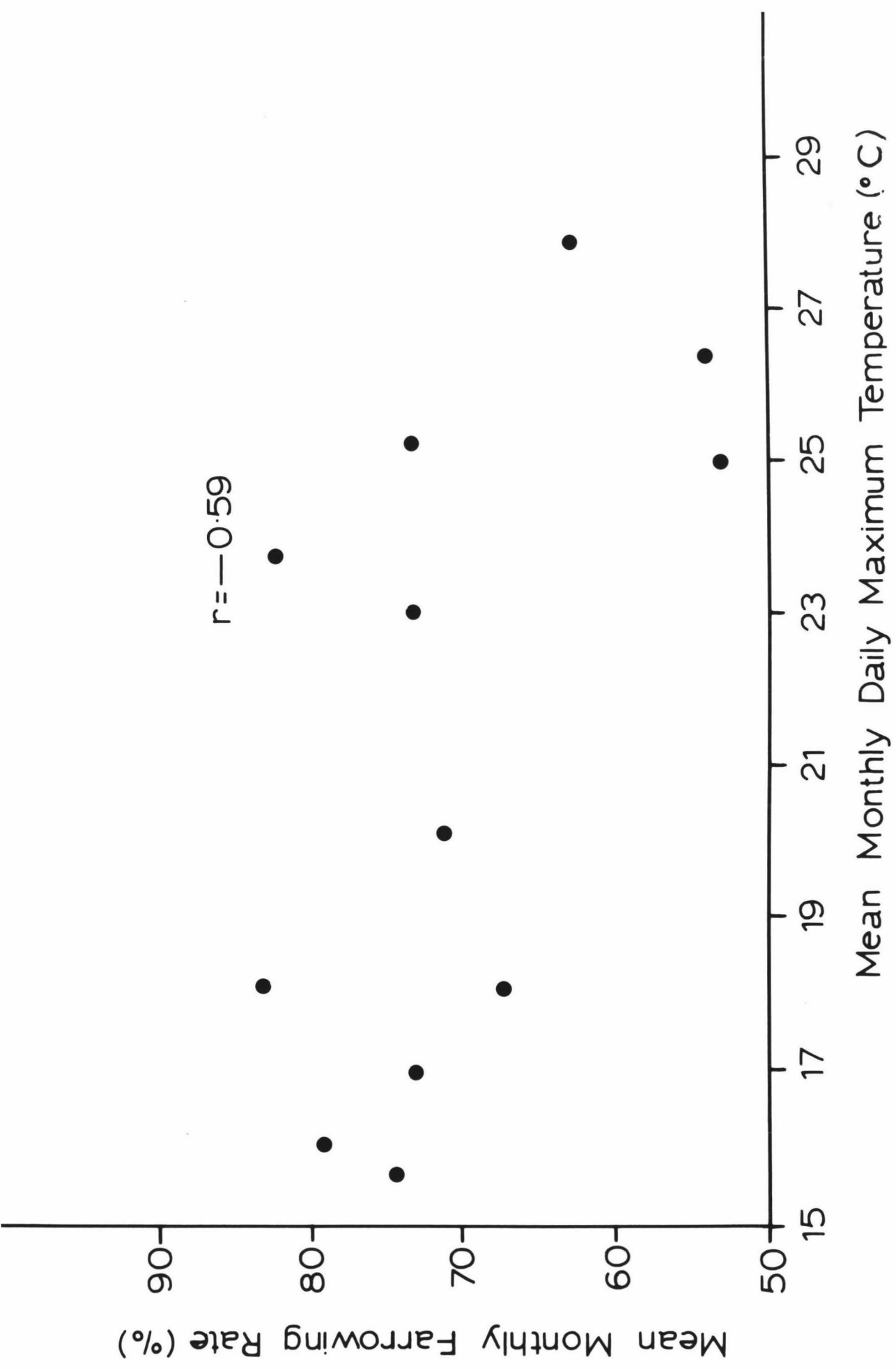


FIGURE 4.1 Relationship between mean monthly farrowing
rate and mean monthly daily maximum
temperature at time of mating.



