A STUDY OF SEASONAL VARIATION IN FARROWING RATE ON PIG UNITS IN NEW ZEALAND

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ABSTRACT

A study was undertaken to determine the extent of seasonal variation in farrowing rate on commercial pig breeding farms in New Zealand and the influence of some environmental factors on reproductive efficiency.

The data comprised monthly farrowing rates covering a two year period and involving five breeding units located in each of four climatic regions ('hot and stable'; 'hot and variable'; 'warm'; and 'cool'). The latter were identified on the basis of mean monthly maximum temperature and mean monthly diurnal temperature fluctuation prevailing during the summer months.

Examination of 11,379 observations revealed an overall farrowing rate of 77.1% with the presence of some seasonal variation.

Only within the 'hot and stable' region did month of mating significantly influence the farrowing rate. However, in all regions some farms exhibited a considerable decrease in farrowing rate from late spring and summer matings compared with other times of the year.

Any possible effect of the regional differences in climate on farrowing rate was overshadowed by marked within-region variation in farrowing rate associated with farms.

In support of a farm influence on farrowing rate a subjective classification of housing standards for breeding stock generally placed those with the highest farrowing rate, irrespective of season or location, in the top category, and 'vice versa'.

In the temperate climate of New Zealand present findings would suggest that 'summer'infertility can probably be avoided in the healthy breeding herd where attention is given to detail in respect of housing and husbandry standards, thereby avoiding the development of stressful conditions particularly during the critical warmer months of the year.

PREFACE

The pig industry has been considered to be free from seasonal constraints on productivity, such as those which affect other farm species. However with the advent of intensive, more efficient farming systems the relationship between season and reproductive performance has recently received an increased amount of study. A depression in reproductive efficiency at certain times of the year, in a number of countries, is now well documented, although the nature of the problem has not been defined and as a consequence the issue is surrounded by much confusion and conflicting reports as to etiology.

In New Zealand, an analysis of records collected at the Pig Research Centre, Massey University, over a seven year period, revealed lowered reproductive performance over the summer months (December to February inclusive).(Hermann,1980.) That seasonal porcine reproductive inefficiency, reported in a number of countries, was also evident in New Zealand stimulated interest in pursuing this topic in more detail. The present study is in the form of a farm survey. It has two main objectives; firstly to determine the extent of seasonal reproductive inefficiency on commercial pig breeding units, in this country, and secondly to examine the influence of some environmental factors on the incidence of the condition.

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REVIEW OF LITERATURE

This review is concerned primarily with the influence of seasonal variation in the outdoor environment on reproductive performance in the pig. Since understanding of the normal situation must precede that of the abnormal, the first section relates to the basic aspects of reproduction in the pig and is intended solely to provide a background to the research undertaken. The second section deals with interrelationships between season of the year and reproductive performance, and the third section examines relationships between specific environmental factors and reproductive performance.

1. Basic Aspects of Reproduction in the Pig

For the survival of a species, animals depend upon their ability to produce viable young. As even small errors in the reproductive cycle may lead to large changes in reproductivity over a long period of time, knowledge of the functioning and control of the reproductive cycle represents an important component in the diagnosis of reproductive failure.(Cole and Cupps, 1959, 1977; Hafez, 1967).

1.1 Endocrinological aspects:

Maintenance of mammalian gonadotrophic function depends upon the integrity of the hypothalamo-pituitary-gonadal axis. Briefly, processes, such as the cyclic phenomena in female reproduction are dependent on the release of follicle stimulating hormone (FSH),luteinizing hormone (LH) and prolactin from the anterior pituitary. The function of the pituitary in turn is regulated by releasing factors secreted by the hypothalamus in response to neural triggers.

It is known that the hypothalamic function is affected by other areas of the brain (i. e.participation of extra-hypothalamic structures such as the limbic system, amydala, hippocampus and midbrain (Ellendorff1978.(fig 1,b). These and other extra - hypothalamic areas are considered to act as "homostat" control centres for integrated hypothalamic function. Extra-hypothalamic structures are the subject of extensive reviews by Clegg and Doyle (1966), Donovan (1971), and Ellendorff(1978).

On the basis of *in vitro* studies it appears that one factor is responsible for the release of both LH and FSH, namely gonadotrophin releasing hormone (GNRH)(Schally *et al*, 1972), but this still remains to be substantiated *in vivo.*

Present knowledge of hypothalamic control of prolactin release from the anterior pituitary is fragmentary. Although mention has been made of an inhibitory control by a prolactin inhibiting factor (PIF)(Nicoll,1971), there is evidence to suggest the presence of a dual control mechanism which also involves a prolactin releasing factor (PRF) (Reichlin *et al*, 1976)(fig 1,d.)

Several regions of the hypothalamus are implicated in the control of reproduction, a major area in the rat and the Rhesus monkey is mediobasal hypothalamus (M.B.H.)(Halasz 1967,Knobil, 1974). These authors found that surgically isolated, MBH is capable of maintaining normal pituitary and gonadal structure and function whereas its removal abolishes normal sexual function. Whether the MBH is the major reproductive control area in the pig is not known. Following its synthesis GNRH passes by axonal transport to the median eminence (ME) of the hypothalamus which is situated immediately dorsal to the pituitary gland. There it is stored and released as required into the hypothalamo-hypophyseal portal vessels for transport to the anterior pituitary (fig 1,c). The exact mode of release of GNRH following stimulation of the ME is not known, but there is an increasing volume of evidence that catecholamines (Dopamine in particular) are involved (Schneider and McCann,1969; Coppola, 1971).GNRH, on reaching the gonadotroph cells of the anterior pituitary combines with a specific receptor site of the cell membrane. Current theories on the mechanisms by which GNRH causes gonadotrophin release and synthesis have been reviewed by McCann (1971) and Jutisz et al (1972).

LH, FSH and prolactin once released from cells of the anterior pituitary, travel via the general circulatory system to specific hormone receptor sites in the gonads (fig 1,e).

In the male, LH binds to specific receptors on the cell membrane of the Leydig cells, stimulating an energy producing system which aids in the synthesis of androgens (fig 1,e). Testosterone, the main androgen, is responsible for the development of secondary sexual characteristics. It also plays a major role in the maintenance of accessory sexual organs and aids in spermatogenesis (Setchell,1977) (fig 1,g). The function of FSH, in the male, is not clear. It is assumed to influence Sertoli cell function, the outcome being the stimulation of seminiferous tubule growth, and spermatogenesis, and stimulation of the Sertoli cells to produce and secrete Androgen Binding Protein (A.B.P.) (Sherwood and McShan, 1977). As yet no definite role has been ascribed to prolactin in the male. It is possible that it aids in testosterone synthesis or output (Bartke, 1971 , Hafez et al 1972) (fig 1,f).

Gonadotrophin action in the female centres around the initiation and maintenance of ovarian function, follicle development and maturation, ovulation, luteinization and steroid synthesis by the corpus luteum (CL) (Sherwood and McShan, 1977).

The role of both FSH and LH in these respects is far from clear, but the necessity for both and their synergistic action has been observed.(Jones and Nalbandov, 1972). In the female, FSH stimulates the growth of ovarian follicles which in turn produce oestrogen.(oestradiol)(Nuti et al,1974)(fig,1,e). Oestrogen passes into the circulatory system and produces distinct changes in the reproductive tract and in behaviour which are associated with onset of oestrus (fig 1,g).

LH, in the female is responsible for ovulation and subsequent growth of the corpus luteum, associated with which is progesterone output. (fig 1,e). The latter hormone produces typical changes in the reproductive tract associated with the preparation of the uterus for reception of embryos (Corner and Allen, 1929; Hendricks and Mayer, 1977)(fig 1,g).

The influence of prolactin on gonadal function remains obscure. There is some evidence that it may constitute part of the luteotrophic complex required for the maintenance of the corpus luteum in ewes (Kann and Denamur, 1974)and marsupials (Tyndale-Biscoe and Hawkins, 1976) but whether the pig falls into this category is unknown (fig.1,f).

1.2. Control of reproductive hormone secretion:

Inputs from extra-hypothalamic areas as well as humoral feedback from the gonads and possibly the adrenal glands are the determinants of hypothalamic and pituitary secretion (Ellendorf, 1976; 1978).

The gonadal steroids, namely oestrogen, progesterone and testosterone have been reported to inhibit or stimulate gonadotrophin production. The concept of long feedback loops was advanced by Martini et al (1968) to describe the action where gonadal hormones indirectly influenced the release of pituitary gonadotrophins through their action on the secretion of gonadotrophin releasing and inhibiting factors from the hypothalamus (fig 1,j). However, it also has been postulated that pituitary cells are affected directly by gonadal hormones (Corbin and Cohen, 1966)(fig 1,i.) In rams, for example, Galloway & Pelletier (1975) showed that testosterone had negative effects both on the pituitary, inhibiting output of LH, and on the hypothalamus,lowering

GNRH production and output. A pituitary-hypothalamic feedback mechanism has also been suggested. This involves the inhibition of releasing factor release by the gonadotrophins themselves (Schally et al, 1972) (fig 1,k).

More recently, it has been postulated that releasing factors inhibit their own secretion providing an ultra-short feedback loop,(Motta et al, 1973) and thus a third level of neuroendocrine control of gonadotrophin output (fig 1,l). Thus these feedback loops together with the various hormones involved, which act either in unison or in opposition to each other, result in overall hormonal control of reproductive function. This is summarised in figure 1.

1.3 Secondary hormones and reproduction:

Optimal reproductive activity will only occur in animals in which there is a proper balance in the secretory activity of all endocrine glands. Therefore, hormonal secretions which may directly or indirectly influence the secretion rate of gonadotrophins or gonadal hormones, or which may so modify the animal's metabolism that the normal functioning of these hormones is impaired, cannot be overlooked. Of the latter group, the role of thyroxine in reproduction has been the most extensively studied. Reineke and Soliman (1953) found abberations of the oestrus cycle appeared in both hypo and hyperthyroid animals. These effects appeared as lengthening, irregularity or complete disappearance of the cycle. Detailed information on the effects of thyroid hormones on reproduction are reviewed by Turner (1959).

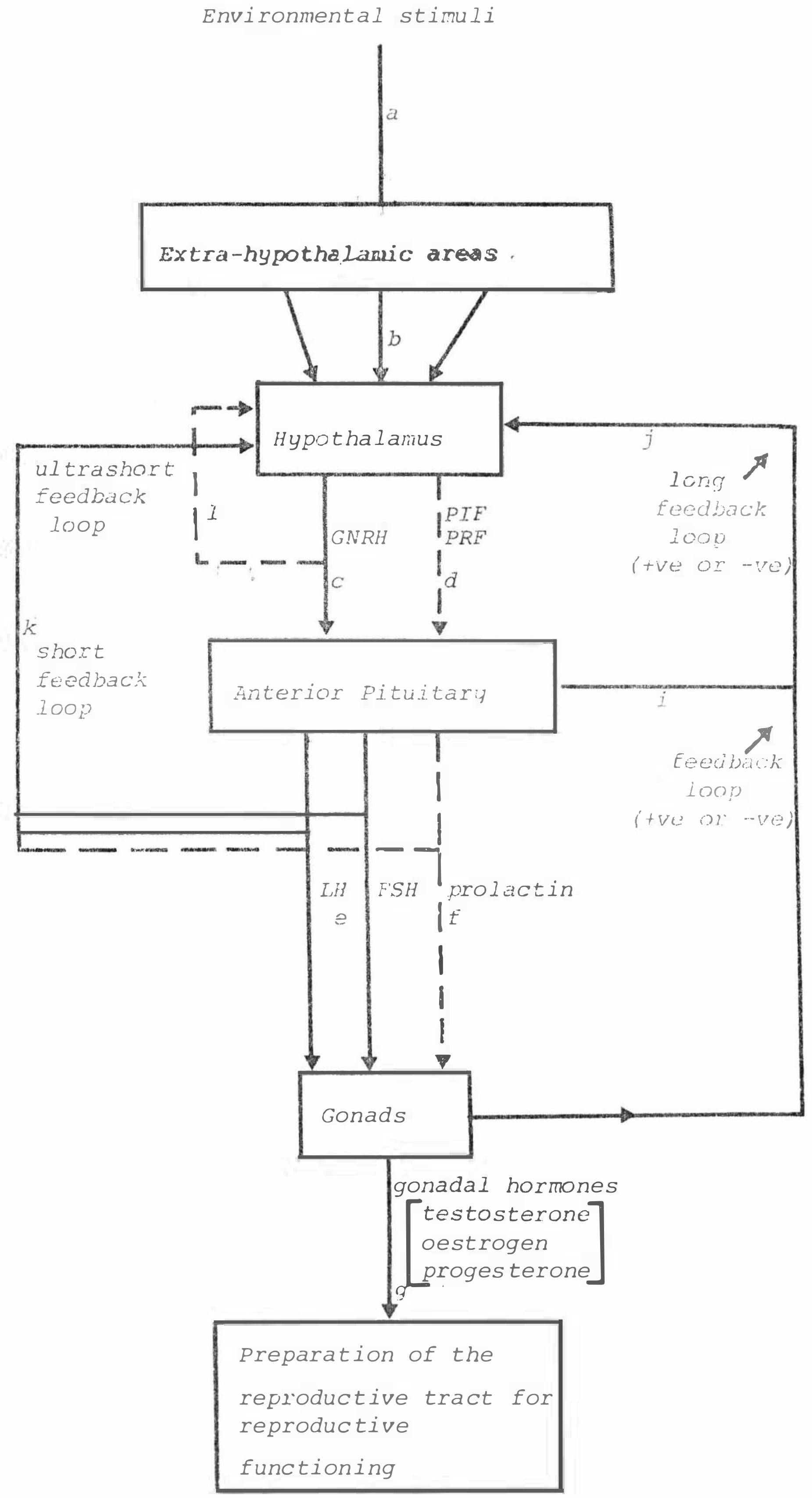


Figure 1: Diagrammatic representation of hormonal control of reproduction.

Determination of the role of adrenal (cortical) hormones in reproduction has mainly resulted from indirect measurements.Some studies indicate that treatment of adrenalectomized animals with adrenal steroids restores the capacity for oestrus cyclicity, conception and maintenance of pregnancy.(Cupps, 1955). Adrenal hormone treatment of normal animals may also cause abortion. It should be noted that these studies did not include the pig. Further aspects of adrenal hormone effects on reproduction function are discussed in the review of Turner (1959). Hays and van Demark (1953) discussed the action of oxytocin and indicated that the hormone played an important role in transport of semen within the female reproductive tract and aided in parturition. Recently Kertiles and Anderson (1979) further elucidated the effect on relaxin in the maintenance of pregnancy and preparation of the birth canal for foetal expulsion, in the pig. Consideration was given to hormonal effects on the duration of delivery, incidence of stillbirths and neonatal survival.

Overall, the hormones having the greatest influence on reproductive performance are the gonadotrophic ones of the pituitary and the steroids of the ovary and testis, but their optimal function can only occur in the animal which is normal in other respects.

2. Ovarian and Uterine Changes associated with Hormonal Secretions

Following attainment of puberty, the sexual life of the sow is made up of a series of recurring oestrus cycles, provided pregnancy does not intervene. Each cycle occupies from 21 to 22 days (McKenzie and Miller, 1930) and four phases may be distinguished, namely Prooestrum, oestrum, metoestrum and dioestrum (fig 2).

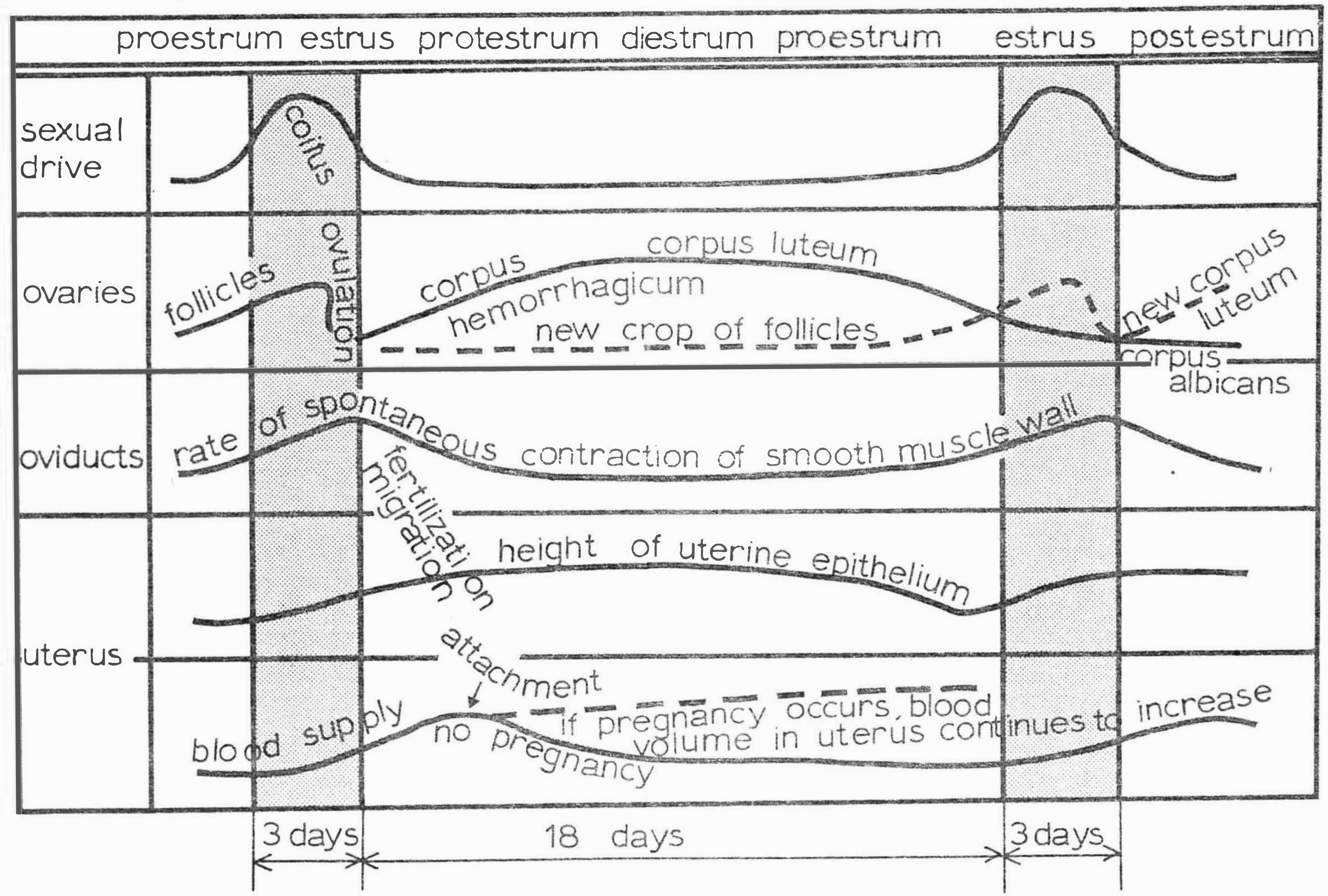
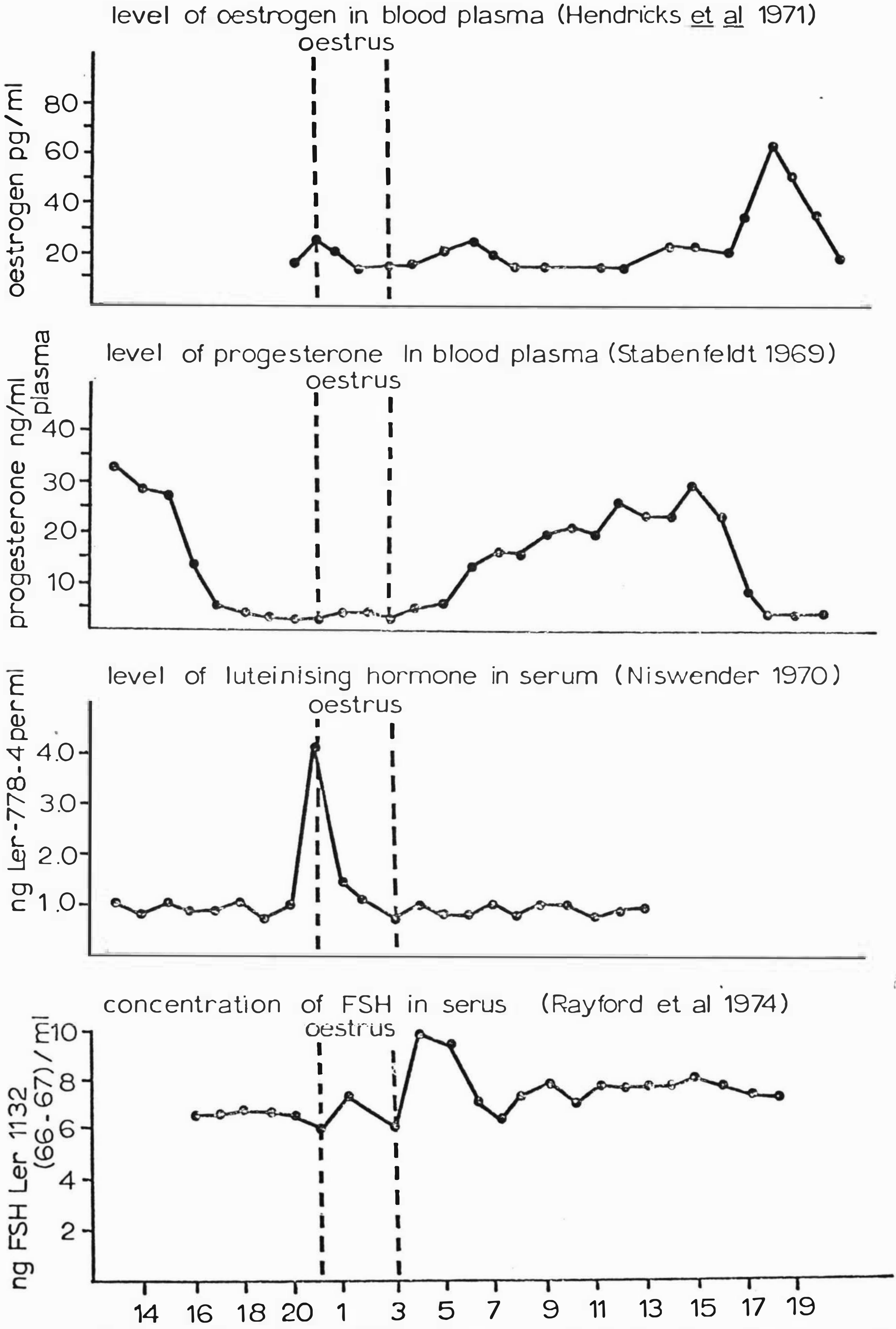


Fig.2(a): Graph showing correlation of changes which occur during the oestrous cycle in the sow. (Compiled from the work of Corner, Seckinger and Keye.)


level of oestrogen in blood plasma (Hendricks et al 1971)

level of progesterone In blood plasma (Stabenfeldt 1969)

level of luteinising hormone in serum (Niswender 1970)

concentration of FSH in serus (Rayford et al 1974)

Fig.2(b): Changes in circulating hormone levels during the oestrous cycle of the sow.

2.1 Oestrous cycle:

2.1.1. Prooestrum:

During this period maturation of the graafian follicles is caused by an increase in FSH secretion following regression of the corpus luteum at the 14th to 16th day of the cycles (fig 2). Just prior to oestrus the pituitary content of LH declines rapidly due to the release of LH into the blood with a corresponding rise in the circulating level. The release of LH accelerates towards the onset of oestrus (Rayford et al, 1971).

Follicular development is associated with increased secretion of oestrogen (mainly oestradiol). The plasma oestrogen level remains low until 2 to 4 days prior to oestrus when there is a rapid increase to reach a well defined peak the day before oestrus. This is associated with a decline in plasma progesterone level following regression of the corpus luteum.(Stabenfeldt et al, 1969).