The findings of Widlt et al. (1975) perhaps bear the most relevance to those of this study. They reported that complete litter loss occurred in only a portion of sows subjected to heat stress during pregnancy (days 1 - 14 gestation). The sows whose pregnancies survived were apparently unaffected by embryonic mortality. A similar all-or-none effect on litter size has also been reported to occur in pregnant rats subjected to heat stress (Euker and Riegle, 1973). Should embryonic mortality have occurred within the first three weeks post mating the sow would be expected to return to oestrus at the normal time. As has already been demonstrated, however, a main feature of the so called summer infertility problem is the prolonged return to oestrus (25 - 35 and greater than 49 days). In this respect, it could have been that oestrus was not detected at the usual time as the sows were not run with the boar. Although there is evidence that during periods of hot weather oestrus behaviour is less obvious (Warnick et al., 1965 and Teague et al., 1968), and the duration of the oestrus period shortened if gilts and sows are housed in situations of increased ambient temperatures (Steinbach, 1972), this would seem unlikely as the same experienced stockman supervised the breeding herd for most of the seven year period. Furthermore, should oestrus have been exhibited by these sows, and gone undetected at around 21 days post mating, one would have expected a later display of oestrus some 21 days on, not at the abnormal times shown in this study. A more feasible explanation for the abnormally long return to service interval is that it is caused by failure to conceive, followed by a period of anoestrus.

Hormonal changes in the sow, known to be associated with increased ambient temperatures could be held responsible for an anoestrus

condition. Smith and Smith (1952) postulated that extreme stress may influence adrenocorticotrophic hormone (ACTH) secretion and hence adrenal and ovarian function. The normal oestrous cycle would therefore be disrupted. Sexual receptivity of the pig is reduced by the change in ACTH secretion (Liptrap, 1970, 1973). Although more research to confirm the postulations is required, it is possible that the course of events resulting from the hormonal changes in the pig associated with elevations in ambient temperature may influence the incidence of sows exhibiting abnormally long return to service intervals.

Despite the absence of any fluctuations in the frequency of visible conceptus from abortions in any months of the year, abortion may account for some of the abnormally long return intervals, although it seems unlikely. However, the permeability of the gut is considered to alter with increased ACTH secretion under heat stress situations. Associated with the change in gut permeability is a transient toxemia which may result in abortion (Liptrap, 1973). Stork (1979) reported a distinct seasonal increase in the abortion rate to sows mated during the period of infertility. His only conclusion in explanation as to why this occurred was that it was problematical. Apart from the occasional abortion which he attributed to a concurrent infection and high body temperature, he considered the epidemiology not to be characteristic of a contagious condition. However, the findings of the present study, namely a lack of visible evidence of abortions is substantiated by the reports of Love (1978) and Paterson et al. (1978), in their Australian work.

An unfavourable interaction between photoperiodism and temperature (in excess of 16 hours of light and greater than 35°C)

on boar semen characteristics reported by Mazzari et al. (1968) could possibly also serve to explain the reduced farrowing rate observed during the summer months. It is unlikely however, as the highest daily maximum temperature recorded outdoors over the period of the study never exceeded 35°C and yet a depression in reproductive performance was recorded during the summer months.

Furthermore, if the increased photoperiod and temperatures associated with the summer months did affect the spermatogenic processes, sows mated by boars with impaired semen would be expected to have a normal return to oestrus interval. This was not so and the sows mated during the summer months which returned to oestrus had a higher proportion of abnormally long return lengths, irrespective of the boar with which they were mated.

The reduction in the number of live births per litter for sows mated to heat-stressed boars reported by Christenson et al. (1972) was not evident from the findings of this study. Similar observations were made by Love (1978) and Paterson et al (1978).

It is apparent that the summer infertility problem cannot be attributed to the boar. The climatic factors associated with the summer months, increased photoperiod and ambient temperatures appear more likely to influence the reproductive performance of the sow.

CHAPTER FIVE

SUMMARY AND CONCLUSIONS

Reproductive data collected in one herd over a seven year period was examined for the existence of seasonal variation and likely causal factors if relevant.

Records pertaining to 1,144 matings showed that farrowing rate was significantly lower for gilts and sows mated during the months of December, January and February compared with the other months of the year between which there were no significant differences.

Lowered reproductive performance during the summer months was manifest as either a delayed return to oestrus or failure to be pregnant at term (25-39 and greater than 49 days post mating).

Despite a 5% difference in farrowing rate to all services in favour of crossbred sows and gilts in general, neither breed of sow (purebred Large White versus Landrace x Large White crossbred) nor parity (1 and 2 versus 3 and above) of the dam influenced either farrowing rate or the proportion of abnormal returns to service.

Farrowing rate to first service post mating was lower compared with that related to all services, an indication that the reduced farrowing rate in the summer months was not associated with sows which simply failed to hold to the first service post mating.