Oestradiol produces follicular and endometrial growth, swelling of the vulva, relaxation of the cervix and an increase in viscid mucus. It also causes the animal to exhibit the behavioural signs of heat (Burger, 1952; Holtz, 1967; Betteridge and Raeside,1962; and Hansel Echterncamp,1972).

2.1.2 Oestrum:

This period can be defined as the one of acceptance of the male and in the sow is of 40-65 hours duration(McKenzie and Miller, 1930). Peak of fertility occurs within the middle 24 hour period (Reed, 1969). At this stage, the ova undergo maturation changes and oestradiol from the now large and mature graafian follicle produces further changes in the genital tract in readiness for acceptance of sperm and capacitation. The oviducts are tonic, epithelium mature and cilia active, contraction of oviducts occur and increased amounts of oviduct fluid are secreted. The uterus is erect and distended, blood supply to the uterus is increased, mucus is secreted and the cervix is relaxed and slightly swollen. The pattern of oestrogen secretion in the sow, suggests that this hormone facilitates the release of LH from the anterior pituitary. This in turn causes growth of corpus luteum and ovulation with the ova passing into the fallopian tubes, where they are in a position for fertilisation. Peak plasma LH level occurs some 4 hours after the onset of oestrus and lasts for approximately 8 hours, before declining to the original level. (Niswender, et al,1970).

2.1.3 Metoestrum:

This is an illdefined period, during which the corpus luteum grows rapidly from granulosa cells of ruptured follicles under the influence of LH (fig 2). The continued secretion of LH is necessary for the maintenance of corpora lutea and the secretion of progesterone. Plasma progesterone level, which rises in the sow within two days after oestrus, suppresses LH and FSH production. The level of progesterone is considerably higher in the sow compared with the ewe or cow (Stabenfeldt et al 1969,b,c), as might be expected in view of the greater amount of luteal tissue present in the former. The presence of this hormone in comparatively large amounts inhibits the secretion of FSH and LH by the anterior pituitary and prevents ovulation and the immediate development of another oestrum. In the ewe and cow apparently there is sufficient FSH released to form follicles during the luteal phase of oestrus and also early gestation. Mid cycle peaks of oestrogen are not evident in the sow but are present in both the cow and the ewe. Parlow et al (1964), noted very little follicular growth in the sow during the period of maximum progesterone excretion. During metoestrum the epithelium of the vagina loses most of its new growth. The mucus secretion decreases and the glands of the endometrium grow rapidly. Towards the middle and end of metoestrum the uterus becomes soft and pliable due to relaxation of the uterine muscle. In the sow the length of metoestrum is approximately equal to the time it takes for ova to reach the uterus, i.e. 3 to 4 days(Corner and Allen, 1929).

2.1.4 Dioestrum:

This is the longest phase of the cycle (fig 2). The corpus luteum is mature and the effect of progesterone on the reproductive tract is marked, as high levels of progesterone continue from day 2 until day 14 to 16 of the cycle, while plasma levels of LH and

and oestrogen remain low throughout . During this period the endometrium becomes thicker and the glands hypertrophy. The cervix is constricted and the vaginal mucus is scant and sticky, the mucus membrane of the vagina is pale and uterine muscle relaxed. Late in this period, if fertilisation does not occur, the corpus luteum regresses and there is a corresponding decline in progesterone level on day 14 to 16 of the cycle; FSH is again produced and new follicles begin to grow followed by onset of prooestrum. A slight increase in LH occurs on day 14-15 with the decline in progesterone. It appears that the LH releasing mechanism is stimulated by the action of oestrogen, progesterone and other external factors affecting the hypothalamus (Hansel et al, 1973).

2.2 Ovulation, fertilisation and conception:

Most sows shed sufficient ova for a potential litter of 12 to 20 piglets (Marshall and Hammond, 1945). Factors influencing the actual number of ova shed include breed (Warnick et al, 1951); breeding method (Newman, 1963),age,(Squiers et al, 1952); and nutritional history (Anderson and Melampy, 1972). Once shed the ova are rapidly transported through the oviduct to the utero-tubular junction. Oxenreider and Day (1965) have estimated a time period of between 66 and 90 hours.

Following entry to the fallopian tubes of the reproductive tract, the number of ova fertilised is dependent upon the concentration of the sperm reaching them. This in turn is determined by the number of viable spermatozoa originally deposited by the boar and the timing of the insemination within the sow's heat period. Mating between the boar and the sow is a prolonged process during which the boar's ejaculate is deposited into the uterus (Glover and Mann, 1954; Glover, 1955). An ejaculate (150 to 500 mls) contains, on average, about 100 million spermatozoa per millilitre (White and Macleod, 1963).

In the pig, the semen reaches the utero-tubal junction within minutes, this rapid transit being attributable to uterine and oviductal contractions and to sperm mobility to a small extent. (Bustad and Book, 1975). It is known that oxytocin from the posterior pituitary is responsible for the initiation and control of the uterine contractions (Hunter, 1972; 1974; Hunter and Hall, 1974).

A number of examinations have been conducted, usually one to two days postmating, to estimate fertilisation rate. Robertson et al (1951) working with gilts, found that 93% of ova had been fertilised. This high rate of fertilisation has been confirmed by other workers. (Squiers et al. 1952; Self et al, 1955; Haines et al, 1959)

A high fertilisation rate is nevertheless dependent on the boar, with factors such as age, breed, nutritional history, the number of services per week and stage of heat at which mating takes place (Rahnfeld and Swierstra, 1970), being of significance. Generally, it is agreed that the actual time of service within the oestrus period has a profound effect on fertilisation rate. The influence of time of mating has been studied by slaughter and observation methods, and also by use of definite intervals of double mating with 'colour marking' sires. (McKenzie 1932, Haring 1937). These techniques have shown that most eggs are shed at about 36 hours from onset of heat and that all have been shed by 48 hours (McKenzie, 1926). Confirmation of this view is provided by Pomeroy (1955) and Burger (1952). The latter mated groups of sows at 12 hourly intervals from onset of heat and found no difference in conception attributable to time of service in Large White sows from 0 to 24 hours and in Large Black sows from 0 to 36 hours after the onset of heat. If service was delayed until late in the heat period, the degree of fertilisation was reduced and where it did occur, subsequent embryonic mortality was high. This may be explained by the findings of Hancock and Hovell (1962), that a delay in mating until 30th to 48th hour after the onset of heat increased the frequency of polyspermic fertilisation, which in turn adversely affected embryo survival. This would suggest that to ensure maximum fertilisation, mating should occur before ovulation. Although ova are usually shed about 36 hours after the onset of oestrus, there is some variation, as the growth rate of follicles which contain the ova is never the same. (Laing, 1957).

Consequently, the actual period of ovulation may occupy several hours. Marshall and Hammond (1945) maintain that ovulation may occur from 24 to 70 hours after onset of heat.

As the results of Krallinger and Schott (1933) among others, have indicated that the life of spermatozoa is in the region of 48 to 54 hours it would appear that service anytime from the onset of oestrus to the time of ovulation would result in the same degree of fertilisation. To ensure a sufficient amount of viable sperm over such a lengthy ovulation period it is generally agreed that mating on the first and again on the second day of oestrus will ensure maximum fertilisation. Several workers have reported increased conception rate from double mating (Squiers _et al_ 1952;Reddy _et al_ 1958). Overall, it would appear that provided the boar and sow are fertile and service does not occur too late in the heat period, any discrepancy that might occur between the number of ova produced and those that survive pregnancy, cannot to any degree be attributed to lack of fertilisation.

2.3 Pregnancy:

2.3.1 General aspects

After fertilisation ova progress down the fallopian tubes reaching the uterus some 24-48 hours later (Burger, 1952). The zygotes remain in the anterior quarter of the uterine horn for 2-4 days when migration and spacing commences (Burger,1952) When blastocyst spacing within uterine horns is complete, by day 12 of pregnancy, uterine contractions decrease under the influence of progesterone, secreted by the lutein cells of the corpus luteum. Progesterone alters the histological structure of the uterine mucosa so that implantation of blastocysts is facilitated. The attachment of the blastocyst to the endometrium occurs between day 12 and 20 and the embryonic membrane extends to full length by day 13. This process defines the placental area for gestation and is thus responsible in part for the size of foetus at term (Perry and Rowlands 1962).

The duration of gestation is typically 112 to 116 days. The corpus luteum (CL) remains fully developed throughout pregnancy and secretes progesterone to inhibit the occurrence of ovulation and to stimulate placental development in conjunction with the oestrogen and relaxin. The successful completion of pregnancy is dependent upon functional corpora lutea as ovarectomy as late as the 110th day of gestation results in abortion (Belt et al 1971).If many embryos are defective and die before or during implantation such that the number of viable embryo is reduced to 4 or less, the sow may return to service (Polge et al, 1966). Embryonic mortality is most likely to occur between 14 and 35 days after conception, complete resorption of embryo can occur up to day 40, but resorption after foetal osteogenesis has commenced produces mummification. From day 35, differentiation and growth proceed rapidly and immune systems develop after day 55, so that by 75th day the foetus is immunologically competent to produce antibodies to complex antigens. Placental growth also ceases at this time.

2.3.2. Endocrinological aspects.

Establishment of pregnancy markedly alters pituitary-ovarian relationships (fig 3). Sexual cycles are suppressed and corpora lutea are maintained for a period longer than the luteal phase of the cycle.

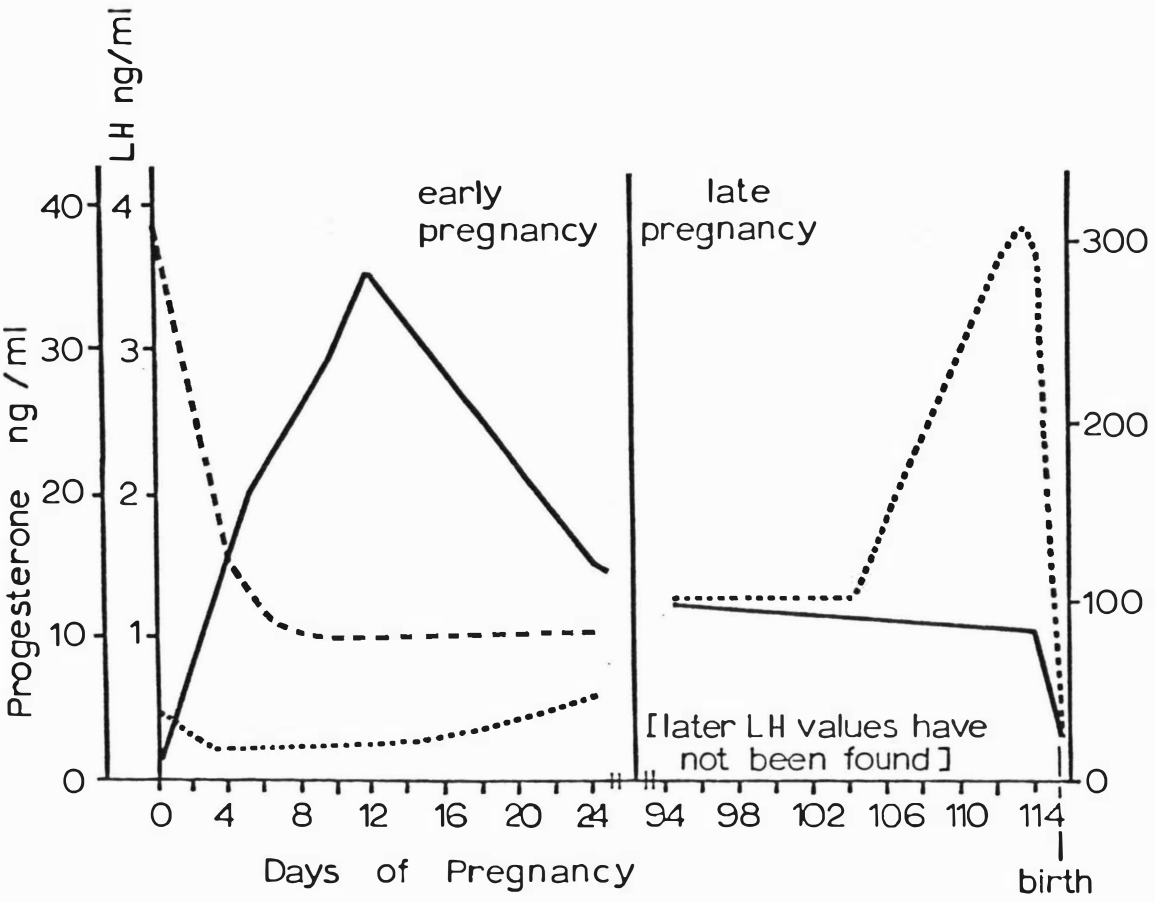


FIGURE 3: Pregnancy blood levels of progesterone,oestrogen and LH in the sow

(Data from references(Ash & Heap (1975),(Guthrie et al,1972)

In the pig, no significant changes in pituitary LH and FSH stores were observed at five different stages of pregnancy by Melampy et al (1966). However a comparison with values found in the oestrus cycle was not made in this study.

Comparing values obtained by Melampy et al (1966) with those of Parlow et al (1964), noted during oestrus cycles, it appears that the pituitary gland of the sow generally contains more FSH and LH during pregnancy compared with, either the metoestrous or the dioestrous phases, probably because of decreased secretion. Plasma LH levels, as determined by radio-immunoassay, during the first 28 days of pregnancy were generally lower than on corresponding days of the oestrus cycle (Tillson et al, 1970).At days 18 and 20 when cycling animals showed a prooestrus rise in LH, the pregnant animal failed to show such an increase. This failure was associated with the maintenance of a high plasma progesterone level, which had declined in cyclic animals (Tillson et al 1970). This progesterone is solely ovarian in origin and none is produced by the placenta.

As pregnancy advances the urinary level of oestrone increases up to the 30th day then declines to a low level until the 60th-70th day. Thereafter oestrone level increases markedly to reach peak by the last day of pregnancy and then declines (lunaas 1962,63). From the failure of observations to detect any significant changes in the ovaries at this time (Melampy et al, 1966) it is assumed that this oestrogen is foeto-placental in origin, as production of oestrogen coincides with placental development. The significance of the high oestrogen level has not been determined although it seems likely that there is some effect on production and release of gonadotrophic hormones. In the pig the conceptus seems to maintain luteal function during critical phases of early pregnancy by overcoming the luteolytic action of the uterus. The nature of the luteotrophic and/or antiluteolytic complex is believed to change during gestation. In early pregnancy the corpus luteum is relatively independent of pituitary control and survival depends on ability of the conceptus to neutralise a uterine lytic factor, probably $PGF_{2\alpha}$ (Horton and Boyser, 1976). Later in pregnancy, up to day 40, LH is the predominant luteotrophic factor and thereafter prolactin becomes increasingly important (Kann and Denamur,1974). Oestrogen, of placental origin, may also play a role in the maintenance of the corpus luteum, possibly acting indirectly to stimulate pituitary prolactin secretion.

Relaxin activity in luteal tissue accumulates to reach a peak in late pregnancy (105 to 110 days). However, somewhere between 44 and 26 hours prior to parturition, relaxin level declines by half with a minimum level being reached one day before delivery. The significance of relaxin in respect of initiation of parturition in the sow has been discussed in some detail by Kertiles and Anderson (1979).

2.4 Parturition

2.4.1 General aspects

At parturition the foetuses are released to pass along the uterine horns (Perry, 1954). The numbers of young born may range up to

15 Altman and Dittmer, 1962). This, however, is subject to a number of genetic and environmental variables; included in which are breed, age, nutritional history, climate and season (Asdell, 1964). A comprehensive review of the sequence of events which occur at parturition is given by Clegg (1959).

2.4.2 Endocrinological aspects

Near to parturition, FSH and LH secretion are at a low level, possibly due to their suppression by the high level of oestrogen present. At parturition, the plasma levels of progesterone and oestrogen decline precipitously due to the regression of the corpus luteum and cessation of placental function. (Raeside, 1963, Moloku and Wagner, 1973). Plasma corticoid levels increase markedly from 3 days prepartum and peak on the day of parturition. There is then a return to preparturition levels two days postpartum. It is probably that oxytocin is responsible for the uterine contractions at parturition and that the cervix opens under the infleunce of relaxin. The mechanisms by which oxytocin and relaxin are released have not been definitely established. A detailed description on the hormonal mechanisms at parturition are discussed by Catchpole (1977) Overall, parturition is a result of many synchronised events. However, the cause and effect relationships between the many hormones involved has not as yet been clearly established.

2.5 The weaning to oestrus interval.

In the sow a post partum oestrus usually occurs 1 to 3 days after parturition, this being followed by an almost complete suppression of ovarian activity for the duration of lactation. Many instances have been recorded of a variable proportion of sows showing oestrus 2 to 3 days after farrowing (Self and Grummer, 1958; Warnick et al 1951). It is generally proposed that this behavioural oestrus is caused by oestrogen, although both progesterone and oestrogen levels have declined postpartum. The frequent occurrence of postpartum oestrus is thought to be due to a high residual level of oestrogen of foetal placental origin. Matings at this postpartum oestrus are infertile as the follicles are immature and ovulation does not occur.(Warnick et al, 1951; Burger, 1952).

As the lactational period is not directly relevant to this study, the physiological and endocrinological aspects are not discussed. However indirect effects are of significance in that as the duration of lactation is extended the subsequent interval from time of weaning to onset of oestrus becomes shortened and less variable. Uterine regeneration takes place very rapidly with the most important changes having occurred by day 7 postpartum. It has been proposed that the uterus is capable of functioning normally by the 14th day postpartum, although complete uterine involution does not occur until the 21st to 28th day postpartum (Palmer et al, 1965b). Weaning prior to three weeks postpartum is therefore likely to result in increased early embryonic mortality (Varley and Cole, 1976). A high incidence of persistent anoestrus and cystic ovarian follices has also been observed to occur (Peters et al, 1969).

The duration of lactational dioestrus can be regulated by the level of suckling as a reduction in the number of piglets per litter or in the frequency of suckling advances the return to oestrus (Smith 1961). Suckling acting through the hypothalamus, promotes lactation and reduces the level of circulating gonadotrophic hormones and thus suppresses ovarian activity (Peters et al, 1969; Rothchild,1967), causing the inhibition of follicular growth during lactation (Crighton and Lamming 1969).

There is some evidence to suggest a gradual decrease in the efficiency of the suckling stimulus as an inhibitor of pituitary activity. Thus, during the first week of lactation there is a decrease in the number and size of follicles present but as lactation proceeds, a gradual increase in follicular size is observed.(Palmer et al,1965a). More specifically it has been suggested that the suckling stimulus inhibits the synthesis of LH and the release of FSH from the pituitary (Melampy et al 1966).

2.6 Reproduction in the male

2.6.1 General aspects

Growth and maturation of the testis, culminating in the onset of spermatogenesis and semen output are some of the most profound physiological changes which occur during the postnatal development of the boar. Spermatozoa production is a cyclical event, subdivided into eight stages on the basis of seminiferous tubule cellular content. This has been discussed in detail by Ortavant et al., (1977). The duration of this spermatogenic cycle is defined in terms of the seminiferous epithelium cycle which is formed by the series of changes occurring in a given area of the seminiferous epithelium between two successive appearances of the same cellular association (Ortavant et al (1977). The mean duration of this seminiferous epithelium cycle was calculated to be 8.5 ± 0.1 days. (Swierstra, 1968), which is a short period compared with 13.5 days in bulls (Hochereau et al, 1964) and 10.3 days in rams (Ortavant, 1956). However, before one spermatogenic cycle has completed its evolution, several new ones start in the same part of the seminiferous tubules. The duration of the subsequent epididymal transit ranged from 9 to 12 days. (Swierstra, 1968). Although this period was estimated at 14 days by Singh (1962) . In comparison epididymal transit times have been reported as 13 to 15 days in the ram (Ortavant, 1959) and 8 to 11 days in the bull (Orgebin 1961). The beginning of spermatogenesis has not been defined, as yet, so the exact length of the process remains unknown. However, in many other species, spermatogenesis extends over about 4 cycles of the seminiferous epithelium. Consequently, until the exact pattern of spermatogonal renewal is known, it is assumed that spermatogenesis of boars extends over four consecutive cycles. Based on this assumption 35 days may be considered a reasonable approximation of the duration of spematogenesis in the boar. The yield of spermatozoa is influenced by numerous factors, many of which affect the primary stages of spermatogenesis and spermatogonal divisions. (Courot et al 1970). Many spermatocytes degenerate, particularly under influences such as elevated scrotal temperature and hence limit the efficiency of spermatogenesis (Mazzarri, 1968). A detailed description of the dynamics of spermatogenesis in the boar is given in a review by Swierstra (1968), while a description of semen characteristics and composition, sperm capacitation and the process of ejaculation are discussed in reviews by Ortavant (1977) and Mann (1954).

2.6.2. Endocrinological aspects

Reproductive processes are regulated to a large extent by two hormones secreted by the anterior pituitary. Although these hormones, namely LH and FSH, were discovered over 40 years ago (Evans et al 1937), their exact role in the initiation and maintenance of spermatogenesis is still not clearly understood.Most simply stated, FSH is thought to stimulate the growth of seminiferous tubules and spermatogenesis affecting the maturation of spermatids and spermatozoa (Means, 1975; Gemzell et al, 1966), while LH facilitates the completion of spermatogenesis by stimulating the Leydig cells to produce androgens (Steinberger et al, 1972). The major testicular androgen thus produced, namely testosterone serves as a circulating precursor for two other types of steroids. These in turn mediate many of the physiological processes involved in male sexual differentiation and virulization (Hansson, 1972; Vreeburg et al, 1971) On the other hand circulating androgens are aromatized in the peripheral tissues of both sexes to oestrogens (Engel, 1973). The latter in some instances act in conjunction with androgens to influence physiological processes. They may also exert independent effects on cellular function and even on occasion have effects in opposition to those of androgens (Federman et al 1958; de Moar, 1973).

3. Characterisation and Incidence of Seasonal Infertility in the Pig.

The domesticated pig is described as a polyoestrus animal, which can cope with a very wide range of conditions, outdoors and indoors; and in most instances reproductive performance is satisfactory (Dyck et al 1974; Steinbach, 1972, 1976). However, with the advent of costly intensive systems of pig production, minor alternations in efficiency of production such as seasonal variation in reproductive performance, are now of major importance in optimizing the use of expensive facilities.

Seasonal reproductive inefficiency has only been detected in recent years with the introduction of detailed recording schemes, now an essential feature of profitable production. Nevertheless, the phenomenon has been reported to occur in a number of countries including the United Kingdom (Stork, 1979), Italy (Enne et al, 1979), South Africa, (Robinson and van Niekerk,1978), France (Corteel et al 1964) Australia (Love, 1978; Paterson et al 1976), and New Zealand (Hermann, 1980).

Literature pertaining to the effect of season on fertility in the pig can be considered in two main sections; season can exert both a direct and an indirect influence on reproductive efficiency.In respect of the latter, season of birth may influence the time of subsequent sexual activity through an effect on time of attainment of puberty. In respect of the former, season has a direct influence on several facets of reproduction in the sexually mature animal.

Manifestations of the latter, in respect of the female include failure to return to oestrus, returns to service of abnormal length, abortion and animals subsequently found not to be pregnant at term. Also included is an increase in stillbirths, decreased litter size, reduced birthweights and viability of young. Corresponding aspects of reproductive performance in the boar, inlfuenced by season include libido, and the produduction and viability of sperm.

3.1. Attainment of puberty

There is evidence that with gilts born in summer months there is a delay in attainment of sexual maturity (Wiggins et al, 1948; 1950; Robertson et al 1951 ; Gossett and Sorensen, 1959; Corteel et al 1964). In contrast, no significant difference in age at puberty due to season was noted by Wise and Robertson (1953) and Sorenson et al (1961). This contradictory evidence is difficult to explain as many authors have neglected to give precise dates of pubertal attainment and the method of detection of puberty is not clear. The latter is of particular significance in view of findings that presence of the male can influence the time of attainment of puberty (Brooks and Cole, 1970).

3.2 Failure to return to service post-weaning.

Seasonal variation in the length of time to return to oestrus postweaning has been reported by several workers in various countries (Mitic et al, 1965; du Mesnil du Buission and Signoret, 1968; Magnani and Casati, 1966; Hurtgen, 1975; Steinbach, 1976b; Webster, 1978; Love, 1978). Figures given in these studies show that although season did influence return to oestrus in all, there is no general agreement as to its effect. Hurtgen (1976) found a larger percentage return within 10 day postweaning in winter and spring compared with autumn and summer. While Legault et al (1975) noted a significantly longer return to oestrus post weaning in late spring and summer compared with winter. However, Magnani and Casati (1966) found little difference in the days from farrowing to onset of oestrus in winter compared with late spring.

In experiments which recorded prolonged returns to oestrus postweaning during summer months,this failure may be associated with either a suboestrus or an anoestrus condition. A recent detailed on-farm investigation by Love (1978) concluded that the " majority of sows that have a prolonged weaning to oestrus interval (greater than 18 days) have ovulated but oestrus has either not been expressed or not observed". Further, behavioural studies by van Putten (1965) and du Mesnil du Buisson and Signoret (1968) reported that oestrus tended to be less clearly expressed in summer than in winter, implying abnormal summer oestrus returns to be caused by a suboestrus condition. In contrast, Hurtgen (1976) diagnosed an anoestrus condition in sows returning in late summer and early autumn. Clinical examination showed that reproductive tracts had a tonic uteri and small inactive ovaries. Although the studies which have examined the seasonal influence on weaning to first oestrus interval are not all in agreement there is a general consensus in support of an increased percentage of sows exhibiting a return to oestrus interval of more than 10 days post weaning during the summer months. This could suggest a need for an extended recuperative period postweaning.

In support,Love (1978) found that in summer, sows which took more than 18 days to express detectable oestrus subsequently had an acceptable farrowing rate of 82.6%. On the other hand a group taking less than 18 days to show detectable oestrus following weaning had a farrowing rate of 68.8%. In support of the proposed need for an extended recuperative period for sows weaned during summer months, Steinbach (1976b) in a study conducted in Nigeria, noted that in the prooestrus and oestrus phases of the cycle, the oviductal epithelium was 28% lower during the summer ("dry period" of the year) than during the "wet"season. It was proposed that "sows may respond more slowly in return to oestrus, possibly due to a lower secretion of gonadal hormones". Support for this hypothesis comes from Webster (1978) who described and evaluated a commercial mixed gonadotrophin preparation in a piggery that consistently experienced summer infertility due principally to a prolonged weaning to oestrus interval. It was found that the average weaning to oestrus interval for treated sows was significantly shorter than for control animals an indication of a negative relationship between plasma gonadotrophin levels and length of weaning to remating interval during summer. It is worthy of note, however, that there are conflicting reports on the length of the weaning to remating interval during summer. While the hormonal role in suboestrus or anoestrus response to seasonal variation awaits further evaluation.

3.3 Duration of oestrus:

In the normally cycling sow Malinkin (1971) and Signoret (1967) have reported seasonal variation in the duration of oestrus as judged by the period of time that the standing reflex could be elicited and by gilts acceptance of the boar. In respect of the former study a maximum period was reached in summer (98.8-111.9 hours and a minimum in winter 24.6 hours). Corresponding values for the latter study were 58.8 and 52.9 hours respectively. However, the variation in values reported by Malinkin (1971) appear extreme. A study reported by van Putten (1965) on the distinctiveness of external signs of heat, found that the standing reflex was not a certain criterion of onset of oestrus.

Contrary to the above findings there are reports that oestrus tends to be expressed more clearly in winter than in summer (Van Putten, 1965). In this study however, poor expression of oestrus was not considered to be related to reduced fertility. It could well be that a prolonged oestrus can occur in summer but it is less clearly expressed compared with winter. In the ensuing sexual cycle Einarrson (1968) observed a decrease in the number of sows with abnormal cycle lengths over summer compared with the rest of the year. Signoret (1967) on the other hand, reported that in normally cycling sows the average length of the oestrus cycle was unaffected by season. Hormonal studies were also undertaken by Signoret (1967) It was noted that the duration of the oestrus response can apparently be controlled by the use of oestrogen, but that aspects of the subsequent sexual cycle appear to be predominantly controlled by other factors, probably of genetic origin. Thus, Signoret,(1967) observed that despite prolonged oestrus duration due to oestrogen dose in ovarectomised females, seasonal variation in duration of subsequent sexual cycle response varied in the same way as with spontaneous oestrus in intact sows. Individual influences were noticed in hormone-treated animals as in normal animals.

3.4 Return to oestrus

There is evidence that stresses manifest in one particular part of gestation are not always apparent at that time. Thus, should reproductive failure result it is difficult and impracticable to diagnose the exact stage in gestation when this occurred. Consequently, most studies concerned with the influence of seasonal variation on gestation have used only an overall index of reproductive efficiency. This has invariably been farrowing rate, which can be defined as; the proportion of services which are successful, i.e. produce a litter.

Despite the limitations of this parameter of reproductive efficiency, many studies have noted a decrease in reproductive performance during summer (Table 1) although the decline in farrowing rate observed has varied with country of origin, and the specific micro environment and management to which the sows were subjected.

The effect of season or specific aspects of the reproductive cycle has been studied by several groups of workers (Corteel et al 1964; Jaussiaux, 1964; Scofield and Penny, 1969; Stork, 1979). There is general agreement that the seasonal effect produced is very much dependent upon the stage of the reproductive cycle which is influenced. One such stage, as described by Wrathall (1975) is the rate of return to service some 20 days after a normal mating. Return to natural service or artificial insemination at this time is associated with ovaries that are functionally normal and a rhythmical oestrus cycle is established but after mating the sow fails to hold to service. One of three factors is involved; either the spermatozoa fail to reach the ova, the ova die within

TABLE 1: Seasonal influence on farrowing rate

Season of mating	number of observations	Proportion of services which produced a litter (%)	Author and country.
Spring	146	86.2	Moore (1972) (U.S.A.)
summer		79.4	
Winter	4169	69.9	Cerovsky (1974) (Czechoslovakia)
Spring		66.5	
Summer		52.3	
Autumn		59.8	
Winter	5091	86.6	Stone (1977) (Australia)
Spring		81.3	
Summer		68.5	
Autumn		82.2	
Summer	491	78	Love (1978) (Australia)
Autumn	452	91.6	
Winter	N.A.	82.7	Robinson and van Niekerk (1978) (South Africa)
Spring		80.3	
Summer		71.3	
Autumn		78.3	
Winter	37563	76.7	Enne *et al* (1979) (Italy)
Spring		72.4	
Summer		55.8	
Autumn		63.9	
Winter	801	75.6	Hermann 1980 (New Zealand)
Spring		75	
Summer		59.2	
Autumn		78.7	

N.A. - not available.

a few hours after fertilisation or insufficient fertilised ova to develop to the 12th day postmating to sustain pregnancy.

It does not appear that return to service at the normal 20-day period is influenced by season. Thus, Love (1978) in a detailed study of records from one breeding unit, found that essentially the same proportion of sows returned to oestrus after a normal cycle length during a period when 'summer' infertility was experienced and a subsequent one where sow fertility was considered to be normal. This component of the infertility problem was fairly constant throughout the year (some 10 to 15% of matings). It was concluded that the 'summer' infertility problem was not due to fertilisation failure or early embryonic mortality where sows would be expected to return to oestrus in the normal 15 to 25 day range. In support of this view, a few detailed studies (Corteel _et al,_ 1964; Jaussiaux, 1964; Hermann, 1980) have found that any increase in the number of infertile sows in the herd during the summer period consists entirely of animals with extended return to service intervals (Table 2).

Return to service some 20 days after mating may occur, following total embryonic loss early in gestation. The causes of embryonic loss are many; Boyd (1966) in his review gave a range of factors which influence embryonic survival (one of which was season of mating). However, little documented evidence was presented in support of this view, as there is a lack of specific literature in this field. However, a few workers have recently made mention of significant increases in the proportion of sows in large breeding

TABLE 2: Seasonal influence on returns to oestrus post mating

Season of mating	number of observations	Proportion of returns of abnormal length	Author and Country
Summer (late)	8489	13.03 (1)	Jaussiaux (1964) France
Autumn (early)		13.07	
remainder of year		3.43 to 6.62	
Summer	491	11.1 (2)	Love (1978) (Australia)
Autumn	452	2.7	
Winter	801	6.2	Hermann (1980) (New Zealand)
Spring		11.3	
Summer		25 (3)	
Autumn		9.9	

(1) = > 45 days; (2) > 25 days; (3) = 25-35 days and > 49 days

herds exhibiting long returns to natural mating or artificial insemination during the summer months (Stork, 1978; Love,1978; Paterson et al 1978; Hermann,1980).

A decrease in fertility of some 10% during the summer months was recorded in breeding units associated with an artificial insemination centre in France. In the same period the frequency of abnormally long returns to oestrus (>45 days) increased to double the values recorded during other months. This encouraged a three-year monitoring of abnormal returns to service post matings in the field (Corteel et al, 1964). The latter reported a significant increase in abnormal returns (> 45 day) during the summer months. It was considered that the death of embryos after implantation could be responsible for a delay in return to oestrus associated with the summer infertility problem.

In support there are reports of this occurring in both sheep (Edey, 1967)and cattle (Stewart, 1952). However, the fertility of females that remate after losing their conceptus is usually impaired (Edey, 1967; Sawyer and Knight, 1975). Again, since investigations into the subsequent fertility of sows returning to service after an extended period post mating found that it was no different to that of sows showing normal returns to oestrus, it seems unlikely that total late embryo mortality is a factor in the expression of'summer'infertility.

Data pertaining to embryo mortality early post mating is scarce. However,Madzirov et al (1952) in a study covering a one year period, reported that in sows slaughtered in the first month of gestation there was no significant monthly difference in embryo survival.

3.5 Fecundity

In respect of fecundity of the sow, there is only limited information of the influence of season on ovulation rate and this is contradictory (Gossett and Sorensen, 1959; Sorensen et al 1961; Moore, 1972; Moore et al 1973; Mahoney et al, 1970). Similarly with regard to the influence of season of mating on litter size at birth there is no general agreement (Table 3). In respect of the 'summer' infertility problem recent evidence (Love, 1978) indicates an "all or nothing phenomenon" in respect of litter size. Thus, the sow either maintains the pregnancy and farrows a normal litter or loses the whole litter and returns to oestrus. In support, a recent study (Hermann, 1980) involving the analysis of breeding records in one herd over a 7-year period reported a decline in farrowing rate in sows mated during the summer months but no effect on either total litter size of birth or live births per litter.

In respect of a possible seasonal influence on abortion rate in sows evidence is sparse. In a recent farm survey conducted in the United Kingdom, Stork (1979) reported an increase (2-3%) in the number of sows aborting during the autumn period,an effect which appeared to be a regular seasonal problem. The nature of the abortifacient (which was capable of causing abortion at all stages of pregnancy) was not identified.

TABLE 3: Seasonal influence on litter size

Season of mating	number of observations	number born per litter	Author and Country
Winter	1,26350	9.21	Anonyme (1954) (Australia)
Summer	1,10530	7.2	
Winter	10222	10.4	Popovic and Salahovic (1973) (Yugoslavia)
Spring		10.1	
Summer		10.3	
Autumn		10.5	
Summer (late)	1979	11.1	Maryushin an Maryushina (1974) (USSR)
Autumn		10.7	
Winter		10.8	
Autumn	2134	8.43	Entwistle et al. (1 978) (Australia)
Yearly Average		11.39	
Summer	383	8.78	Love (1978) (Australia)
Autumn	414	8.66	
Winter	2760	10.7	Robinson and van Niekerk (1978) (South Africa)
Spring		10.9	
Summer		10.4	
Autumn		10.5	
Winter	801	11.9	Hermann (1980) (New Zealand)
Spring		11.3	
Summer		11.8	
Autumn		11.8	

The incidence of still births is known to be positively associated with litter size, while prolonged parturition is probably another causal factor , since most still births occur as a result of anoxia. Whether seasonal variation occurs in this factor is not clear, evidence in the literature being both scarce and contradictory (Table 4). Again, in respect of a seasonal influence on subsequent birthweight, information is scarce. However, Enwistle et al (1978) reported that piglets born from sows mated during the summer months had a significantly lower birthweight than those born from matings in the winter months. On the other hand Milosavljevic and Sovljanski (1969) and Sreckovic et al (1974) reported no significant season effect on body weight at birth. This conflicting information is not surprising in view of the many factors which influence birthweight e.g. nutrition of the sow and litter size (Clawson et al 1963 ; Lodge et al 1966a; 1966b;O'Grady,1967 Esley et al 1969).

Overall it seems clear, from recent reports that there is a 'summer' infertility problem in several of the major pig producing countries. The main effect of which is a reduced farrowing rate in the herd. Several studies have attributed this to abnormal returns to service. Another effect noted has been prolonged return to service postweaning, while subsequent litter size of birth does not appear to be influenced by this condition.

TABLE 4: Seasonal influence on the number of stillbirths

Season of farrowing	number of litters	Stillbirth rate (%)	Author and Country
Winter Spring Summer Autumn	352	13.44 11.26 8.64 11.05	Milosavljevic and Sovljanski (Yugoslavia) (1969)
Winter	1330	6.66	Sreckovic *et al* (1974)
Spring	1269	6.73	
Summer	1667	6.79	
Autumn	1501	6.86	
Summer Winter	N.A.	2.8+	Scofield and Penny (1969) (United Kingdom)

\+ Increase in summer relative to winter

3.6 Reproduction in the male

Seasonal changes in the reproductive activity of the boar have not been as widely studied as in the sow. The subject has been reviewed by Ortavant et al (1964) and Asdell (1964). It appears that male mammals display less dramatic and characteristic seasonal differences in behaviour compared with the female. Nevertheless seasonal variation in reproductive performance has been recorded following examination of the gonads, accessory organs and semen (Table 6). Research in this field has usually involved either weighing the various organs or the determination of levels of hormone activity. Studies of semen characteristics have also been undertaken.

In the summer months, Love (1978) found that in most cases,boars which were associated with an unsuccessful mating one week,would have a record of success at both the previous week and on the next mating. In addition no increase in the number of sows returning to oestrus at the normal time was noted during summer. On the basis of these results it was concluded that the boar was not involved in the seasonal infertility problem.

Libido in the male, which is independent of sperm production, is generally lower in summer months than in the other seasons (Niwa and Muzuho, 1954; Lawrence et al 1970). Burger (1952) and Steinbach (1975) in their semen studies, which included collection, both noted that lack of libido, as measured by the reaction time and by the boars refusal to mount a dummy, showed a seasonal trend. On the other hand, Gravogel (1966) and Robinson and van Niekerk(1978) found that libido and general sexual behaviour in the boar during the summer months, did not seem unusually low. In conclusion, since the boars in the various studies were kept under different conditions and were of different breeds and ages, it is not possible to draw conclusions from the few studies reported, on the effect of season on male reproductive performance.

In the more detailed studies, Niwa and Muzuho (1954) were unable to detect seasonal changes in spermatogenic activity of the testis although sperm concentration tended to be higher in summer and the duration of sperm viability was lower. No observed seasonal variation in sperm motility was recorded. Nigerian data, reported by Steinbach (1975) also recorded seasonal differences in the concentration of spermatozoa. There were no seasonal differences in sperm cell motility or in the proportion of abnormal cells in this study. Cerovsky (1974) observed that the percentage of abnormal spermatozoa in the ejaculations of 60 boars rose from 23% in winter to 74.2% in summer. It was found that the most frequent cause of infertility was a high percentage of spermatozoa with protoplasmic droplets. In general, herd studies have reported no seasonal variation in boar fertility. In France, no seasonal variation was observed in the reaction time, duration of ejaculation, sperm volume or composition (Signoret,1970)(Table 5).

TABLE 5: Seasonal influence on boar performance

Season	number of observations	Boar performance characteristics							Author and Country
		Ejaculate volume(ml)	Sperm concentration ($x10^{-9}$/ml)	Sperm motility (%)	Sperm Survival (hours)	Abnormal Sperm(%)	Libido Av. mount latency (mins)	Libido Av duration ejaculation (mins)	
Winter	730	301.5	.163	81	29.4				Mikitas (1969) (USSR)
Spring		213.1	.186	75.5	25.9				
Summer		209.8	.178	69	21.6				
Autumn		251.3	.170	79.5	29.3				
Winter	232	260	.251	82					Folomeyeyev (1975) (USSR)
Spring	232	247	.212	86					
Summer	244	237	.235	80					
Autumn	241	244	.242	80					
Winter	413	211	.203	83.3					Kovalenko (1975) (USSR)
Summer	413	204.6	.200	82.6					
Winter and Spring	60+					26.8			Cerovsky (1974) (Czechoslovakia)
Summer						74.2			
Winter	804	299.6	.332				1.2	6.3	Signoret (1970) (France)
Spring	857	284.3	.341				1.2	5.73	
Summer	801	301.6	.326				1.2	5.43	
Autumn	791	211.7	.332				1.1	5.66	

+ Refers to number of boars in study

4. The Influence of Environmental Factors on Reproductive Performance

Seasonal differences in reproductive efficiency of the sow may result from an intrinsic rhythmical mechanism, but it is likely that environmental factors regulate or modify such a mechanism.

The feral pig, in some countries, is found to be a seasonal breeder. For example, in Russia, feral pigs breed from November to January, while in Iraq, breeding is from April to May (Asdell,1964). With respect to New Zealand, the domestic pig released by Cook is found to breed all the year round (Asdell,1964). These wild pigs, however, have been adapted to their environment through natural selection. They also have the possibility of seeking favourable micro-environments within a stressful macro-environment.

By contrast, domestic pigs have been selected and bred by man for productive traits. In addition, they may be transferred from one environment to another and the chance of escaping from a stressful environment into a less stressful one is usually restricted. Thus, the domesticated pig may be poorly adapted to its environment. On this basis it is likely that seasonal variations in ambient temperature, photoperiod and humidity along with changes in nutrition,managerial practice and disease status affect the reproductive performance.

A clearly defined 'cause and effect' relationship between specific factors and reproductive disorders is uncommon. Although in the following text it has been necessary to impose a division of topics in order to consider all the various factors, which influence reproductive efficiency individually, this is not a reflection of the practical situation as many reproductive disorders in fact appear to be of multifactorial origin.

4.1 Light

The importance of light, particularly daily photoperiod on the reproductive performance of domestic animals has been well established in species such as sheep (Ortavant,1961; Dun et al,1966), horses (Buckhardt, 1947) and goats (Clegg and Ganong, 1959). However, in polyoestrus species, such as cattle and pigs, where seasonal periodicity in reproductive function is less marked, the importance of light as a stimulus in influencing a wide range of reproductive responses is less conclusive. Nevertheless, variations in reproductive performance have been reported in cattle (Sweetman,1950) and in pigs (Klotchov et al, 1973; Steger et al,1971).

Most studies relating to the influence of lighting regime on reproductive performance in the pig, have been concerned with the attainment of sexual maturity. However, experimental findings in this field have been contradictory. Hacker et al,(1974); Anon (1977) and Ntunde(1978) found that where gilts were exposed to a 12:12 hour light:dark regime compared with constant darkness from either birth or over a prolonged period of time to puberty the attainment of sexual maturity was reported to be up to forty days earlier in gilts subjected to the light regime. Similarly Martinat et al (1970) indicated that a fewer number of gilts showed delayed onset of puberty in continuous light compared with natural light.Surmuhin et al (1970) noted that the uterus and ovaries were some 18 to 25% larger in nine-month old gilts exposed, from 3½ months of age, to 12 to 14 hours of daylight compared with 8 hours. In contrast, Dufour and Bernard (1968) reported that gilts reared from eight weeks of age in almost complete darkness were sexually mature 11 days earlier than their counterparts reared under natural conditions. However, optical enucleation in this study resulted in a 14 day delay in onset of oestrus.

Several workers have studied the influence of lighting regime on oestrous behaviour and ovulation rate in gilts. Dufour and Bernard (1968), in the study referred to previously, found that the second oestrus was exhibited earlier in the almost dark environment but ovulation rate in the dark was similar to that of the control group kept in a natural lighting regime. However, the numbers included in this experiment were small.

Klotchkova et al (1973) reported that gilts exposed to light intensities of approximately 100lux for 17 hours, or 24 hours daily for 10 to 20 days before oestrus during the winter period had similar or only slightly higher ovulation rates to those of gilts kept in natural light (8-10 hours per day approximately). Waddill et al (1968), who kept gilts in continuous light for one complete oestrus cycle, found that mean ovulation rate was almost identical to that of controls kept under normal spring-time daylight conditions. It was suggested that the amount of daylight during spring may have been sufficient to elicit an optimum ovulation response in the cycling gilts.

Belyaev et al (1968) demonstrated that a prolonged photoperiod (up to 17 hours) during the time of mating in autumn-winter resulted in an increased proportion of sows exhibiting prolonged heat periods. When the light treatments were continued after mating into pregnancy (Klotchkov et al 1973) it was reported that the 100lux for the 17 hours or 24 hour regime resulted in consistent increased in the number of embryos at 25 days and subsequent number of piglets born at term. It was suggested that the beneficial effects of extra light given before service and during pregnancy might have been due to a stimulatory effect on the corpus luteum, this leading to increased progesterone secretion with a favourable effect on embryonic survival. A similar trend of increased litter size with prolonged duration of light, beyond 12 hours was found by Anon (1977). Steger et al (1971) found a decrease in the prolificacy of sows kept in darkness but in contrast Hacker et al (1974) observed an improvement,while Benkov (1974) reported no significant difference in litter size of sows exposed to 16 hours of light compared with 1½ hours. Unfortunately, most studies deal with the effect of light on the gilt, there being a lack of comparable data relating to the sow.

In respect of the effect of intensity of light, as opposed to photoperiod on reproductive peformance, there is little information available. Abrosimova et al (1971) showed that the illumination, in a variety of light intensities of both incandescent and fluorescent lights did not influence the bodyweights of gilts. On the other hand Yurkov (1978) recorded a higher number of live born piglets, heavier birthweights and lower preweaning mortality in sows subjected to 100lux for 14 hours daily compared with 60lux and 10lux for a similar period.

In the male, there is little information on the effect of lighting regime on sperm production and quality. Steger (1971) noted that the housing of breeding boars under dark conditions was not satisfactory, in terms of spermatozoa production, mobility of sperm ejaculate volume or libido. Mazzarri et al(1968)found that semen production was disturbed in an experiment comparing boars subjected to either 16 hours or 10 hours of light daily. Decreases in total number of sperm per ejaculate, sperm mobility and fertilising capacity were noted in the 16 hour, light treatment, although the volume per ejaculate was increased.

In respect of light intensity Yurkov (1978) noted that supplementary artificial light for 8 hours daily at an intensity of 100 to 150 lux had a beneficial effect on semen production. In two studies (Yurkov, 1976; 1978) 100-150lux light intensity compared with 10 lux resulted in a higher number of sperm per ejaculate and a higher ejaculate volume. Clearly in an intensive livestock industry, such as pig production sincethe duration and intensity of the lighting regime can be manipulated to best suit productivity there is an urgent need for confirmation or otherwise of the limited experimental data reported in this field.

4.2 Effect of cold.

In farm livestock, cold normally represents a smaller problem than heat. Most investigators agree that cold has minimal effects, if any,on reproduction in the pig. (Swierstra and Rahnfeld, 1972; Dyck, 1974) Outside the zone of thermoneutrality the difference between normal and lethal body temperature is of the order of 15-20°C in cold but only about 3-6°C in heat (Bianca, 1976).

Exposure to cold has been found to increase the length of the oestrus cycle in the rat (2°C)(Denison and Zarrow, 1955) and delay the onset of breeding in mice (-3°C) (Barnett and Manly 1966). However, studies carried out over an 8 year period by Swierstra and Rahnfeld (1972) on the reproductive performance of adult sows and boars kept outdoors in Canadian sub zero winter conditions, revealed no adverse effect of cold on ovulation rate, conception rate, prenatal survival or litter size and no depression of boar performance.