Month of mating did not influence either total litter size at birth nor the number of live births in the litter. Contrary to expectation, purebred sows produced larger litters compared with the crossbred females.

Farrowing rate was found to be negatively correlated with monthly mean daily maximum temperature. The degree of association although statistically significant ($r = -0.59^*$) was not high. A lower and non-significant negative association was found to exist between farrowing rate and the respective mean monthly diurnal temperature range ($r = -0.36^{ns}$).

That the reduced farrowing rate from summer matings was not associated with normal returns to oestrus (18 - 24 days and 40 - 49 days post mating) indicates that neither fertilization failure, nor embryonic mortality were likely to be causal factors. Again, no visual evidence of increased abortions from summer matings relative to those during other months of the year would serve to rule out this factor as one of significance in respect of reduced farrowing rate.

That the reduced farrowing rate during summer months was associated with abnormal return to service intervals would seem to eliminate reduced fertility in the boar as one possible cause of the problem.

Overall, evidence has been presented which indicates that the so called "summer infertility problem" is present in New Zealand but the cause of the problem remains unknown. It is undoubtedly a complex one in which "heat stress" is but one component. "Abnormal returns to service", a major feature of the problem is indicative of an interference with endocrine function, this leading to temporary infertility. Clearly there is need for detailed study in this so far neglected field in attempting to solve this problem.

APPENDIX I

COMPOSITION OF MEAL FED TO BREEDING STOCK AT MASSEY
UNIVERSITY PIG RESEARCH CENTRE

	<u>% Dry Weight</u>
Barley Meal	83.33
Bran	8.33
Dried Blood	2.96
Fish Meal	2.04
Bone Flour	2.96
Salt	0.25
Vitamin/Mineral Additives ("Tasmix")	0.21
A D E (Mcal/kg dm)	3.32
CP (% dm)	15.90
Lysine (% dm)	0.74
Meth. and Cyst. (% dm)	0.53
Tryptophan (% dm)	0.23
Isoleucine (% dm)	0.44
Calcium (% dm)	0.83
Phosphorus (% dm)	0.81

APPENDIX II

COMPOSITION OF PELLETTED MEAL FED TO BREEDING STOCK
ON PASTURE AT THE MASSEY UNIVERSITY PIG RESEARCH CENTRE

	<u>% Dry Weight</u>
Barley Meal	87.00
Meat Meal	10.00
Fish Meal and Dried Blood	2.00
Steamed Bone Flour	0.50
Iodised Salt	0.25
Co-opervite Pig Breeder (32 TE) Vitamin/ Mineral Supplement	<u>0.25</u>
	<u>100.00</u>

APPENDIX III

ANALYSIS OF VARIANCE : TRANSFORMED FARROWING RATE DATA
(ALL SERVICES)

Source	d.f.	M.S.
$R(\mu)$	1	165.27430
$R(\alpha / \mu)^Y$	11	0.13415 *
$R(\beta / \mu, \alpha)^Y$	1	0.31738 *
$R(\alpha \beta / \mu, \alpha, \beta)$	11	0.00887 ^{ns}
Residual	144	0.06310
<hr/>		
TOTAL	168	
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Source	d.f.	M.S.
$R(\mu)$	1	165.27430
$R(\beta / \mu)$	1	0.31738*
$R(\alpha / \mu, \beta)$	11	0.13415*
$R(\alpha \beta / \mu, \alpha, \beta)$	11	0.00887 ^{ns}
Residual	144	0.06310
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TOTAL	168	
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^YThe order of fitting the effects (α and β) was found to be unimportant in the analysis of variance.

APPENDIX IV

ANALYSIS OF VARIANCE : TRANSFORMED FARROWING RATE DATA
(INITIAL SERVICES ONLY)

Source	d.f.	M.S.
$R(\mu)$	1	171.45760
$R(\alpha/\mu)$	11	0.16054**
$R(\beta/\mu, \alpha)$	1	0.03212 ^{ns}
$R(\alpha\beta/\mu, \alpha, \beta)$	11	0.01579
Residual	142	0.06720
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TOTAL	166	
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Source	d.f.	M.S.
$R(\mu)$	1	171.45760
$R(\beta/\mu)$	1	0.03453
$R(\alpha/\mu, \beta)$	11	0.160319
$R(\alpha\beta/\mu, \alpha, \beta)$	11	0.01579
Residual	142	0.06720
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TOTAL	166	
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APPENDIX V