In a similar study Dyck (1974) examined the effect of cold stress on ovulation rate and embryonic survival by housing one group of 37 gilts in a temperature controlled barn (10-16°C) and another group of 24 gilts outdoors with access to shelter cabins. During December to March, where outdoor temperatures of -19°C to -26°C were not uncommon cold stress did not affect ovulation rate or embryonic survival.

In the boar, Hacker _et al_ (1971) showed that exposure to excessively cold conditions during the prepubertal stage can lead to testicular hypoplasia and delayed onset of puberty. _In vitro_ experiments on freezing semen for artificial insemination (A.I.) have shown that sperm fertility may be affected (Hess _et al_,1957; Hoffman, 1959 Baier 1962). These studies suggest that,while direct cold on semen may seriously affect reproductive capacity, the animals body can buffer cold stresses that may be imposed. by the environment. (Swiestra and Rahnfeld 1972). The extent of tolerance to cold depends to a large extent on level and quality of the diet, degree of insulation of the superficial tissues of the body and behavioural responses. Moreover these factors which are desirable in livestock namely, a high rate of growth and high reproductive performance are associated with a high metabolic rate and hence a high heat production which is conducive to a high tolerance to cold.

4.3 Effect of heat

Heat refers to those environmental elements which either interfere with the dissipation of body heat to the environment (high ambient temperature and humidity) or which impose an external heat load on the animal (solar radiation). The more heat an animal produces internally by its metabolism the less its capacity of tolerating external heat.

4.3.1 Fertility. The deleterious effects of high ambient temperature on fertility have been noted in herd studies. Those which recorded seasonal variations in herd fertility considered it to be the resultant effect of high temperatures at a critical time in the reproductive process, such as the weaning-remating period or preimplantation stages (Grandhi et al, 1977; Bakker and Davies, 1972; Stone, 1978).

In studies where detailed meteorological records were available, the seasonal infertility pattern coincided with an elevation in ambient temperature at specific stages in the reproductive cycle. The ambient temperature at which reproductive inefficiency may become evident varies with the individual and the herd situation, e.g. nutritional status and standard of housing and also upon the duration of the heat stress. Despite these variants, herd studies in countries as far apart as Canada, Nigeria, South Africa, Australia and England have all reported that the first time in each year the monthly average outdoor temperature exceeded 21 to 25°C reproductive inefficiency became apparent.

Studies in temperate countries have indicated that a maximum outdoor temperature, just above 20°C is sufficient to trigger a lowered reproductive response (Stork, 1979; Grandhi et al, 1977). In tropical countries similar studies have implied that although this ambient temperature is sufficient to interfere with reproductive performance there is no marked effect until values for outdoor temperature are in the range 30 to 40°C (Steinbach, 1973; Robinson and van Niekerk, 1978; Love, 1978; Paterson et al, 1978). In the sow, reproductive efficiency may be affected through a direct influence of high ambient temperature on age and weight at onset of puberty, oestrus cycle characteristics, ovulation rate and on pregnancy and lactation.

4.3.2 Puberty: Heat stress effects on the attainment of puberty in gilts have been reported by Jensen et al (1970) who observed oestrus symptoms in only two out of ten heat stressed gilts at about the tenth month of age. However, within two weeks following removal of the heat stress, the remaining gilts had shown oestrus and were bred. Steinbach (1973), from studies conducted in Nigeria, concluded that gilts, which had most of their growth during outdoor temperatures of 28°C and above, showed retarded body development. This was attributed to a reduction in feed intake in the hot conditions.

4.3.3 Characteristics of the oestrus cycle: There is evidence from studies conducted in climatic chambers and in the field that exposure of sows to hot conditions can adversely affect several characteristics of the oestrus cycle.

Teague et al (1968) reported that exposure to ambient temperatures of 30°C or 33.3°C for one oestrous cycle, in climatically controlled chambers resulted in an increasing proportion of gilts,(up to 10% of 80 gilts at 33.3°C) failing to show signs of oestrus for the duration of the treatment. Warnick et al (1965) observed that three of thirteen gilts exposed to a constant temperature of 33.3°C for 36 days,in a climatic chamber did not return to oestrus. Following slaughter of the gilts, it was observed that recent corpora lutea were present, an indication that ovulation without oestrus had occurred (Warnick et al,1965). Whether the effect of a high ambient temperature on oestrus behaviour results from an anoestrus or suboestrus condition is uncertain. Steinbach (1976) reported a 10% higher incidence of anoestrus in gilts during the hottest month of the year (mean monthly temperature 28°C). Duration of oestrus was found to be negatively associated with ambient temperature (Steinbach 1976a). The latter also observed variation in endometrial water content and a significant decline in cell height of the oviduct wall with increasing air temperature, an indication of an anoestrus condition. This is in contrast to Warnick et al (1965). Variation in onset of oestrus was not observed by Edwards et al (1968) nor by d'Arce et al (1970) who in their studies with gilts confined them in hot chambers. d'Arce et al (1970) and Miskovic et al (1978) found no significant change in the length of the oestrous cycle resulted from exposure of gilts to high temperatures (above 33°C).

In contrast to those findings, Edwards *et al* (1968) reported a lengthening of the oestrous cycle following daily exposure of gilts (17 hours) to 38.9°C and 32.2°C (7 hours) ambient temperature for one oestrous cycle. Although several deaths occurred which were directly attributable to the high temperature conditions, mean oestrous cycle length of the remainder was only two days longer than normal.

With regard to the weaned sow, there does not appear to be any detailed information on the effect of ambient temperature on the duration of the weaning to remating interval. In respect of relative humidity (RH) Lynch (1977),using 24 sows per treatment, compared two levels of relative humidity (75-80%) and(65-70%)at 27°C. Relative humidity level did not significantly affect the length of the weaning to mating interval (5.4 days at high RH compared with 6.1 days at low RH).

4.3.4 Ovulation rate: In the majority of studies relating ambient temperature and ovulation rate, as determined by corpora luteal count, no significant treatment effect has been noted. (D'Arce *et al*,1970; Edwards *et al*,1965; Warnick *et al*,1965). However,trends shown for ovulation rate to be lower at the higher temperatures could well have been significant had larger numbers of animals been on experiment. In fact, Teague *et al*,(1968) reporting results on 240 gilts, where a series of fixed temperatures were imposed over one oestrous cycle prior to breeding, observed reduced ovulation rates at temperatures above 27°C with the lowest corpora lutea count being at the highest dry bulb and dew point temperatures. However, dewpoint temperature alone did not significantly influence ovulation rate.

Most of the work reported on ambient temperature and ovulation rate has been done in climatic chambers for a relatively short period at a constant temperature. Although this research is valuable in outlining basic mechanisms, results cannot readily be interpreted in terms of animal response to natural climatic conditions where they may become acclimatized over time. Reproductive adaption to long term heat exposure has been observed in rats (Kotby and Johnson, 1962) and in ewes (Thwaites, 1967).

As for naturally varying tropical temperatures (24-30°C) are concerned there is no indication of a decline in ovulation rate even in severely heat stressed gilts (Steinbach, 1976). Where ambient temperature has influenced ovulation rate, the effect may well be an indirect one. It is well known that feed intake is reduced at high ambient temperatures (Edwards _et al_,1968; Teague _et al_,1968). While an increased level of feeding prior to ovulation in the gilt favours a higher production of ova. In respect of the gilt, Edwards _et al_ (1968) reported that animals exposed to a high temperature (38°C) in a climatic chamber suffered severe loss of appetite during confinement compared with those kept at 23°C. Similar findings have been reported by Heitman _et al_(1951), Culver (1961) and Jensen (1963) from their work in climatic chambers. In support of the view that a reduced ovulation rate in hot conditions results from a lowered appetite McGillivray _et al_ (1962) and Ray and McCarty (1965) found a decline in ovulation rate following a reduction of meal intake for a short time before onset of oestrus and ovulation in gilts.

4.3.5 Fertilisation rate: Data relating to the effect of elevated ambient temperature on fertilisation rate, in the pig, are sparse.

Teague et al (1968) reported that exposure of gilts to 35^{0}C for 24 hours on the first day after mating resulted in 13.2% fewer viable embryos at the 25th day of pregnancy than in control sows exposed to 15.5^{0}C for the same period of time, although the difference was not significant.

More specific data on direct relationships between high ambient temperature during mating and subsequent fertilisation rate have emerged from studies on a variety of animals.(Waites,1973; Ulberg and Sheean 1973). Dutt (1963;1964) found that ewes placed in a room with the temperature at 32.2^{0}C just prior to time of expected mating, had a decreased fertilisation rate. Rich and Alliston (1970) also reported that fertilisation rate was reduced when ewes were exposed to heat stress at mating (21.1^{0}C to 32.2^{0}C ambient temperature), but not significantly so.

As fertilisation rate depends upon both ova and sperm, the effect of ambient temperature on semen quality must receive some consideration. Observations on rabbits have indicated that sperm can be influenced by environmental conditions prior to fertilisation in such a way that they retain their fertilising capacity but contribute to subsequent embryo mortality prior to implantation (Waites, 1976; Howarth et al, 1965; Thibgull et al, 1966). The lack of investigations into the effect of heat stress at mating on fertilisation rate in the pig is presumably due to the high fertilisation rates in this species as shown by Squiers et al (1965); Self et al (1955) and Haines et al (1959) among others.

4.3.6 Embryonic Survival: There is general agreement that a high ambient temperature has a detrimental effect on embryonic survival, but the magnitude of the effect is subject to variation. Following exposure of gilts to an environmental temperature of 32°C from 11 days prior to breeding until slaughter at 25 days post mating, Warnick et al (1965) reported a decrease in live embryos but the effect was not significant. A similar result was obtained by Miskovic et al (1978) who noted that exposure to ambient temperatures of 33 to 42°C over one oestrous cycle and the first 24 to 28 days of pregnancy did not significantly influence the number of live embryos. Teague et al (1968) compared gilts, confined at different temperatures, from one oestrous prior to breeding until slaughter, post mating. Live embryos at 25 days ranged from 8.4 at 33.3°C dry bulb and 28.9°C dew point to 11.2 at 30°C dry bulb and 20.2 dew point. Although the difference in the number of embryos was not significant, it confirms the trend noted by Warnick et al (1965). In the study of Teague et al (1968) dew point temperature alone did not have any influence on embryo survival. The tendency for a decreased embryonic survival with increased ambient temperature has also been reported for other species. Both Yeates (1953) and Ulberg (1958) have shown deterimental effects on embryo survival in ewes subjected to high ambient temperatures before onset of oestrus.

In the pregnant female, the influence of high temperature on embryo survival has received some attention. It has been shown that a temperature stress for a short period of time immediately post mating can bring about failure of development of the fertilised ovum. Edwards et al (1968) found that exposure of gilts to hot conditions from the 1st to the 15th day of gestation (at 38.9°C for 17 hours daily and 32.2°C for the remainder) resulted in lower conception rates and also significantly fewer viable embryos when compared with similar heat stress imposed during 15 to 30 days post breeding or 3 to 5 days prior to breeding. The results indicated that heat stress during early gestation is of greater significance in respect of embryonic mortality than either prior to breeding or post implantation. However, the temperatures to which the pigs were exposed were extremely severe and caused several deaths. Similar results were reported by Tompkins et al (1967) for sows, in conditions hot enough to cause some deaths. Significant increases in embryonic mortality were reported if a 5 day heat stress (36.7°C) was applied on the day after mating but not on day 20 post mating. When sows were exposed to the same heat stress for a shorter period of time (24 or 48 hours) on the first or twentieth day of gestation there was a decrease in the percentage of viable embryos. Thus, it appears that elevated ambient temperature has an adverse effect on embryonic survival in sows, if thermal stress is applied during the first few days post mating.

Further information in support of a detrimental effect of high ambient temperature on the preimplantation embryo comes from Omtvedt et al (1971). Gilts subjected to heat stress (37.8°C for 17 hours daily followed by 32.2°C for 7 hours) for either 0 to 8 days or 8 to 16 days post breeding tended to have lower conception rates and fewer viable embryos at 30 days post breeding than gilts confined to control chambers (23.3^{o}C) over the same period. In respect of normal returns to oestrous Omtvedt et al (1971) found that 6 out of 14 gilts subjected to heat stress immediately following breeding (0 to 8 days) did not hold to service. In a second group 14 gilts, subjected to a similar heat stress 8 to 16 days postmating, only 3 returned to oestrus. In a control group maintained at an ambient temperature of 23.3^{o}C all animals held to first service.

Omtvedt et al (1971) found that the greatest reduction in viable embryos was among gilts stressed 8 to 16 days post breeding (41.9% compared with 20% for the 0 to 8 day stress period), an indication that the implanation period may be the most critical one in respect of embryonic survival. This is in agreement with Warnick et al (1968), who reported a deleterious effect on embryonic survival where a high temperature was imposed after embryos entered the uterus. Embryonic survival in gilts kept at 32.2^{o}C until 3 days post breeding then at 15.5^{o}C until the 25th day post breeding was compared with gilts kept at 15.5^{o}C until day 3 post breeding and then 32.2^{o}C until day 25 post breeding. Following slaughter on the 25th day post mating, gilts on the former treatment had 11.6 viable embryos, on average, compared with 13.6 for the other treatment. This suggests that the period after the embryo has entered the uterus is the more critical one in respect of heat stress. In support, work done by Nelson et al (1970) also shows that embryos are more susceptible to heat stress during the period of implantation than immediately following breeding.

These experiments conflict with similar ones which have examined the heat stress period in early pregnancy in ewes. Ulberg and Burfening (1967) reported that the embryo is most sensitive to the effects of high ambient temperature during the first few days after mating when it is still in the oviduct. Ewes subject to high air temperatures at the time of mating had a reduced reproductive rate, resultant from an increase in embryonic death. In their study involving heat stressed and control ewes, there was a transfer of ova before entry into the uterus. Ova transferred from heat stressed ewes subsequently had an increased death rate, an indication that damage had occurred before entry into the uterus. Following ova transferred from control animals to heat stressed areas, the death rate was markedly lower.

Studies involving exposure to heat which, in some cases related to very high environmental temperatures, have produced little or no effect on swine reproduction during mid pregnancy (15 to 90 days post partum) (Heitman et al, 1951; Edwards et al ,1968; Tompkins et al, 1967; Omtvedt et al ,1971).

By the last two weeks of pregnancy the situation, as regards heat stress on reproductive efficiency may well have changed. Omtvedt et al (1971) reported that with gilts exposed to high temperatures (37.8°C for 17 hours and 32.2°C for 7 hours daily) for 8 days from the 102nd to the 110th day of pregnancy, almost half of the piglets in each litter were dead at birth. Whether these losses occurred at the time of actual heat stress or were the result of subsequent prolonged parturition was not clear. No other reports relating to this period of pregnancy have appeared in the literature.

Should this be a real effect, a rapid increase in susceptibility to heat stress during the terminal weeks of gestation is probably due to the increased metabolic heat production observed to occur by Verstegen et al (1971) among others and whose magnitude has been calculated by Mitchell (1962). It has been observed in tropical field studies that sow deaths from heat stroke occurred only in animals subjected to high temperature combined with high humidity during the final stage of pregnancy. The percentage of stillbirths which occurred during the hot humid months was reported to be 5 to 6% higher than at other times of the year (Steinbach, 1973).

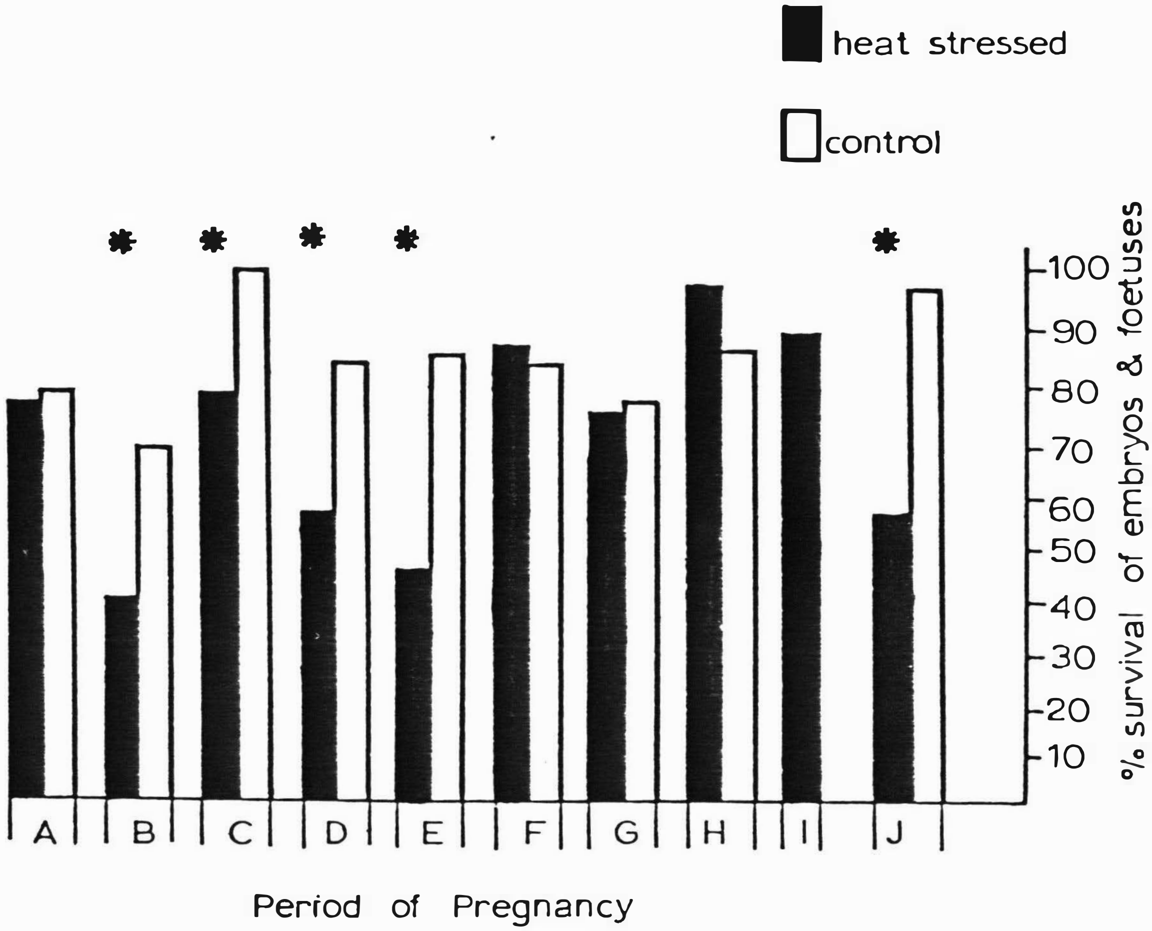
Overall, while there is general agreement that hot conditions are not conducive to a high embryo survival rate in the pig, the critical period when embryo mortality occurs, defies a clear definition.

4.3.7 Litter weight: It appears that embryos grow slowly during the first two-thirds of pregnancy and very rapidly thereafter.(Cole and Cupps, 1977). Thus, it seems feasible that the influence of heat stress on embryo growth is not great in early pregnancy but could be considerable in the later stages of gestation. Nevertheless several climatic chamber studies have reported that gilts exposed to heat stress (30 to 40°C) at various stages in early pregnancy (up to 30 days) tended to have smaller embryos at slaughter(which was usually at the 25th day of gestation) compared with those confined at much lower temperatures (Edwards et al 1968; Nelson,1970;Omtvedt et al, 1971; Wildt et al ,1975).

Unfortunately data relating to the effect of heat stress in late pregnancy are sparse. However, in one experiment, where gilts were subjected to heat stress late in pregnancy (day 102 to 110 at 37.8°C for 17 hours followed by 32.2°C for 7 hours daily) birthweights tended to be lower compared with those of the control group (23.3°C daily) but not significantly so (Omtvedt et al,1971)

Overall, there is general agreement that in the pig heat stress in early pregnancy is detrimental to embryo survival,this being manifest in a reduced farrowing rate or smaller litter size (fig 4). The effect of heat stress in late pregnancy is less clear, though limited evidence indicates an increased number of stillbirths and a reduction in birthweights.

4.3.8 Mode of action of heat stress: Whether heat stress in the sow has a direct effect on the conceptus or the action is indirect, resulting from physiological disturbances such as endocrine imbalance, is unknown. Observations with sheep have demonstrated the susceptibility of the fertilised ova to direct temperature stress (Ulberg and Burfening , 1967)Extremes of both high and low temperature applied directly to the eggs of a number of species before or soon after fertilisation have resulted in irregularities, such as, a high incidence of polyspermy (Waites, 1968). The majority of experiments, however, have been conducted in vitro and thus do not simulate conditions within the reproductive tract.



Period of Stress	*Source of data*
A= one oestrous cycle prior to mating up to mating	*Edwards et al (1968)*
B= Day one to 5 inclusive post-mating	*Tompkins et al (1967)(*P< 0.05)*
C= Day one to 8 " " "	*Omtvedt et al (1971) (*P< 0.01)*
D= Day one to 15 " " "	*Edwards et al (1968)(*P<0.01)*
E= Day 8 to 16 " " "	*Omtvedt et al (1971)(* P< 0.01)*
F= Day 15 to 30 " " "	*Edwards et al (1968)*
G= One oestrous cycle prior to mating until 25th day post mating	*Edwards et al (1968)*
H= Day 53 to 61 " " " "	*Omtvedt et al (1971)*
I= Day 81 to 85 " " " "	*Heitman et al (1951)*
J= Day 102-110 " " " "	*Omtvedt et al (1971)(* P <0.01)*

** = significant difference*

FIGURE 4: Variation in the survival of porcine embryos and foetuses due to the effect of prolonged temperature stress at precise stages of the oestrous cycle and pregnancy.

In attempts to distinguish between the direct action of heat on the ova, as distinct from the uterus, ova have been transplanted from heated or unheated donor sheep and rabbits into the uterus of heated or unheated recipients. No difference was found in the viability of unfertilised sheep ova transferred from donors maintained at 21.1°C or 32.2°C to mated recipients. However, the reciprocal transfer of fertilised ova indicated that the reproductive tract of ewes maintained at 32.2°C provided a less favourable environment for embryo development than did the tract of ewes maintained at 21.1°C (Woody and Ulberg, 1964). It was concluded by these and other authors (Ulberg and Burfening,1967) that most important direct effect of elevated temperature was on the ovum during first cell division. In vitro, fertilised rabbit ova cultured at 40°C during first and second divisions were reported to have a lower chance of survival in a normal uterus than ova cultured at 33°C but their chances of survival were greatly improved if heating was delayed until the 3rd or 4th cell division (Alliston et al, 1965). The morphological change observed to take place in ova during early cleavage presumably accounts, at least in part, for the reduced implantation rate observed during a brief application of heat to rats (Fernandez-Cano,1958a,b and sheep (Dutt, 1964).

The mode of action of heat on young embryos is still unknown. There is some evidence of interference with R.N.A.synthesis since stressed embryos incorporated more radioactivity than controls when immersed in a medium containing {^{3}H}uridine (Sheean and

Ulberg, 1971) or {^{3}H}leucine (Sheean and Ulberg, 1973). Such embryos were still capable of initiating an implantation site, but they died subsequently. Apart from this there has been speculation about endocrine imbalance and altering the chemical environment of the uterus. There is some evidence which suggests an indirect influence of elevated temperature upon the embryo mediated via the endocrine system but it is sparse (Alliston and Ulberg,1961; Woody and Ulberg, 1964).

Madan and Johnson (1973) reported that a heat load sufficient to raise the deep body temperature of heifers 1°C to 1.5°C not only shortened the duration of oestrus but depressed both the base line LH and peak LH hormone levels in plasma. There was no indication that suppression of this peak was sufficient to interfere with normal ovulation. In contrast, studies where pigs at oestrus were subjected to temperature stress (32°C at 75% RH) have shown increases in LH levels (Riggs et al 1974). It has been suggested that stress exerts its effect only indirectly on gonadotrophins and that increased glucocorticoids produced in a stressed animal may block or reduce the secretion of the pituitary gonadotrophins, especially LH (Hagino et al, 1969). Baldwin and Sawyer (1973) reported that in rats the administration of a synthetic glucocorticoid will alter the oestrous cycle length and block the ovulatory surge of LH, apparently by inhibiting the synthesis and release of pituitary LH. This suggests that heat stress prior to ovulation blocks the ovulatory release of LH thereby changing the normal pattern of oestrous behaviour and ovulation. In pigs, Schotten and Liptrap (1978) reported that exposure to an environmental temperature of 32°C for 3 hours resulted in an elevation in progesterone values and a rise in total glucocorticoids . The elevated levels of progesterone and glucocorticoids recorded during the follicular phase in sows coincided with increases in cystic ovaries. It was suggested that increases in glucosteroids and progesterone, of adrenal origin, may be involved in the onset of cystic ovaries in the sow.

The possible involvement of the adrenal gland, in heat stress, indicated by increased embryonic mortality was shown to occur in ewes which had been injected with hydrocortisone acetate (H.C.A.) (Howarth and Hawk, 1968). Both Adrenocorticotrophic hormone (A.C.T.H.) and cortisone are known to depress embryo survival in mice (Robson and Sharaf 1951; 1952) and in rats (Seifer et al 1951) and administration of A.C.T.H. can cause a delay of oestrous in immature mice and gilts (Christian, 1964; Liptrap, 1970).

Plasma A.C.T.H. as well as adrenal corticoid hormonal levels have been shown to markedly increase in heat stressed pigs (Marple et al 1972; 1974), Fernandez-Cano (1958b) found that exposure to elevated ambient temperature on day three and four (for 5 hours per day) following mating increased preimplantation embryonic mortality in intact rats but not in adrenalectomised rats. Further observations by Howarth and Hawk (1968) over a two-year period indicated that HCA which affected embryonic survival in sheep was most detrimental during August and September where the maximum temperature was 27.9 to 30.2°C but had virtually no effect during October to January inclusive where the maximum temperature was 6.7

to 17.6^{0}C. These authors suggest that adrenal hyperactivity could be a factor of significance in the effect of adverse environmental conditions on reproductive performance.

Several experiments have investigated the relationship between progesterone level and reproductive performance. Glasgow, Mayer,& Dickerson (1951) found a significant correlation between the concentration of progesterone and embryonic survival.However Nalbandov ,1958;Spies et al,(1959) found that injection of progesterone during early pregnancy failed to improve embryonic survival rate. Nevertheless Davis and Sorenson (1959) have reported an increased embryo survival at 40 days postmating following a single dose of progesterone 7 days after mating. However, elevated progesterone has prevented ovulation and altered the length of the oestrous cycle in rats. (Davis and Sorensen,1959) while Hansel et al,(1972) found progesterone inhibited ovulation in the pig by suppressing the pre ovulatory surge of LH.

Investigations on heat stressed pigs (at 32.2^{0}C) reported that plasma progesterone level was raised compared with that of control gilts maintained in a cool environment (23.2^{0}C) (Kreider and Wetteman, 1977). This study also reported that both the numbers of gilts pregnant and the number of corpora lutea, at day 30 post-mating were higher in heat stressed gilts. These results are, in contrast to the majority of studies discussed earlier which have generally indicated that heat stress has a detrimental effect on these aspects of reproductive function in the gilt. However only small numbers of animals were used in this experiment. Also

Ryles (1961) in an experiment involving heat stressed ewes did not detect a significant influence of daily progesterone injection on embryonic mortality. Similarly, Thwaites (1970) and Bolt and Spies (1964) failed to find that progesterone therapy enhanced embryonic survival.

Information on the effect of oestrogen on reproductive performance is sparse. Hacker et al (1979) reported a negative relationship between the number of stillborn and the level of urinary oestrogen. Foxcroft (1978) reported that, in respect of ovarian responses to oestradiol benzoate (O.B.) there was a marked seasonal effect. Rising ambient temperatures were associated with a significant depression in ovulatory response.

Numerous studies have been reported concerning the influence of ambient temperature on thyroid activity (Wan and Li, 1971;Bakke and Lawrence, 1971; Johnson and Yousef, 1966), but only a few have concerned the pig (Sorenson, 1962; Dent et al, 1976). The latter reported that serum thyroxine level was decreased by 25 to 30% with prolonged exposure to a high temperature (up to 37°C) particularly if relative humidity was also high. Animals exposed to heat may reduce their food intake voluntarily and this in turn may influence thyroid function (Yousef and Johnson,1966). It is known that high environmental temperatures reduce basal metabolic rate (Johnson and Ragsdale, 1960), which may have a subsequent effect on reproductive function. However Holmes (1979) in his review, noted that under hot conditions thyroid activity may be depressed regardless of level of food intake.

Limited evidence from a small number of cattle indicate that the serum concentration of prolactin increases during brief exposure to high temperature (Smith et al 1977). There have been reports of increases in prolactin levels during the summer months in dairy cows (Thatcher,1974; Koprowski and Tucker,1972; Schams, 1972) and in male goats (Buttle, 1974), but whether this is a temperature effect or not is uncertain. It is noteworthy that in rams (Pelletier, 1973), and in rats (Relkin, al 1972) it has been observed that there is a relationship between light photoperiod and plasma prolactin level. The effect which a rise in prolactin level may have on reproductive function is not understood, although in humans there is evidence that elevated prolactin levels impair the action of gonadtrophins on the gonads (Besser 1978). Van Landeheim and van de Wiel (1977) reported a surge of prolactin during oestrus, which may indicate a luteotrophic function. However, a seasonal surge which was observed 5 to 7 days before oestrus coincided with a decrease in progesterone concentration which may point to a luteolytic role. There is thus some indication that prolactin level may be involved in the reproductive dysfunction of heat stressed sows but overall, as is the case with the other hormones discussed, there are inadequate data for any firm conclusion to be drawn.

4.3.9. The influence of heat stress on the male: The thermoregulatory mechanism of the scrotum and testis in the boar have been studied by McNitt et al (1972) among others. As is the case with other male mammals, high environmental temperatures can have serious effects on sexual activity, spermatogenesis, characteristics of the ejaculate and subsequent reproductive performance.

(i) Libido: Although Wetteman et al,(1973) observed no difference in the pattern of sexual behaviour of boars kept at either 23°C or 32°C for 90 days, Niwa and Mizuho (1954) noted reduced sexual interest during the hotter months of the year. Similarly, Steinbach (1972) found that the rate of refusal to mount a dummy sow and ejaculate was positively related to the mean monthly effective temperature. In addition ejaculation time was reported to be prolonged under conditions of heat stress, both diurnally and seasonally.(Steinbach,1972). Although the neuro-humoral mechanisms involved in libido are largely unknown, it has been suggested that the lack of sexual drive during heat stress may be related to a reduced level of plasma testosterone (Steinbach, 1972). There is evidence that some synthesis of androgens continues during a period of heat stress but there is a decline in the level of circulation of testosterone, this influencing fertility through an unfavourable effect on libido (Bedrak et al 1973; Rhynes and Ewing,1973) The sexual interest of a heat stressed boar may be adversely affected through a depression in thyroid activity. High environmental temperature is known to depress thyroid function (Ingram and Stebozinsk, 1965) and thyroidectomy has been shown to markedly reduce libido in young bulls (Peterson et al 1941).

(ii)Spermatogenesis: Although spermatogenesis is a continuous process, the level and quality of sperm production can vary with environmental stress imposed on the boar. Generally the scrotum forms a fairly good method of thermoregulation. McNitt et al (1972) observed that raising the ambient temperature to 40°C resulted in a deept testis temperature increase of only 0.6°C (36,4 to 37°C), while Mazzarri (1971) reported that acute local heating of boars' scrotum to 44°C for three hours (which increased the intratesticular temperature from 35.5 to 39.5°C) did not affect spermatogenesis. However, increases in ambient temperature can affect semen production, although this has only been reported in local heating experiments where the testicular temperature was raised to above 40°C by heating the scrotum to 48°C (Mazzarri ,1971).

It remains uncertain as to the stage of the spermatogenic cycle which is most seriously affected by high ambient temperature. Steinberger and Dixon (1959) found, in rats, that the primary spermatocycles were most sensitive to a heat load of 43°C while Austin, Hupp and Murphee (1961) concluded that heat injures the maturing spermatogenia.

(iii) Semen charactistics: Wetteman et al (1976), who exposed boars to 34.5°C for 8 hours and 31°C for 16 hours daily for 90 days, observed decreases in sperm motility and concentration. This was accompanied by a change in the morphological characteristics of the ejaculate. During weeks 2 to 5 after initiation of heat stress the percentages of abnormal cells and those with aged acrosomes was shown to increase. Similarly the number of abnormal cells increased rapidly from 4% prior to the heat treatment to 24%, 4 to 6 weeks after the temperature stress in controlled experiments (McNitt and First, 1970; Christenson et al,1972) but no seasonal variation that could be attributed to high ambient temperatures was found in semen characteristics of boars maintained under natural conditions (Lawrence et al 1970; Olutogun and Steinbach, 1973). Findings by Wetteman et al (1973) suggest a degree of adaptation may occur in prolonged heat stress situations, since acrosomal abnormalities were increased only during the period 2 to 5 weeks after the start of the treatment and returned to a normal level for the remaining experimental period of 8 weeks.

Other experiments have reported significant decreases in sperm cell concentration and in the total number of sperm ejaculated with temperature increases (Lawrence et al,1970; Steinbach, 1972). The order of this reduction in ejaculated sperm varied between 2.5 billion and 4 billion for each 1°C increase in ambient temperature (Wetteman et al 1973; Christenson et al 1972; Steinbach, 1972)

In controlled experiments sperm motility was found to be suppressed following acute heat treatment at ambient temperatures of around 33°C reaching the lowest levels at about 50% between 16 and 45 days post treatment (McNitt and First 1970; Christenson et al, 1972; Wetteman et al, 1973). However in a similar heat stressed situation, but in a naturally varying environment this was generally not so. (Wagelie et al 1959; Lawrence et al 1970; Steinbach, 1972).

The important consideration in male animals affected by thermal stress is the viability and capacity to fertilise ova. Christenson et al (1972) observed a reduction in the pregnancy rate and embryonic survival when gilts were inseminated with semen from boars which had been subjected to short term temperature stress 16 to 58 days previously. Similarly Wetteman et al (1976) indicated that the conception rate may be reduced in gilts artificially inseminated with semen from boars subjected to elevated ambient temperature while the subsequent litter size may be smaller in those which become pregnant. Overall, although the degree of sexual activity and high environmental temperature seem to be inversely related, there is little evidence that boars raised and used in naturally occurring high temperature areas are less fertile compared with animals from temperate areas (Egbunke and Steinbach,1972), despite the marked decreases in boar fertility at high temperatures noted by controlled room experiments. This discrepancy may be largely a factor of acclimatization, as suggested by Wetteman et al (1976). Furthermore, on the assumption that changes in semen characteristics observed by McNitt and First (1970), and reported earlier, are accompanied by reduced fertility it may be that, relatively short hot spells, lead to severe fertility problems. This would suggest that while the thermoregulatory system of the boar is able to cope successfully with relatively static high ambient temperature levels, abrupt rises in temperature of even up to 2 to 3^{o}C above normal are liable to reduce fertility some 2 to 3 weeks later, an effect which may last for up to 1 to 2 months.

4.5 Nutritional aspects:

Although nutritional status has a direct effect on reproductive efficiency it is unlikely to be a causal factor of seasonal variation in this characteristic (Reid, 1960; Wrathall, 1975).

It is worthy of note however that toxic substances in newly harvested grain have been implicated as the cause of a higher incidence of abortions in sows during pregnancy during autumn months of the year. A peak rise in the number of abortions was noted after the barley harvest (Stork, 1979).

An interaction between a nutritional effect and stress brought about by exposure of the animals to a high ambient temperature may be of importance in respect of reproductive performance. On exposure to hot conditions, one of the first reactions of the animal is a reduction in appetite in an attempt to reduce the metabolic heat load for dissipation. This in turn could have an unfavourable effect on reproduction. With pigs, increasing the ambient temperature (25 to 30°C) in climatic chambers, resulted in a lowering of meal intake and decreased conception rate, embryo survival and size and weight of the litter at term.(Heitman and Hughes, 1949). Similar effects have been noted in other climatic room studies where ambient temperature was kept in the region of 30-33°C.(Edwards et al 1968; Teague et al,1966). Although this situation is removed from practice and may not occur in animals acclimatized to hot conditions, Steinbach (1976) did report a decrease in farrowing rate during the summer months, and the hot conditions also resulted in a reduction in meal intake.

Seasonal variation in nutritional level could be one of the many indirect effects of heat stress on reproductive performance. However, studies have shown that a major reduction in feed intake is necessary for any decrease in reproductive efficiency to occur. Oestrous activity frequently continues until a major loss in bodyweight has occurred, although severe inanition may interefere with conception and especially implantation (Anderson and Melampy,1972). Pregnancy and high embryonic survival rates have been maintained in pigs starved of feed, but not water, for up to 37 days.(Anderson 1975). In a subsequent study conducted along similar lines (Anderson and Dunseth, 1978), the number of foetuses surviving to day 70 of pregnancy was similar for starved (0.8kg meal/day) and fed (1.8kg meal/day) sows, but foetal development was retarded in the former, Nevertheless by day 110 there was a marked reduction in foetal survival rate of starved dams (0.8kg meal/day) compared with the controls (1.8kg meal/day).

In the mature boar, widely varying planes of nutrition may be tolerated without detrimental effects on, spermatogenesis, or libido, but on a very low level of feeding the volume of the ejaculate may be reduced (Stevermer et al, 1961). However, neither motility nor fertility of the spermatozoa was affected over a prolonged period in this study.

It is of particular significance that when a general decrease in feed intake occurs with increasing heat load, the full allocation of vitamins and minerals is also decreased. Inadequacies of a number of major and trace minerals and vitamins are known to be associated with all aspects of reduced reproductive performance. Comprehensive reviews on the effects of mineral and of vitamin deficiencies on reproductive performance in the pig, have been published by Tassell (1967), Lamming (1969) and Wrathall (1975).

4.5 Health status:

There is little information available pertaining to either the optimal conditions for the development and spread of diseases or the seasonal variation in disease level within the pig herd. However, it is likely that certain diseases may be more prevalent at particualr times of the year. This arises due to a specific susceptibility of the host to pathogenic organisms, highly infective on account of prevailing environmental conditions. The pathogenesis of reproductive disease in pigs has been discussed in the comprehensive reviews of Wrathall (1975) and Dunne and Leman (1975). It is highly probable that warm and humid conditions favour the survival and transmission of certain diseases. This was shown in the transmission of toxoplasma (Frenkel 1973), while Dziaba (1971) and Kovalenko et al (1971) both found the susceptibility to erysipelas to be increased during the hot summer months.

A subject of increasing interest and importance in the control of infectious diseases is the aerobiology of pathogenic organisms. Changes in ambient temperature, relative humidity, wind speed and solar radiation are factors which may profoundly alter the longevity and dissemination of air borne organisms and thereby affect the pathogenesis of several diseases (Roller and Stombaugh, 1974). As these environmental factors may also be implicated in stressful conditions to which the animals are subjected they may aggravate the susceptibility to many infectious diseases.

It is clear that the interrelationships between the physiological effects of stress, the particular pathology of a disease and the immunological defence mechanisms of the animals are complex in nature making it difficult to ascertain whether disease can be implicated in seasonal reproductive problems in the pig.

EXPERIMENTAL PROCEDURE

The study comprised an examination of reproductive performance over a 2-year period in 20 pig breeding farms located in various regions of New Zealand.

1. Establishment of Climatic Regions and Selection of Farms

In relation to the choice of farms for inclusion in the investigation, a widespread distribution within the country was considered to be desirable. This would enable an assessment to be made of the effect of an extensive range of climatic conditions on reproductive efficiency in the breeding herd.

Initially, areas within the country where there was a relatively high density of breeding units were identified. This was done with the assistance of pig Advisory Officers of the Pork Industry Council, who were located throughout the country. All meteorological stations within each area, previously selected on the basis of its size of pig breeding population, were listed, the relevant data being obtained from the New Zealand Meteorological Service Miscellaneous Publications, (1973). The stations were subsequently ranked with respect to mean monthly maximum temperature and mean monthly diurnal temperature fluctuation (The difference between mean daily maximum and minimum values), over the months of December to February inclusive. The latter were the "hot" months of the year in New Zealand, and those during which low fertility has been recorded (Hermann, 1980), All temperature measurements were related to data collected over a minimum period of eight years, and longer in the case of meteorological stations where earlier information was available. These two climatic variables were chosen since, as discussed in the previous review of literature, they are the most likely ones to have an influence on reproductive efficiency in the breeding herd.

On the basis of values recorded for these parameters over the chosen three-month period, six climatic regions were identified. These were as follows:-

Region	Mean monthly maximum temperature (°C)	Mean monthly diurnal temperature fluctuation (°C)
Hot and stable	23 and above	<10°C
Hot and variable	23 and above	≥10°C
Warm and stable	20 to 22.9	<10°C
Warm and variable	20 to 22.9	≥10°C
Cool and stable	19.9 and below	<10°C
cool and variable	19.9 and below	≥10°C

These defined regions were identified in the field by the use of a system of point symbols (Tuller, 1977). In this case each symbol represented one specific range of mean monthly maximum temperatures and mean monthly diurnal temperature fluctuations. This approach was considered preferable to drawing isolines because of the complex manner in which the different climatic elements, that combine to affect the two chosen thermal parameters, vary with topography. It is recognised, however that the definition of regions, of similar climate, on the basis of point symbols is not without some limitations, as each pig unit has its own microclimate and meteorological records for the area can only provide approximate values. Nevertheless the approach where each pig unit is associated with a local meteorological station is considered a more exacting one than the alternative of subdivision of the country on a geographical basis, where the climatic environment is likely to vary not only between but also within selected areas.

Following identification of the six climatic regions, a list of the meteorological stations, along with a covering letter was sent to the Pig Advisory Officer in each relevant region. The latter was requested to identify pig breeding units which were close to a local meteorological station and also provide details of the farms. These included, herd size, breed(s), type of buildings and their standard of construction and availability and extent of breeding records. The ultimate objective was to obtain pairs of farms in the same locality and close to a meteorological station, but which had a contrasting system of housing. In respect of the latter the aim was to obtain one member of the pair who operated an extensive system, where the buildings were of a low standard of construction and the other who farmed intensively in well constructed though not necessarily climatically controlled buildings. By adoption of this approach it was hoped to gain information on the influence of building design on the incidence of seasonal infertility.

The outcome of this approach was the identification of 45 farms but unfortunately few were paired as requested in the correspondence sent to the Advisory Officers. The reasons given for failure to comply with the request were,the unavailability of such farm pairs or where pairs of farms did exist the inability of one or both farms to provide accurate breeding records for the time period envisaged namely a minimum of two years.

The approach made to these 45 farmers was initially via their local Pig Advisory Officers and then by correspondence to obtain an indication of the extent of their recording data pertaining to matings and subsequent farrowings. The outcome was, only 25 of the farms were ultimately selected to participate in the study. They were the only ones able to provide accurate records of reproductive performance in their herd over the minimum period of two years.

These 25 selected farms were subsequently visited by the co-ordinator of the project and either the owner or manager of the property was interviewed. This took the form of asking a standard set of questions prepared beforehand and recording the answers. An example of the questionnaire is given in Appendix I.

It was aimed at obtaining information on the breeding, housing, feeding and management policies adopted on the unit. Recent disease outbreaks on the unit and the general health status of the stock were noted. Completion of the questionnaire was followed by a detailed inspection of the herd and examination of the premises, where further details of the herd and its management were obtained. The local pig Advisory Officer was always present at these visits and participated in discussion. A further 5 farms were eliminated from the survey on information obtained during the interview. The prime reason for their rejection was on mating procedures adopted, such as the running of a boar with a group of dry sows. This obviously affects the accuracy of the records by the introduction of non-recorded matings. Another reason for rejection of a farm was on the data, which although it covered the minimum two-year period, was incomplete.

The distribution of the remaining 20 farms within the 6 climatic areas was as follows:

	No.of farms	No.of observations
Hot and stable	5	3255
Hot and variable	5	2887
Warm and stable	3	2873
Warm and variable	2	632
Cold and stable	2	440
Cold and variable	3	1292

This uneven distribution of the farms and particularly the number of observations per region prompted the amalgamation of the "warm and variable" and "warm and stable "region respectively thereby giving four climatic regions as shown below.

Region	Mean monthly maximum temperature °C	Mean monthly diurnal temperature fluctuation
Hot and stable (HS)	23 and above	< 10°C
Hot and Variable(HV)	23 and above	≥ 10°C
Warm (W)	20 to 22.9	-
Cool (C)	19.9 and below	-

The meteorological stations corresponding to the 20 survey farms were then re-assessed in respect of the two year period pertaining to the recorded data (i.e. November 1976 to October 1978 inclusive). This was done to observe if the mean monthly diurnal temperature fluctuations over this two year period were such that each station remained within the limits of its originally designated region.(The location of the farms finally chosen within each climatic region is shown in Figure 5).

2. Description of Farms

Full details of each farm have been documented and these are lodged with the Dairy Husbandry Department, Massey University. In brief all 20 farms finally included in the survey were operated as commercial units and six of them supplied breeding stock to the industry.

Individual herd size ranged from 40 to 250 breeding sows. The breeds kept were principally Large White, Landrace and crosses of these two breeds.

2.1 Housing: In both between and within farms in each climatic region there was a great variety of housing types, which ranged from specialised buildings of standard design to simple general purpose wooden sheds. This was accompanied by an equally wide variation in standard of construction, which generally did not show a close relationship with type of housing, except where the buildings were of recent construction.