ANALYSIS OF VARIANCE : PROPORTION OF THE TOTAL RETURNS
TO ALL SERVICES OF ABNORMAL LENGTH (TRANSFORMED DATA)

Source	d.f.	M.S.
$R(\mu)$	1	69.785599
$R(\alpha/\mu)$	11	0.2216644*
$R(\beta/\mu, \alpha)$	1	0.135737 ^{ns}
Residual	101	0.1128802
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TOTAL	114	
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Source	d.f.	M.S.
$R(\mu)$	1	69.785599
$R(\beta/\mu)$	1	0.153631 ^{ns}
$R(\alpha/\mu, \beta)$	11	0.2200377*
Residual	101	0.1128802
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TOTAL	114	
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APPENDIX VI

ANALYSIS OF VARIANCE : PROPORTION OF THE TOTAL RETURNS
TO ALL SERVICES OF ABNORMAL LENGTH (TRANSFORMED DATA)

Source	d.f.	M.S.
$R(\mu)$	1	44.023995
$R(\alpha/\mu)$	11	0.141219 ^{ns}
Residual	62	0.1007171
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TOTAL	74	
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APPENDIX VII

ANALYSIS OF VARIANCE : PROPORTION OF TOTAL RETURNS TO
INITIAL SERVICES OF ABNORMAL LENGTH (TRANSFORMED DATA)

Source	d.f.	M.S.
$R(\mu)$	1	62.744204
$R(\alpha/\mu)$	11	0.2999831**
$R(\beta/\mu, \alpha)$	1	0.146214 ^{ns}
Residual	82	0.1080061
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TOTAL	95	
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Source	d.f.	M.S.
$R(\mu)$	1	62.744204
$R(\beta/\mu)$	1	0.169719 ^{ns}
$R(\alpha/\mu, \beta)$	11	0.2978463**
Residual	82	
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TOTAL	95	
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APPENDIX VIII

ANALYSIS OF VARIANCE : PROPORTION OF TOTAL RETURNS TO
INITIAL SERVICES OF ABNORMAL LENGTH (TRANSFORMED DATA)

Source	d.f.	M.S.
$R(\mu)$	1	41.075963
$R(\alpha/\mu)$	11	0.2120129*
Residual	55	0.1013391
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TOTAL	67	
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APPENDIX IX

COEFFICIENT OF DETERMINATION VALUES (R^2):- FOR YEARLY
ANALYSIS OF TOTAL BIRTHS PER LITTER DATA

Year	R^2 (Y.)
1970	42.5
1971	49.0
1972	43.6
1973	36.0
1974	34.6
1975	43.5
1976	36.1
1977	47.4

$$\text{Coefficient of Determination } (R^2) = \frac{\text{sum of squares due to the model}}{\text{total sum of squares}} \times \frac{100}{1}$$

APPENDIX X

ANALYSIS OF VARIANCE : TOTAL BIRTHS PER LITTER OF ALL
FARROWING DATA POOLED OVER YEARS

Source	d.f.	M.S.
Month of mating (M)	11	10.01 ^{ns}
Breed of Sow (B)	1	0.28 ^{ns}
Parity of Sow (P)	1	55.84*
M X B	11	8.80 ^{ns}
B X P	1	60.84**
M X P	11	9.55
Residual	748	9.04
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TOTAL	784	
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APPENDIX XI

COEFFICIENT OF DETERMINATION VALUES (R^2):- FOR YEARLY
ANALYSES OF THE NUMBER OF LIVE BIRTHS PER LITTER

Year	R^2 (%)
1970	54.9
1971	44.1
1972	33.9
1973	38.1
1974	33.6
1975	38.3
1976	34.3
1977	48.7

$$\text{Coefficient of Determination } (R^2) = \frac{\text{sum of squares due to the model}}{\text{total sum of squares}} \times \frac{100}{1}$$

APPENDIX XII

ANALYSIS OF VARIANCE : NUMBER OF LIVE BIRTHS PER LITTER OF
ALL FARROWING DATA POOLED OVER YEARS

Source	d.f.	M.S.
Month of mating (M)	11	5.02 ^{ns}
Breed of Sow (B)	1	60.63 *
Parity of Sow (P)	1	1.04 ^{ns}
M X B	11	12.74 ^{ns}
B X P	1	38.71*
M X P	11	10.38 ^{ns}
Residual	748	9.11
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TOTAL	784	
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