As one aim of the project, accepting that a seasonal variation in farrowing rate was found to exist, was to investigate the influence of housing system as a contributory factor, housing types were subjectively classified on a five point scale (1 = very good; 2= good; 3 = reasonable;4= poor; 5 = very poor). The

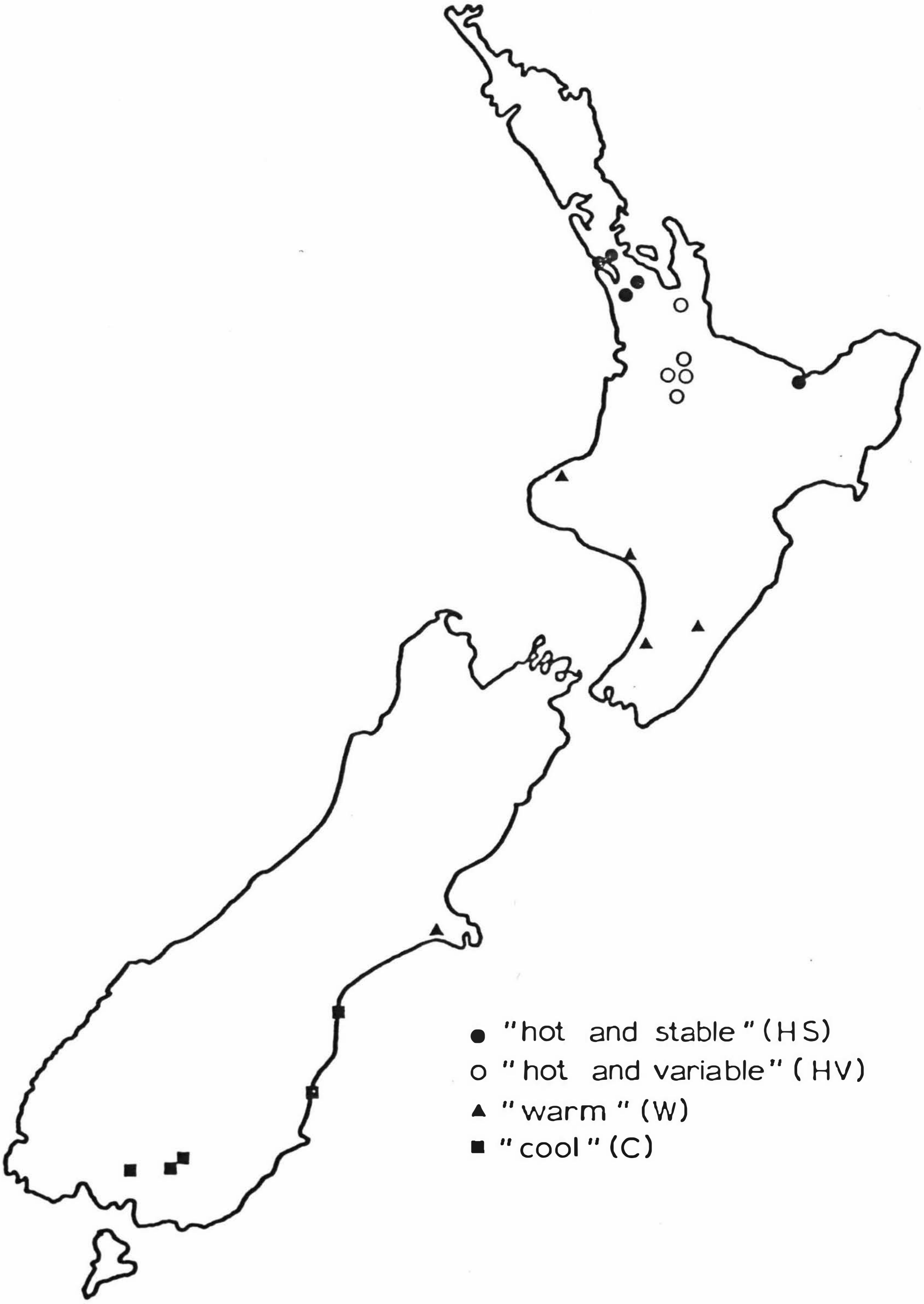


FIGURE 5: Location of the farms within the four climatic regions

index took into consideration the ability of the structure to buffer the animal against diurnal variation in ambient temperature and generally provide an environment free of stress. This was assessed indirectly by giving consideration to building design (eg.,fully enclosed, partially enclosed etc.), pen layout (eg., solid or tubular partitions),degree and standard of insulated construction, extent of control of ventilation and air movement, lying area(eg slatted concrete, no bedding, deep bedding, straw bedding), and group number in relation to pen size (Table 6)

Three persons, working in collaboration, were involved in the allocation of the various type(s) of housing on each of the twenty farms to appropriate grades on the 5 point scale. All those on the panel (two Pork Industry Council Advisory Officers and the co-ordinator of the project) were familiar with housing standards advocated for pigs and had visited the farms on several occasions in the course of their duties.

2.2 Nutrition: The composition of diets varied markedly both between and within farms. Dietary composition depended on the location of the farm and availability and cost of various feedstuffs such as seasonal variation in the availability of whey. Of the 20 farms, ten fed either proprietary or home mixed meal rations only, while a further six farms also fed meal diets but these were supplemented with whey in season(August to May approximately). The remaining four farms provided their breeding stock with a diet of meal and a wide range of industrial by-products. Most of the farms who used home mixed rations or waste by-products sought advice from their local Pig Advisory Officer in respect of

TABLE 6: Classification of housing types for accommodating breeding stock on the farms.

		Housing for breeding stock	
Region	Farm	Post weaning to mating	Pregnancy
1	1	1	1
	2	5	5
	3	2	4
	4	1	2
	5	5	5
2	1	3	3
	2	1	1
	3	5 → 1	5 → 1
	4	3	4
	5	5	3
3	1	3	3
	2	3	5
	3	5	5
	4	4	3
	5	3 → 1	3 → 1
4	1	4	3
	2	1	1
	3	3	5
	4	2	1
	5	4	5

Scale: 1 = very good 2 = good 3 = reasonable 4 = poor 5 = very poor

→ indicates a change in classification of housing types following construction of new buildings within the two-year period.

diet formulation.

It was not possible to accurately assess dietary intakes on the farms, this being particularly so where milk by-products were used to supplement a meal diet. However, on a general assessment of the body condition of the stock at the time of visiting each farm, it was considered that all were receiving adequate nutrition. Although a major limitation of this assessment was that it was made only once, the accompanying Pig Advisory Officer on the visits affirmed that the feeding level on each of the farms had been adequate to the best of his/her knowledge over the previous two-year period.

2.3 Disease control: All farms reported a reasonably high health status in the herd although it was considered that adequate disease precautions and parasitic control measures prevailed on only 15 of them. The other 5 farms employed the minimum measures of preventative medicine, eg.,no regular worming routine, replacement stock not necessarily purchased from herds of high health status. No major disease outbreaks were recorded in any of the 20 breeding herds over the period covered by the survey. Nevertheless endemic disease levels were suspected in some cases following examination of the records eg.,the presence of abortions and expulsion of mummified foetuses, an indication of possible parvovirus or leptospirosis infection.

2.4 Management: Homebred gilts were generally mated on the second or third oestrus following attainment of sexual maturity,while purchased stock went to the boar at the first detectable oestrus.

None of the farms induced early attainment of puberty. Litters were weaned between 3 and 6 weeks of age and the sows then moved to either pens or individual stalls which were adjacent to a boar pen. Sows were observed daily for oestrus detection. No laboratory or electronic methods were used to detect oestrus or pregnancy on any of the farms. Natural service was used on the 20 fams and all matings were supervised in that the stockman was present during the period that the sow was with the boar. Only on two of the farms was the boar assisted at the time of service. Sows were usually double mated on successive days, if the duration of oestrus permitted, matings taking place morning and/or evening. Each boar was generally mated with one or two sows per week. The boar to sow ratio was generally of the order 1 to 25 or less but on one farm a 1 to 50 ratio was recorded.

3. Collection of Records and Preparations of Data for Analysis

Service registers covering the two-year period were obtained from each farm. These were in a standard form in respect of seventeen of the farms who used recording materials provided by the Pork Industry Council. Included in the latter was a service card which covered mating dates in chronological order, expected return dates and due to farrow dates. Corresponding records from the remaining three farms were provided on two cards. One contained mating dates only and the other was a sow perfomance card from which it was possible to obtain the date of farrowing. Treatment of the data prior to its analysis involved collation and verification of the service records, and a check on whether the mated females subsequently gave birth to a litter or not. Where the latter occurred, the service records were examined in further detail to determine whether the animal(s) in question returned to service and were subsequently mated; were culled from the herd and the reasons thereof (whether due to infertility,physical damage or illness etc.);went to full term and were subsequently found not to be pregnant, or were noted to abort. These categories are defined as follows:-

Returns to service: This was recorded if a sow exhibited external of oestrus and would accept service more than 18 days after the date of original mating, otherwise the original mating was excluded as not valid.

Not-in-pig: This is a term used to describe sows which are not observed to return to oestrus but are found to be 'not-pregnant' at about the time they would normally be expected to farrow.This category includes animals which show "pseudo-pregnancy" or were empty or barren. It also includes undetected abortions.

Cull: This is recorded if a sow is removed from a herd due to illness, physical damage or found not to be pregnant to the third return service. However only sows which had been culled due to 'non-pregnancy' were included in the calculation of reproductive performance. Sows which died or were culled after mating for reasons which were not related to their reproductive performance were not considered.

Abortion: An abortion is recorded if non-viable piglets are expelled before term. However as abortions do not appear to be a characteristic of seasonal infertility (Love, 1978; Hermann,1980), those which were recorded in this study, were not included in compilation of the data. Obviously, some abortions which were undetected and had consequently been included in the "Not-in-pig" term were unknowingly incorporated in the calculation of reproductive performance. The sole criterion of reproductive efficiency used in this study was Farrowing Rate. This can be defined for a given period as

$$\frac{\text{The number of sows which farrowed}}{\text{The number of sows mated}} \quad \times \frac{100}{1}$$

It is worthy of note that this measure of reproductive efficiency takes into consideration females which return to service, sows found to be 'not-in-pig' at the time they would normally be expected to farrow, the proportion of animals which had been culled from a herd because of repeated failures to hold to service and undetected abortions. Studies by Corteel et al (1968); Love (1978) and Hermann (1980) have indicated that seasonal variation in reproductive efficiency of a herd is characterised not only by the overall farrowing rate, but also by the farrowing rate to initial services only and the proportion of returns to services which were of abnormal length. However the standard of the records on many of the survey farms, in respect of the identification of individual sows made retrieval of any data other than the overall farrowing rate impossible.

Farrowing rate was calculated on a monthly basis. A period of 19 days would have been more appropriate as Signoret (1970) found 19 days to be the oestrous cycle length of 94.5% of sows/gilts in a large survey study. This 19-day time period would eliminate any bias occurring due to the double inclusion of a sow within one time period. However, a time period of one month was selected as the small herd size and hence the small total number of matings on some of the farms in the survey would have resulted in an absence of any observations if a period of less than 28 to 31 days had been chosen; this still occurred in respect of one month on one farm using a 28 to 31 day time period.

Overall, 11,861 service records were obtained and 11,379 yielded useable data; a wastage rate of 4.1%. Reasons for discarding material included, inaccuracies in recording, illegibility of cards, unknown outcomes of pigs sold off the farm and where reasons for culling could not be determined.

4. Statistical Analysis:

The outcome of 11,379 services was calculated on a monthly basis as a proportion of the number of sows mated which were subsequently reported to have farrowed. The raw data were Binominally distributed. Thus to analyse the effect of; year and month, region and farm, on farrowing rate, (for the purposes of significant testing) it was necessary to transform the raw data to overcome the dependence between first and second moments of the data distribution.

The data were transformed according to the Freeman-Tukey variance stabilising arc-sine transformation (a) (Freeman and Tukey, 1950)

where $a = \frac{1}{2} \text{arcsine}\sqrt{\frac{x}{n + 1}} + \text{arcsine}\sqrt{\frac{x + 1}{n + 1}}$

where n = the sample size

and x = the number of successes observed

Linear models were fitted to the data using the G.L.I.M. computing package (Generalised Linear Interactive Modelling). The methods the G.L.I.M. package uses are described by Nelder and Wedderbarn (1972)

The transformed farrowing rate data were analysed at 2 levels; a regional level (model 1) and a farm within region level (model 2).

Model 1 was a threeway crossed classification,with interaction model, describing annual and monthly farrowing rate,to all services on a regional basis with farms within each region as replicates.

Model 1: The equation of the model is

$$Y_{ijkl} = u + \alpha_i + B_j + C_k + (\alpha B)_{ij} + (\alpha C)_{ik} + (BC)_{jk} + (\alpha BC)_{ijk} + e_{ijkl}$$

where Y_{ijkl} = The observation on the lth individual in the kth month, of the jth year within the ith region.

u = The overall population mean

α_i = The fixed effect of the ith region (i = region 1 to 4)

B_j = The fixed effect of the jth year (j = 1 to 2 year)

C_k = The fixed effect of the kth month (k = 1 to12 months)

$(\alpha B)_{ij}$ = The effect of the interaction between region and year.

$(\alpha C)_{ik}$ = The effect of the interaction between region and month

$(BC)_{jk}$ = The effect of the interaction between year and month

$(\alpha BC)_{ijk}$ = The effect of the interaction between region,year and month.

e_{ijkl} = A random error term peculiar to the observation specified by the i,j,k,l, subscripts, describing the deviation of the observations from the expected value under the model.

Model 2, is a two-way crossed classification, with interaction model, describing monthly farrowing rate, to all services on a farm within region basis, with years as replicates. Years were used as replicates for farms, as the annual variation was found to be non significant in accounting for variation in farrowing rate.

Model 2: The equation of the within-region model is:

$Y'_{ikl} = u' + \alpha'_i + C_k' + (\alpha C)'_{ik} + e'_{ijkl}$

where

Y'_{ikl} = The observation of the lth individual in the kth month on the ith farm.

u' = The overall population mean

α'_i = The fixed effect of the ith farm (i= from 1 to 5)

C'_k = The fixed effect of the kth month (k=1 to 12 months)

$(\alpha C)'_{ik}$ = The effect of the interaction between farm and month

e'_{ikl} = A random error term peculiar to the observation specified by the ilk subscripts, describing the deviation of the observation from the expected values under the model.

Using the G.L.I.M. package to analyse the transformed data, the contribution of each term in the model was measured by changes in the deviance resulting from insertion (or deletion) of the factor from the fitted model.(This is analogous to the sums of the squares in a typical fitting constants analysis).

Analyses of variance were constructed through a process of model and sub-model fitting. Tests of significance were carried out using the F test for normally distributed variables. The least significant difference test was used to obtain the level of significance of the differences between the effects which had significant F values in the analysis of variance on the transformed data.

In the results section the raw farrowing rates are presented. However, as the analysis of variance was performed on the transformed data, the significance values pertain to the transformed data. This is the reason for anomalies which may be seen between the significance values and the corresponding raw data values presented.

RESULTS

1. Overall Farrowing Rate:

The resultant farrowing rate, for all services during the two-year survey period, was 77.1%

Annual farrowing rates presented in Table 7, show a slightly lower (-0.9% units) value for the second year, but the difference between years was not statistically significant (Appendix II).

2. Monthly Variation in Farrowing Rate:

Overall, monthly farrowing rates, illustrated in Figure 6, show that matings conducted during the months of November to February inclusive resulted in lower farrowing rates (73.2%) relative to matings taking place during the other months of the year (79.1%). This difference, however did not attain statistical significance (Appendix II). Reference to Table 7 shows that the monthly trend in farrowing rate was evident during both years of the study, but more marked in the second year. However, the year x month of mating interaction was not statistically significant (Appendix II).

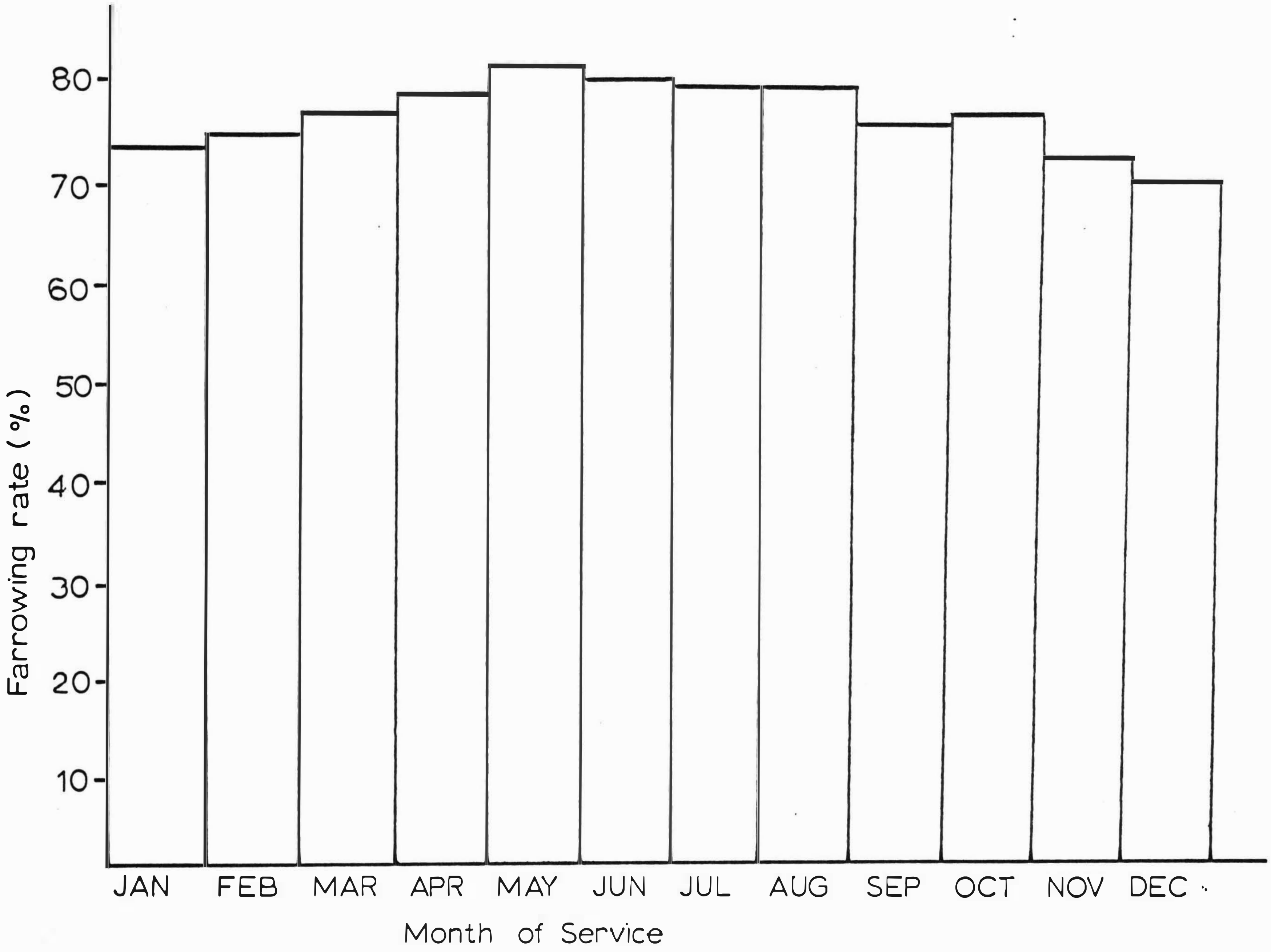


FIGURE 6: Farrowing rate relative to the month of service

TABLE 7: Influence of month of mating on subsequent farrowing rate

month year	JAN	FEB	MAR	APL	MAY	JUNE	JUL	AUG	SEPT	OCT	NOV	DEC	OVERALL
1	74.5	76.7	80.4	77.6	80.5	79.8	80.3	78.3	77.7	77.3	73.8	74.5	77.6
2	72.8	73.9	74.3	81.7	83.1	81.3	78.2	81.4	75.6	77.6	72.2	67.9	76.7

3. Regional Differences in Farrowing Rate:

Mean farrowing rates in the four regions for each year of the survey and overall are shown in Table 8.

TABLE 8: Overall farrowing rates in the four climatic regions.

Region	HS+	HV+	W+	C+
Year				
1	76.7	78.2	76.6	80.4
2	76.9	78.1	74.5	78.6
Overall	76.8^{2}	78.2^{1}	75.5^{2}	$79.6^{1,2}$

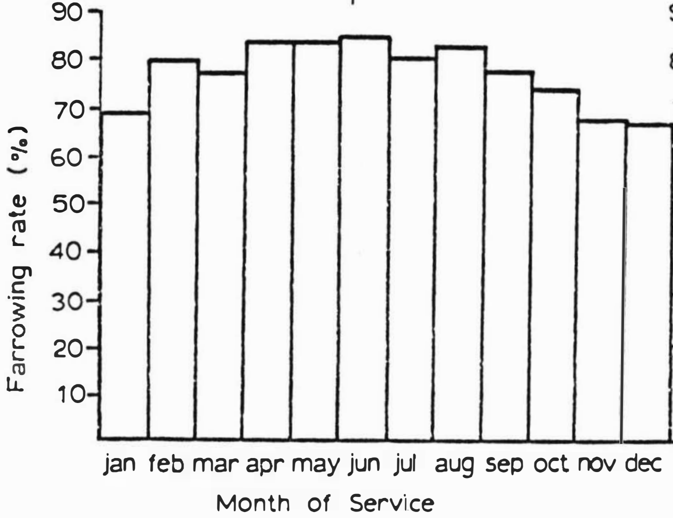
means with different superscript numbers differ significantly ($P < 0.01$)

\+ HS = Hot and stable HV=Hot and variable W= Warm C=Cool

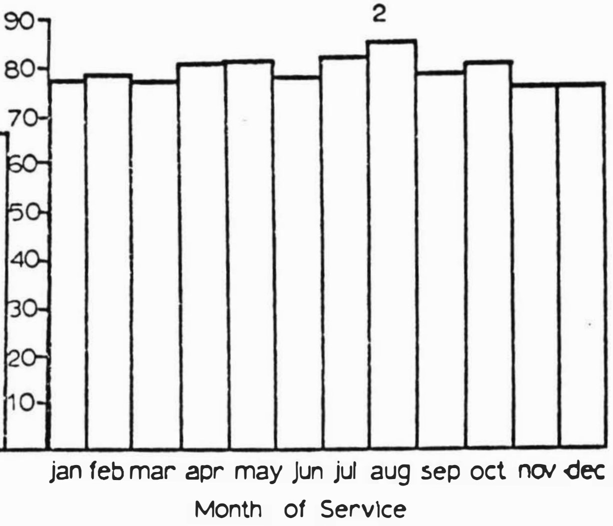
Fig 7. Monthly farrowing rates relative to month of service in each of the four climatic regions

1 - 'Hot and stable' (HS)
2 - 'Hot and variable'(HV)
3 - 'Warm' (W)
4 - 'Cool' (C)

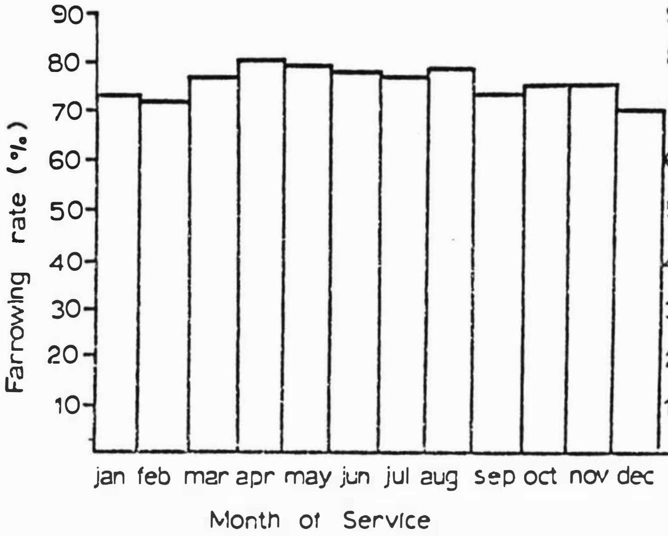
1


Farrowing rate (%)
90
80
70
60
50
40
30
20
10
jan feb mar apr may jun jul aug sep oct nov dec
Month of Service

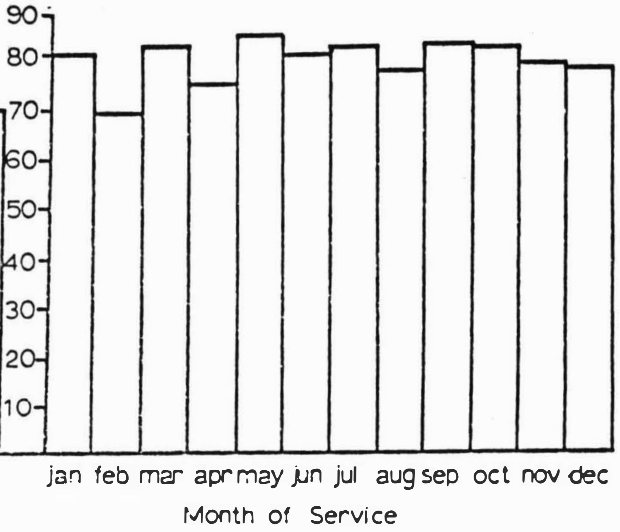
2


90
80
70
60
50
40
30
20
10
jan feb mar apr may Jun jul aug sep oct nov dec
Month of Service

3


Farrowing rate (%)
90
80
70
60
50
40
30
20
10
jan feb mar apr may jun jul aug sep oct nov dec
Month of Service

4


90
80
70
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Month of Service

Statistical analysis of the transformed data (Appendix II) revealed that overall farrowing rates was significantly higher for the HV region relative to HS and W regions, between which there was no difference. A difference in overall farrowing rate between the W and C regions, in favour of the latter just failed to attain statistical significance at the 5% level of probability. Although, a difference in farrowing rate was also noted between the HS and the C region it was not significant ($P < 0.05$)

There was no significant year x region interaction for farrowing rate (Appendix II).

3.1 Monthly variation with region: Data shown in Figure 7 give subsequent farrowing rates to monthly matings recorded in each of the four climatic regions. Statistical analysis of the data on a regional basis (Appendix IV) revealed that within the HS one, the month of mating significantly ($P < 0.05$) affected the resultant farrowing rate. Within the other three regions, month of mating did not influence subsequent farrowing rate ($P > 0.05$) (Appendix IV).

Figures given in Table 9, which refer specifically to the HS region , show that matings conducted during the months of November and December resulted in significantly lower farrowing rates relative to matings which occurred during the autumn and winter months. (April to August inclusive). The resultant farrowing rates for both November and December matings were also significantly lower than those for February matings ($P < 0.05$). Farrowing rates for January, March, September and October matings were significantly lower than for matings in the months of May or June ($P < 0.05$).

TABLE 9 Differences^{+} in resultant farrowing rates to monthly matings in the 'hot and stable' climatic region

Row column	JAN	FEB	MAR	APL	MAY	JUN	JULY	AUG	SEPT	OCT	NOV	DEC
January	-	+10.1	+8.3	+14.2	+14.1*	+14.7*	+11.3	+12.5	+8.8	+4.7	-1.4	-1.7
February		-	-1.8	+ 4.1	+ 4.0	+ 4.6	+ 1.2	+ 2.4	-1.3	-5.4	-11.5*	-11.8*
March			-	+ 5.9	+ 4.0*	+ 6.4*	+ 3.0	+ 4.2	+0.5	-3.6	- 9.7	-10.0
April				-	- 0.1	+ 0.5	- 2.9	- 1.7	-5.4	-9.5	-15.6**	-15.9**
May					-	+ 0.6	- 2.8	- 1.6	-5.3*	-9.4*	-15.5**	-15.8**
June						-	-3.4	- 2.2	-5.9*	-10.0*	-16.1**	-16.4**
July							-	+ 1.2	-2.5	- 6.6	-12.7*	-13.0*
August								-	-3.7	- 7.8	-13.9*	-14.2*
September									-	- 4.1	-10.2	-10.5
October										-	- 6.1	- 6.4
November											-	- 0.3
December												-

+ monthly differences in farrowing rate are expressed as deviations, in percentage units from the month in the left hand column.

In this table ** = $P < 0.01$ and * = $P < 0.05$

3.2 Influence of farm within region: Overall farrowing rates for the individual farms within each of the four climatic regions are shown in Table 10. Using linear model techniques, differences in overall farrowing rate between the farms within each region have been calculated (Appendix III).

TABLE 10: Overall farrowing rates for farms within each region

Region / Farm	1	2	3	4	5	overall
HS	91.4^{1}_{a}	72.3^{2}	65.1^{2}	85.2^{1}_{b}	65.4^{2}	76.8
HV	79.1^{1}	88.3^{2}	$80.9^{1,2}_{a}$	90.7^{2}_{b}	70.6^{3}	78.1
W	74.3^{1}_{a}	$81.5^{1,3}_{b}$	55.9^{2}	82.1^{3}	$79.6^{1,3}$	75.5
C	74.1^{1}	87.9^{2}	72.6^{1}	90.5^{2}	69.4^{1}	79.5

In this table different superscript numbers denote $P < 0.01$ and different subscript letters denote $P < 0.05$

Statistical analysis of the transformed data for farms in the 'hot and stable' climatic region revealed that the overall farrowing rates were significantly higher ($P < 0.01$) for farms 1 and 4 relative to farms 2,3 and 5, between which there was no difference ($P > 0.05$). A difference in overall farrowing rate between farms 3 and 4, in favour of the former was significant at the 5% probability level (Appendix IV).

In respect of farms within the 'hot and variable' region, farms 2, 3 and 4 each had a higher overall farrowing rate compared with farm 5 ($P < 0.01$). The difference in farrowing rate between farm

Fig 8: Farrowing rate in relation to month of service for the five farms in the 'Hot and stable' climatic region.

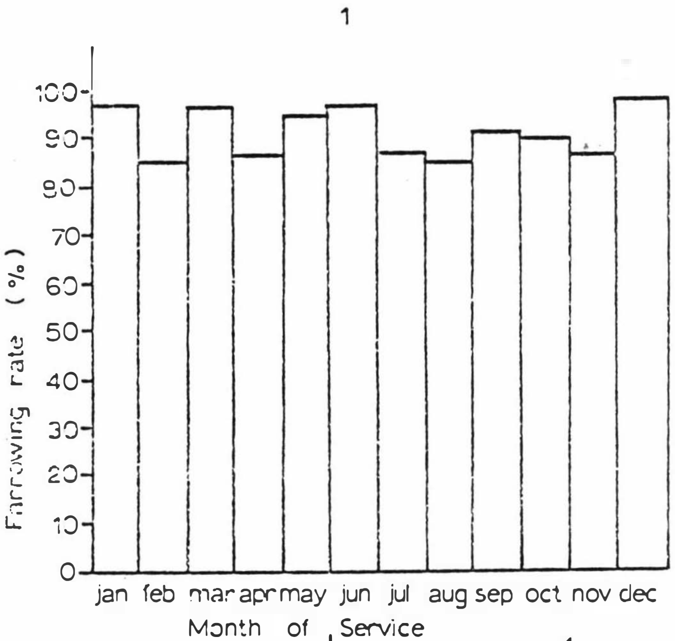
1 - Farm 1

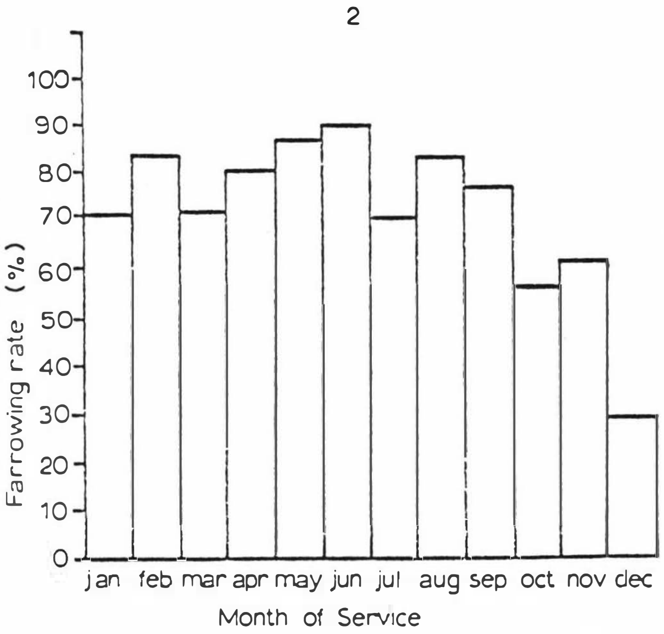
2 - " 2

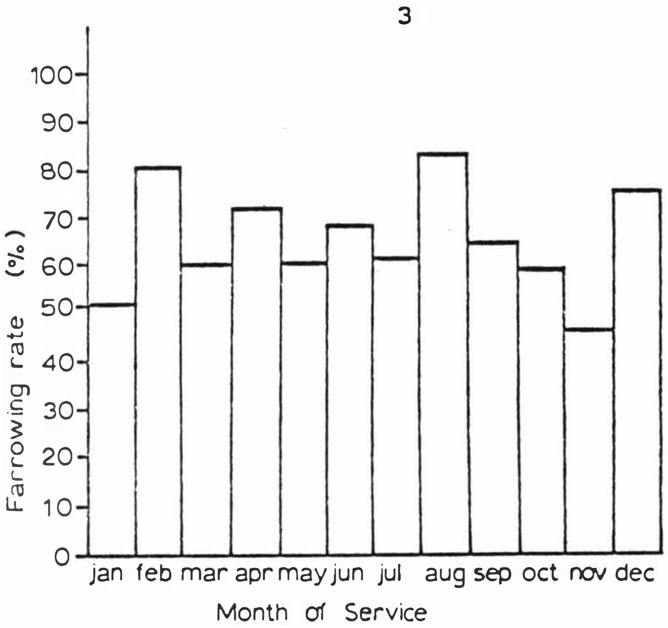
3 - " 3

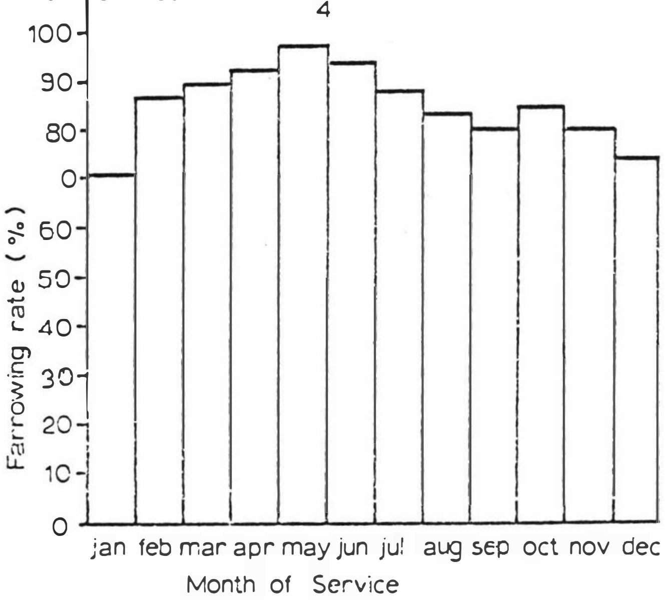
4 - " 4

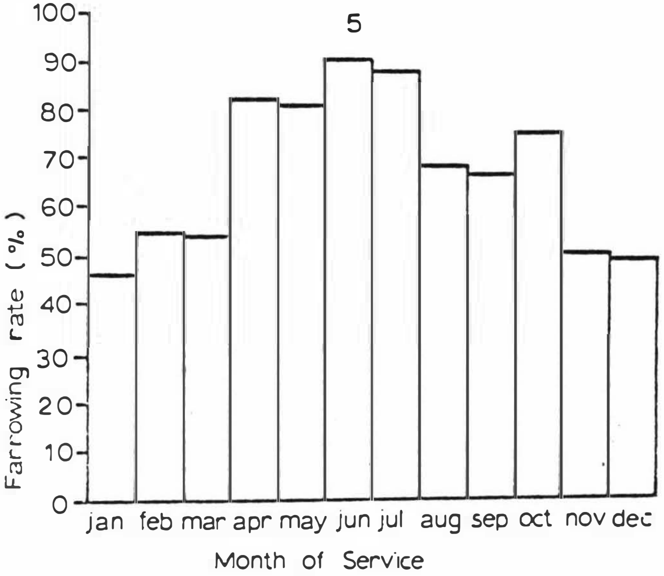
5 - " 5


1
Farrowing rate (%)
100
90
80
70
60
50
40
30
20
10
0
jan feb mar apr may jun jul aug sep oct nov dec
Month of Service


2
Farrowing rate (%)
100
90
80
70
60
50
40
30
20
10
0
jan feb mar apr may jun jul aug sep oct nov dec
Month of Service


3
Farrowing rate (%)
100
90
80
70
60
50
40
30
20
10
0
jan feb mar apr may jun jul aug sep oct nov dec
Month of Service


4
Farrowing rate (%)
100
90
80
0
60
50
40
30
20
10
0
jan feb mar apr may jun jul aug sep oct nov dec
Month of Service


5
Farrowing rate (%)
100
90
80
70
60
50
40
30
20
10
0
jan feb mar apr may jun jul aug sep oct nov dec
Month of Service

1 and 5 was also significant in favour of Farm 1.($P<0.01$). The difference in overall farrowing rate between farm 1 and 3 was not of statistical significance, but a difference at the 5% level of probability occurred between farms 3 and 4 ,with farm 4 having the higher overall farrowing rate (Appendix IV).

With reference to farms in the 'warm' region statistical analysis of the transformed data (Appendix IV) showed that the overall farrowing rate for farm 3 was lower relative to that for the other four farms ($P<0.01$). Overall farrowing rate showed no significant difference between farms 2, 4 and 5 or between farm 1 and 5, but a difference in farrowing rate between farm 1 and 2, in favour of the latter, was significant at 5% probability level.

In the 'Cool'region farm 2 and 4 had the highest overall farrowing rates and these differed significantly ($P< 0.01$) from corresponding values for the other farms, between which there were no differences ($P< 0.05$.)

Monthly farrowing rates for each of the five farms within the 'hot and stable' climatic region are shown in Figure 8. There was no significant Farm x month of mating interaction ($P> 0.05$)(Appendix V). Nevertheless, reference to Figure 7 shows that the overall significant seasonal pattern exhibited for farrowing rate in this region was not representative of each of the five farms. Thus, there was a trend for variation between farms. The monthly farrowing rates recorded for farm 1 were consistently high. There was no indication of a decrease for matings conducted during the late spring and summer months (Nov to Jan. inclusive)(94%).

High monthly farrowing rates were also observed for farm 4. However, a seasonal pattern, similar to that for the region as a whole was discernable. Matings conducted during the months of November to January, inclusive resulted in lower farrowing rates (75.3%) relative to matings taking place during the other months of the year (88.3%). A seasonal trend in monthly farrowing rate was evident in both farm 2 and 5.

In farm 2, a marked decrease in farrowing rate was noted for matings which occurred during the months Oct. to Dec. inclusive (48.8%) relative to the remainder of the year (79.3%), with a particularly low farrowing rate of 29% recorded during the month of December.

In farm 5, a decrease in farrowing rate for animals mated over the late spring and summer months (Nov. to Mar.inclusive)(50.8%) was apparent when compared to the farrowing rates from matings taking place during the other months of the year (75.3%).

Generally, low monthly farrowing rates were recorded in farm 3. Although monthly fluctuations in the farrowing rate were observed, there was not consistent pattern.

Monthly farrowing rates for each of the five farms in the other three climatic regions are shown in Appendix V. Again, there was no significant Farm x month of mating interaction ($P > 0.05$) in any of the regions,(Appendix IV) but a trend for variation between farms was also observed.(Appendix V).

DISCUSSION

The present study was designed to obtain information on the degree of seasonal variation in farrowing rate prevailing in New Zealand pig units. It may be argued that the values and trends recorded were unique to the 20 co-operating farms and may have occurred only during the two-year period of the investigation. However, although these farms were not randomly selected, they can be considered to be representative of many similar sized units in New Zealand.

The overall farrowing rate on the farms (77.1%) was well below the level of 85%, a value often quoted as that which should be attainable on efficient commercial enterprises (Wrathall 1977). This suggests that infertility was undoubtedly present. Examination of the data on a regional basis revealed that the farrowing rate for each region showed no marked divergence from the overall mean. Although, mean farrowing rate for the 'Hot and variable' region was significantly higher compared with the 'warm' and 'cool' regions the differences were small and not considered likely to be of practical significance.

Closer examination of the data at farm level showed that this factor was a major source of variation in farrowing rate within each region. Of particular significance was that 30% of all farms had an overall farrowing rate above 85%. This indicates that the infertility problem, highlighted in the overall and regional farrowing rates is not indicative of low fertility on all the farms in the study. Nevertheless, of the remaining 70% of farms which had an overall farrowing rate below 85%, 11 farms had a farrowing rate below 80% which included three farms where the overall farrowing rate was more than 20% units below the acceptable 85% level.

The co-operating farms were spread over a range of outdoor climatic conditions and subject to a variety of managerial systems under equally diverse housing standards. As reproductive traits, in the pig, are mainly influenced by the environment and cross breeding (King, 1972; Bichard and Smith, 1972), this wide range in overall farrowing rate for farms is not unexpected.

Examination of farm performance in farrowing rate on a regional basis showed that the extent of the variation in this parameter was similar for all regions and of greater magnitude than the differences between regions. This would indicate that the difference in conditions on the farms had a greater influence on overall farrowing rate than the annual variation in climatic conditions between the regions. It is worthy of note that there was no marked regional variation in the annual means for the climatic variables. However, much depends upon the variation about the annual means in each region, for without a knowledge of such variation it would be unwise to conclude this is the sole reason for the fairly similar overall farrowing rate found for each region. Within each region there were two or three farms which had an overall farrowing rate above 80%, a value often quoted as a baseline below which remedial action should be taken (Wrathall, 1977). This could imply that the climatic conditions prevailing in New Zealand throughout the year do not adversely affect farrowing rate and consequently differences recorded in this parameter are linked with conditions specific to individual farms. Alternatively, it could equally well be that farrowing rate is influenced by the climatic environment of the country but for other reasons some farms, but not others, are capable of buffering this effect. There are probably also a few farms where the outdoor climate may aggravate an existing fertility problem. Clearly, from a consideration of overall farrowing rates, infertility is present in all four regions but this is overshadowed by a marked farm variation within each of them. This raises the question of what proportion of the infertility occurring in each region is seasonally orientated and what influence has the farm situation upon it.

Overall, although season of mating did not significantly influence reproductive performance, monthly farrowing rate reached its lowest level in those animals mated in November to February inclusive. In contrast the highest fertility level occurred in animals mated in April to August, inclusive. These monthly differences although of some practical significance were not nearly as marked as comparable values from overseas, where 'summer' infertility has been noted to occur (Enne et al, 1979; Bevier and Backstrom, 1980).

A further analysis of monthly farrowing rates, on a regional basis revealed a significant seasonal difference within the 'hot and stable' region. Thus, the subsequent farrowing rate for sows mated during late spring and summer was lower (70.2%), than that for the late autumn-winter period (81.9%). A similar but non-significant seasonal pattern was identified in the 'warm' region, but there was no detectable monthly effect for the 'cool' region. The seasonal trend in porcine reproduction noted within the regional data may be indicative of the presence of 'summer' infertility in New Zealand. It is worthy of note, however, that a comparison of mean farrowing rates for the summer or late spring and summer period with overseas studies, where 'summer' infertility has undoubtedly occurred, indicates that the extent of the infertility is less severe in the present study (Stone, 1977; Enne et al, 1979; Bevier and Backstrom, 1980).This is is understandable as the climate in New Zealand is less extreme than that in which the overseas studies were conducted. For example, maximum daily ambient temperatures frequently in excess of 32^{o}C were reported over the'summer' infertility period by Stone (1977) and Paterson et al (1978). In contrast, although corresponding ambient temperatures in excess of 32^{o}C have been reported in New Zealand, such elevated values are comparatively rare, particularly for any length of time.

Of particular significance in the current regional analysis of months farrowing rates is the absence of a seasonal difference in the 'Hot and variable' region. It may be that the variation in diurnal temperature enables an animal to recuperate, from a heat stress situation during the hotter months of the year which may otherwise have a detrimental effect on reproductive performance. However the likelihood of this effect seems remote. Despite a lack of information concerning this subject, it has been reported that infertility can be a problem during the autumn months (Stork, 1979)a season in which diurnal temperature variation can be quite marked. Furthermore, in the present study, the difference in mean monthly diurnal temperature fluctuation between the 'Hot and stable' region and the 'hot and variable' one is comparatively small. Consequently any differences in this parameter are unlikely to be responsible for the difference in monthly farrowing rate between the two regions in question.

It is also worthy of note that taking one mean temperature figure to represent a monthly situation has many limitations. Thus an accurate comparison is difficult as all relationships established between the temperature value and the measure of reproductive inefficiency chosen relate only to the month when service took place and not to the time when reproduction actually failed. This reasoning is equally applicable to the mean monthly maximum temperature value also considered in the study. To further

This pattern established between mean monthly maximum daily temperature and the monthly farrowing rate in the 'hot and stable' and the 'warm ' regions resembles that recorded in several overseas studies (Corteel et al, 1964;Stone, 1977; Robinson and van Niekerk, 1978; Enne et al., 1979; Stork, 1979). It should be noted, however, that the maximum decrease in the monthly farrowing rate within these two regions, generally occurred before the highest monthly mean daily maximum temperature was attained.(ie. in the spring and early summer months)(Figure 9)

It is worthy of note that in some overseas studies ,where 'summer' infertility has undoubtedly occurred, a decline in farrowing rate was also observed during spring (Stone, 1977; Bevier and Backstrom , 1979). Unfortunately, detailed information concerning the climate had not been presented. In the present study, examination of the meteorological data shows that daily maximum temperatures similar to those experienced during the month with the highest mean monthly maximum temperature (February) occur during the preceding period (November to January inclusive). The higher farrowing rate recorded in February compared with that for the months of November, December and January, may possibly be taken as an indication of the ability of some of the (less stress susceptible) breeding stock to acclimatise to the " hot " conditions by this time. Alternatively, in view of the changeable outdoor climate experienced during the months of November, December, and January, it may be that farrowing rate is not only influenced by the level of maximum ambient temperature per se but by the rate at which changes in ambient temperature occur around the mating time.

FIGURE 9: The mean monthly maximum daily temperature and the monthly farrowing rate relative to the month of service in each of the 4 climatic regions.

Regions:

1 - 'Hot and stable' (HS)
2 - 'Hot and variable'(HV)
3 - 'Warm' (W)
4 - 'Cool' (C)

complicate the situation, many studies of porcine infertility in the summer months, which have implicated heat stress as a major causal factor, suggested different 'stress' susceptible stages, eg., the weaning to remating period (Mitic et al, 1965; Steinbach, 1976b; Love, 1978); around the time of mating and immediately postmating (Tompkins et al, 1967; Omtvedt et al, 1971) and the period of implanation (Nelson et al; 1970; Omtvedt et al; 1971).

Despite the difficulties in making an accurate comparison between mean daily maximum temperature and reproductive efficiency, one study has recorded a significant negative association between this climatic variable during the week of mating and the subsequent reproductive performance of a herd (Paterson et al; 1978) A significant negative correlation has also been reported between the mean monthly daily maximum temperature and mean monthly farrowing rate, but the association was of a low order (Hermann, 1980). In view of the limitations of the monthly temperature parameter discussed previously, this low relationship is perhaps not unexpected. Nevertheless, data presented in Figure 9, which relate to the present study provide some evidence of a negative association between mean monthly maximum daily ambient temperature and monthly farrowing rate in the 'Hot and stable' and the 'warm' climatic regions. There is no indication of a similar relationship in either the 'hot and variable' or the 'cool' climatic regions respectively.

In the absence of objective data, however, these views must remain as speculative.

Overall, it seems that exposure to thermal stress is likely to be implicated in 'summer' infertility. Here thermal stress can be considered to encompass all the climatic factors eg. radiative heat load (Bond _et al_, 1954); relative humidity (Teague _et al_,1968) and wind velocity (Morrison _et al_, 1976). However, it is probable that exposure to 'hot'conditions is but one of a number of 'stressors' involved in 'summer'infertility. Furthermore, it is recognised that the external environmental conditions to which a pig unit is exposed are only of significance in so far as they are capable of determining the microenvironment of the stock within. Throughout a given year a pig unit may well be subjected to a wide range of external environmental conditions which differ with the location, even in the same climatic region, of the country (eg. thermal stress, disease status). However, the type of environmental control operating on individual units may modify the state of stress imposed on the animal by the external environment.

An examination of the monthly farrowing rates for individual farms within each region shows that the variation between farms is far in excess of the regional differences. In view of this wide variation in farrowing rate, it seems likely that the regional differences noted in this parameter are more the end result of the degree of control exerted over the environment on each of the five farms within each region than of the regional differences encountered in outdoor conditions. This probably serves to explain the differences in the regional farrowing rate pattern, particularly between the 'hot and stable' and the 'hot and variable' climatic regions.

Despite the wide variation in monthly farrowing rates for the farms within the 'hot and stable' region, a degree of 'summer' infertility was still evident. That 'summer'infertility was less evident in the 'hot and variable'region was undoubtedly the result of marked farm variation in farrowing rate throughout the year. Thus, although one farm obviously had a 'summer' infertility problem, this was offset by high monthly farrowing rates throughout the year on three farms and a constant fertility problem on the fifth farm in this region; the end result was the lack of an overall seasonal pattern in farrowing rate for this region.

This pattern was also evident in the 'warm' and 'cool' climatic regions where farms showing some degree of seasonal infertility were considered along with farms which had achieved high farrowing rates irrespective of season and on the other extreme units plagued with a persistent infertility problem. Thus, even though there was evidence of 'summer' infertility in all the regions, its incidence could only be reflected in the monthly farrowing rate trend for the 'hot and stable' region. Thus, present findings would suggest that the 'summer'infertility problem did occur on some farms in all four climatic regions but appears to be more in evidence in the 'hot and stable' region.

Of particular significance however, is that even in this region not all the farms experienced 'summer' infertility. The wide variation in overall farrowing rate, between individual farms in each region, may be taken to indicate that the extent of the environmental control measures operating on each farm, are of major importance in influencing the reproductive efficiency of the herd. With reference to farm variation in monthly farrowing rate in the 'hot and stable' climatic region, it is worthy of note that an independent classification of the standard of housing for breeding stock, applied to all 20 farms, placed one farm, a unit with extremely high farrowing rates irrespective of season, in the top category. On the other hand, another farm, in this region with a marked incidence of 'summer' infertility, was assigned to the lowest housing category. Further examination of the building score awarded to each farm showed that those with the highest housing standards all achieved the better farrowing rates. In contrast farms with the lowest building standards generally exhibited the lowest overall farrowing rates and experienced highest seasonal 'summer' decline in farrowing rate.

Overall, many types of housing were encountered in the study with no similar standard being in evidence for any one region. Consequently, it is quite probable that the variable standard of housing for breeding stock on the farms accounts, in part at least, for the variation in farrowing rate recorded for individual units within each region.

The possible effect of housing standard for breeding stock on farrowing rate,is illustrated by reference to one farm where over the two-year period,new buildings were erected such that the building classification changed from the lowest to the highest category. Following the building alterations there was a dramatic favourable change in farrowing rate (Figure 10). Thus, mean monthly farrowing rate rose from 77.1% where the stock were extensively housed (ie. outdoors with uninsulated shelter, group penning,group feeding), to 91.7% following their transfer to the new intensive accommodation (ie. entirely indoors; high standard of insulation, individual penning). Unfortunately, no comparison could be made for the summer or late spring and summer period as the change took place in February 1978. As no disease problems were evident before the change of housing and there were no subsequent changes in the basic stock, the labour operating the unit or source of feed the difference in farrowing rate could be considered to be indicative of the effectiveness of the new housing in insulating the breeding stock from environmental stresses. It is worthy of note that 'summer'infertility has been reported to occur on farms where the buildings are of a high standard of construction (Love, 1978; Paterson et al, 1978; Bevier and Backstrom, 1980). In one such climatic area,Driggers et al; (1976) reported that only when zone cooling with mechanical refrigeration was there a favourable effect on the 'summer' infertility problem experienced in intensively housed breeding stock.

In contrast to this complex means of control, in one New Zealand study even the construction of a pen, shaded from the sun by wooden slats over the yard area, resulted in a marked improvement

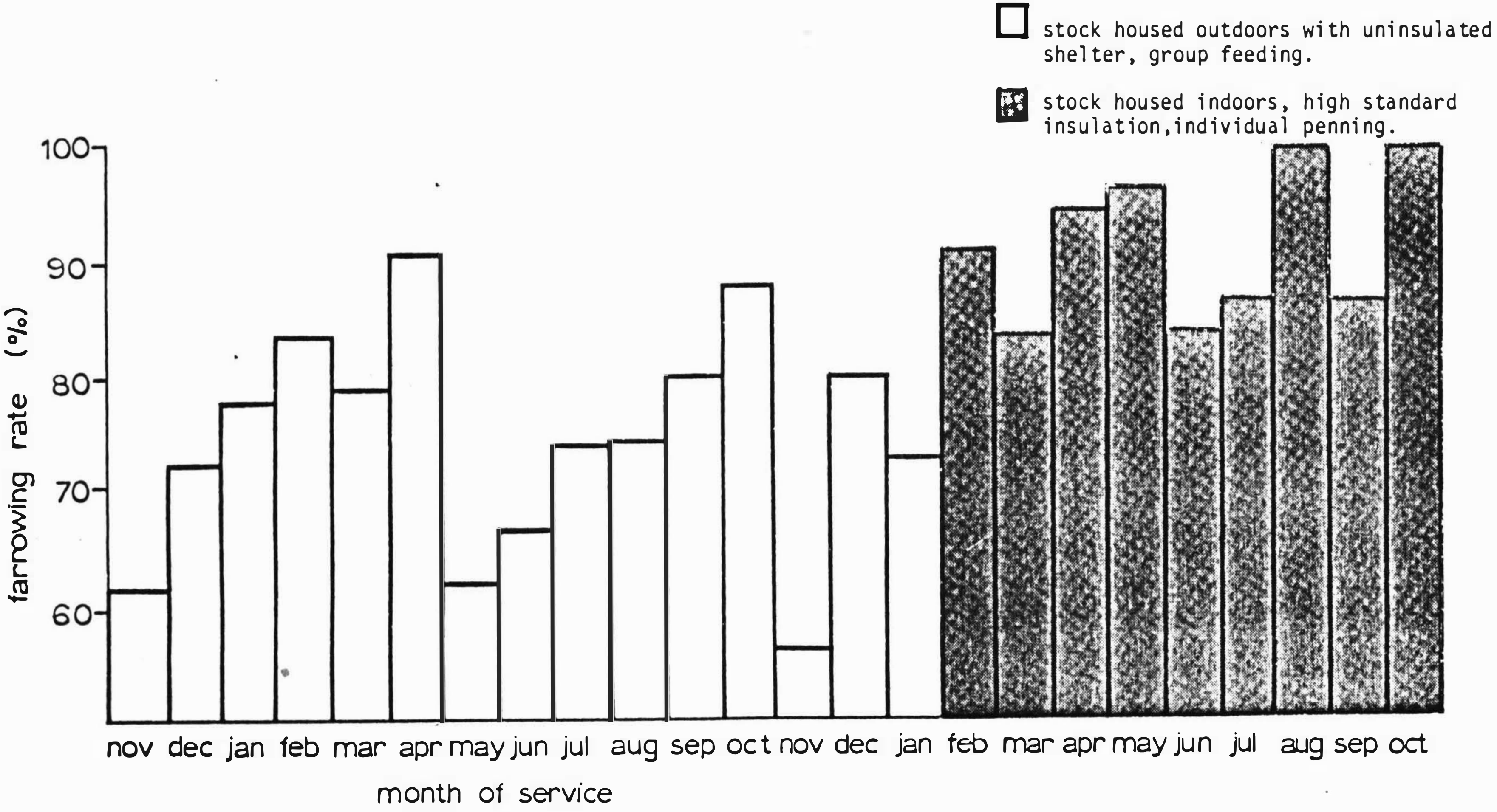


FIGURE 10: The influence of a change in the standard of housing on the monthly farrowing rate relative to the month of service on one farm.

in conception rate (67% versus 87%) (Shearer, 1975). In general, it would appear that in the temperate climate of New Zealand resort to housing of a high standard of construction (ie. in respect of insulation, and ventilation control) is capable of buffering the hot conditions of the summer environment, thereby alleviating stress and thus having a favourable influence on what otherwise could well have been a fertility problem.

Housing standards are, however, not the only means of environmental control operating on pig units which may modify the reproductive efficiency of a herd. Other factors likely to be implicated in reproductive inefficiency include those associated with feeding and management; the social environment (eg.pen size in relation to group size, individual versus group penning, unequal sizes and ages in a group, proximity of gilts and weaned sows to the boars) and disease level(s)(eg. leptospirosis, parvovirus). In view of the range in housing standards for breeding stock encountered in this study a similarly comprehensive variation in other factors which make up the farm environment would not be unexpected.

Support for the view that individual management can influence reproductive performance comes from a recent American study, involving 20 farms. On the latter the stock were derived from the same genetic pool, the buildings were of standard design and construction and feeding practices were similar. Despite this high degree of uniformity, there was marked farm variation in sow fertility. It was concluded that the standards of management on individual units was a prime factor influencing reproductive efficiency on these farms (Bevier and Backstrom, 1980). Unfortunately a critical evaluation of the factor which make up the farm environment on the units in the present study was impossible, as most farms were visited once and only a few a second time. Nevertheless, there are farms in this study where the level of the overall farrowing rate and its monthly variation could well be linked with farm practices in operation. One farm in both the 'hot and variable' and 'warm' regions, despite having buildings low in the classification score experienced no seasonal variation in farrowing rate and maintained a high overall performance. This could indicate that a high standard of husbandry on the farm can counteract a decline in farrowing rate, particularly during the critical summer months which has been shown to occur on farms in the same region but with higher building standards.

There is some indirect support for the view that stressors other than those of a thermal nature may be implicated in the 'summer' infertility problem. Thus, one Australian study has reported on inverse relationship between parity on the likelihood of sows being affected by the 'summer' infertility problem (Love, 1978). However, in contrast both Hermann (1980) and Hurtgen <u>et al</u> (1980) noted that the 'summer' infertility problem was similar for all sows irrespective of their parity number.

Some overseas studies have indicated that monthly variation in reproductive performance can be attributed, in part, to specific farm practices. Thus Stone, (1977) in a study of four farms, located in a similar climatic region, noted that on two of them which had markedly higher farrowing rates and a lower summer decline in this parameter breeding stock were hand-mated. This is in contrast to limited supervision at mating for stock on the other two farms. Although the former farms also had marginally better housing, it was concluded that the possibility that mating technique favourably influenced conception rate could not be ignored. In the present study, handmating was the mating technique used on only two units. The fact that these two farms also recorded the highest overall farrowing rates irrespective of season may be suggestive of the beneficial advantages of close supervision at mating. Alternatively, the adoption of this technique may be taken as a reflection of a high managerial ability and good stockmanship in general on these two farms.

The importance of a high standard of stockmanship in order to alleviate seasonal 'summer' infertility can be concluded from the reproductive aspects discussed in the review of literature. Such as the ability to detect oestrus, which may not be displayed clearly during the summer (hot) months (van Putten, 1965), thereby necessitating increased supervision over this period.

The role of social and behavioural stress on reproductive performance has been reported in several studies (Maclean, 1969; Shannon, 1969). Maclean (1969) attributed a significant prolonged return to oestrus postweaning, in a group housed situation as opposed to an individually penned one, to fluctuations in the dominance order of sows mixed together after weaning. In support,Shannon (1975) found that gilts which were loosely confined (4.46m^2/gilt) conceived at a higher rate than gilts penned intensively (1.49m^2/gilt). In another study,where 5392 sows were moved into either individual crates or group pens (6-20 females) after weaning, Hurtgen et al;(1980)reported that the subsequent farrowing rate was 81.6% and 71.7% respectively. However, group size postweaning was not found to have an additional effect on farrowing rate from matings during the summer period.

Of particular significance,in the present study,was the number of farms which experienced a fertility problem outwith the summer period. This raises the question of disease as a prime or contributory factor in 'summer' infertility. It is known that the incidence of several diseases is influenced by environmental factors,including climate. However acting against the direct implication of infection in 'summer'infertility is the reoccurrence of the problem in subsequent years in the same sows, as noted by Love (1978) and Hermann (1980) among others. In support post mortem examination of affected sows upon return to oestrus has revealed no consistent lesions or likely causative factors (Williamson et al,1980). There is support, however, that disease, by contributing to an overall stressful situation, may be a secondary factor in the 'summer' infertility problem.

In the present study most of the herds which experienced 'summer' infertility still had a high level of infertility during the remainder of the year. A study, mentioned earlier, reported that the general level of infertility appeared to be mediated by the same factors as 'summer'infertility. It was concluded that infertility due to stress is a constant problem, likely to be exaggerated by the higher temperatures of summer (Williamson et al, 1980). Although there was no evidence, in the present study, that disease is implicated in the 'summer' infertility problem it cannot be dismissed as a possible contributory factor in the creation of a stressful situation which is conducive to the onset of 'summer' infertility. Furthermore it is important to note that the incidence of various diseases in a herd can detract from the presence of a 'summer' infertility problem by adversely affecting fertility at other times of the year.

Overall this study does provide some evidence that 'summer' infertility is to be found on New Zealand pig units. It is not possible, however, to be more specific,particularly in respect of the likely degree of severity of the problem within the pig industry or the degree of its relationship with the outdoor environment. This can be attributed to the presence of marked variations in farrowing rate, between the farms in the survey which was not related to their location nor in many cases with the season of mating. It appears that some farms no matter their location in respect of outdoor climate are capable of maintaining a satisfactory reproductive performance throughout the year. Others are not,but again the problem time is not always the hotter months of the year.

There is some evidence to show that the adoption of certain farm practices,although difficult to define specifically, other than they conform to recommendations, enable a high farrowing rate to remain throughout the year. While closely located units with low standards as regards housing and/or management are more likely to experience a 'summer'infertility problem.

Unfortunately, as was evident in this study, infertility can arise from other causes than the direct effect of the outdoor climatic environment, even on units where the standard of housing and husbandry are high. This makes it very difficult to independently assess the extent of a specific type of infertility particularly where the number of co-operating farms in the study is small, as in the present one.

Should further investigation in this area be considered it is essential that the studies take into account the large variation in monthly farrowing rates for farms, the problem of assessing a complex physiological process on the basis of one parameter only ie. farrowing rate and the limitation of using limited regional climatic data as the assessment for an individual farm situation. Perhaps the greatest problem of all is the presence in any study involving individual farms of any one of a number of factors being a cause of low fertility with no possibility of knowing which one is relevant in any particular situation. This will only be accomplished when there is increased information on factors which are actually involved and how they act.

Generally with the data from the present study, it is impossible to be specific in respect of the likely degree of severity of the 'summer' infertility problem within the pig industry or the degree of its relationship with possible causal factors. It would seem that in the temperate New Zealand climate other factors, known to influence farrowing rate and which vary widely between farms, have a greater influence than the outdoor climatic environment. On the other hand, in many 'hotter' countries, which have reported a 'summer' infertility problem, the climate prevailing during the summer months seems to be by far the dominant factor influencing reproductive efficiency over this period.

Clearly, since in a type of investigation such as the present one, farms can never be considered as replicatesin its design, it is necessary to involve a large number of co-operating units in order to minimise effects specific to farms. Only by adoption of such a procedure will it be possible to determine whether or not 'summer'infertility is prevalent within the country and if so, its regional significance.

Secondly with survey type data, it is only possible to get an indication of the influence of environmental factors on the incidence of 'summer' infertility. Precision in this respect can only be achieved by reference to detailed studies confined to a few individual units. This approach, by standardising many other factors known to influence reproductive efficiency, will aid in the isolation of those of concern. Again, in aiming to quantify the effect of the outdoor environment on sow fertility, concentration of effort on a few units will allow for a detailed evaluation of the microenvironment on each of them.

CONCLUSIONS

This study has demonstrated the existence of seasonal variation in farrowing rate in New Zealand pig herds, with the trend to lower performance in the summer months, but has not allowed the extent of the problem to be quantified on a national basis.

An examination of the influence of some environmental factors on the incidence of 'summer' infertility was limited in view of the wide number of uncontrolled variables in operation. However, it would appear that in the temperate New Zealand climate the outdoor environment does not have a dominant role in influencing the seasonal pattern in farrowing rate. Housing standards and level of husbandry employed on individual units appear to be of much greater significance in respect of the reproductive efficiency of a herd.

APPENDIX I

Guideline Questionnaire

Location:

Name and address:

Distance from and name nearest met.station:

General comment on (Topography-area etc.)

Size of herd:

Records

years of data at hand?

Data available

- *mating date*
- *farrowing date*
- *sow number*
- *Boar number*
- *Litter data* *specify -litter number,stillbirth litter wgt,weaning wgt no.*

Breed

a Boar breed/s (over total recorded period)

b Sow breed/s (over recorded period)

Comment

Sow culling

what number of sows do you cull per year?

what age do you cull at?

(Criteria for culling-)?see supplement

Do you "buy in" replacement stock ?   yes   no

If yes, where do you purchase them?

Do you buy gilt or sow replacement stock?

Breeding management

what methods do you use for oestrus detection?

what management procedure do you adopt for gilt/wean sows (wean - mating)?

During remating period where and how are sows housed?

(grouped together, individual pens, grouped together but individual feeding etc)

Do you use boars, near or in with, or in sight of sows to be remated?

Time of mating

How long are boars and sows in mating pen (one day, 2 days, at supervised time only, mated 1 x 2 x 3 x at what times penned together, i.e. early morning, late afternoon, early morning?)

Do you supervise mating? *yes* *no*

at what age do you first mate gilts?
(1st, 2nd,3rd oestrus)

General supervision of pre-pubertal gilts

Boar management

number of boars on farm

sow/boar ratio
how many matings per week?
what age do you cull boar?
General boar culling criteria?

Management in pregnancy

what are the housing conditions for gestating sows? Indoor,outdoor,stalls tethered, grouped in pen; grouped but separate feeding.

at what age do you wean piglets (past and now) ?

Disease

what disease precautions and preventative (or treatment do you use?) (mange dress,worm treat,other test eg Blood tests for lepto or aujeszky) general disease status.

Have you had any prevalent disease in herd in past ?

see supplement

Nutrition

Type offered

meal, whey, whey+meal, garbage:-

If whey what number of months is whey supplied?

Composition of feed (additives etc)

Grain (is it stored)

what storage facilities?

How long is grain stored? when brought in?

what is general feeding pattern for gilt/sow/boar?

Gilt pre-pubertal (kg) feeding fattening herd?

prior to mating (flushing?)

mating

immediately post mating

pregnancy

farrowing

lactation

remating

Sow Nutrition

remating (flush?)

mating

soon after mating

gestation

farrowing

lactation

Boar nutrition

Have you changed nutrition over past years?

(if so have you noticed any difference due to the change?)

Has the management been the same over the recorded period?

SUPPLEMENT

(A) Sow culling

what criteria do you use for culling (tick box)

( ) Performance (reproductive failure)(and what return do you cull at 1st( ) 2nd ( ) 3rd ( ) other ( )

( ) age at culling (what maximum culling age)

2( ) 3 ( ) 4( ) 5( ) 6 ( ) 7 ( ) 8 ( )+8 ( ) litter

( ) locomotor defects disturbances

( ) death (% sow mortality/year)

( ) condition of sow (conformation)

( ) udderline- do you cull for pendulous udders, teat number etc

( ) miscellaneous reasons

eg. ( ) savaging

( ) mothering ability (poor)

( ) size of sow (weight.age,Food conversion Efficiency)

( ) small litters

( ) grading at progeny

( ) economic situation

( ) other reasons (specify)

Gilt selection criteria

( ) genetic gain (Dam/Boar record)

( ) size gilt

( ) age gilt

( ) udderline of gilts,number of teats, inverted etc.

( ) condition of stock

( ) health status

( ) other reasons (specify)

Boar selection criteria

( ) genetics (Record, Feed Conversion efficiency,Growth rate,lean %)

( ) general structural soundness

( ) performance of boar (mating ability)

( ) disease status (Blood test lepto Aujeszky)

What criteria do you use for culling decisions?

( ) performance

Do you examine (for genital soundness) yes ( ) no ( )

( ) size (managerial problems of mature boar)

( ) locomotor defects

( ) poor service technique

( ) age

( ) disease status of boar

( ) condition of boar

( ) policy for fast utrnover for maximum genetic gain

( ) other criteria (eg. economics)

Disease

Have you encountered these diseases on your property

(years if only over some of record year) or other important diseases

( ) leptospirosis

( ) Brucellosis

( ) Aujeszky

( ) parvovirus

( ) others specify i.e. (smedi, enzootic pneumonia, mange,worms,foot lesions)

APPENDIX II

Analysis of variance of subsequent farrowing rate (Transformed data) to all services model 1

Source	DF	Mean square	F ratio
Region	3	0.18432	4.88 **
Year	1	0.00802	0.212NS
Month	11	0.05385	1.43 NS
First order Interaction			
Region x year	3	0.02545	0.674NS
Region x month	33	0.03178	0.842NS
Year x month	11	0.01968	0.521NS
Second order Interaction			
Region x month x year	33	0.017465	0.467NS
Residual	384	0.03774	

** = P <0.01

* = P <0.05

NS = Not mathematically significant

APPENDIX III

Influence of farm within region

A Linear model analysis of Farm within region

	overall FR Differences$^+$ (% units)
(HS)	
Farm 1	*+25.8*
Farm 2	*+ 6.3*
Farm 3	*- 1.1*
Farm 4	*+ 9.5*
Farm 5	*0.0*
(HV)	
Farm 1	*+ 8.5*
Farm 2	*+17.9*
Farm 3	*+10.2*
Farm 4	*+19.8*
Farm 5	*0.0*
(W)	
Farm 1	*- 4.9*
Farm 2	*+ 2.1*
Farm 3	*-23.2*
Farm 4	*+ 2.7*
Farm 5	*0.0*
(C)	
Farm 1	*+ 6.0*
Farm 2	*+19.9*
Farm 3	*+ 4.2*
Farm 4	*+22.4*
Farm 5	*0.0*

+ differences (expressed as % units) have been presented as deviations from farm 5 in each of the 4 climatic regions.

APPENDIX IV

Analysis of variance: for month and farm with regional differences in farrowing rate (Transformed data) {Model 2}

		HS	
Source	DF	Mean Square	F Ratio
Farm	4	0.51138	24.67 **
Month	11	0.06954	3.35 *
Farm x month	44	0.02826	1.36 NS
residual	60	0.02073	
		HV	
Farm	4	0.21860	10.59 **
Month	11	0.02226	1.08 NS
Farm x month	44	0.02846	1.38 NS
residual	60	0.02061	
		W	
Farm		0.32192	21.51 **
Month		0.01325	0.885 NS
Farm x month		0.01919	1.28 NS
residual		0.14966	
		C	
Farm		0.35251	10.86 **
Month		0.03719	1.25 NS
Farm x month		0.02922	0.976 NS
residual		0.02995	

** = $P < 0.01$

* = $P < 0.05$

NS = not significant

APPENDIX V

Farrowing rates in relation to month of mating for farms within each region

'Hot and stable Region' (HS)

Farm	Month	Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
1	TS	67	56	59	52	61	62	53	63	57	56	69	58	713
	SS	65	48	57	45	58	60	46	54	52	50	60	57	652
	FR	97	85.7	96.6	86.5	95.1	96.8	86.8	85.7	91.2	89.3	86.9	98.3	91.4
2	TS	55	60	57	50	45	50	61	62	48	55	41	45	629
	SS	39	50	41	40	39	45	43	52	37	31	25	13	455
	FR	71	83.3	72	80	86.7	90	70.5	83.4	77.1	56.4	61	29	72.3
3	TS	48	45	25	46	81	62	36	59	42	47	62	48	601
	SS	25	36	15	33	49	42	22	49	27	28	29	36	391
	FR	52.1	80	60	71.7	60.5	67.7	61.1	83.1	64.3	59.6	46.8	75	65.1
4	TS	59	60	65	53	65	50	68	71	51	57	76	47	722
	SS	42	52	58	49	63	47	60	59	41	48	61	35	615
	FR	71.2	86.6	89.2	92.5	96.9	94	88.2	83.1	80.4	84.2	80.3	74.5	85.2
5	TS	63	51	57	66	36	37	40	56	36	47	50	51	590
	SS	29	28	31	54	29	33	35	38	24	35	25	25	386
	FR	46	54.9	54.4	81.8	80.6	89.2	87.5	67.9	66.7	74.5	50	49	65.4

'Hot and variable Region' (HV)

Farm	Month	Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
1	TS	35	23	45	41	53	46	28	51	37	44	59	35	497
	SS	30	13	36	36	43	44	23	44	31	34	37	22	393
	FR	85.7	56.5	80	87.8	81.3	95.6	82.1	86.3	83.8	77.3	62.7	62.9	79.1
2	TS	35	34	44	33	37	29	28	34	33	36	44	40	427
	SS	27	34	39	29	37	23	28	29	29	31	37	34	377
	FR	77.1	100	88.6	87.9	100	79.3	100	85.3	87.9	86.1	84.1	85	88.3
3	TS	49	46	31	39	50	49	46	51	54	48	46	40	549
	SS	37	40	25	36	41	37	37	44	45	45	27	30	444
	FR	75.5	86.9	80.6	92.3	82	75.5	80.4	86.3	83.3	93.8	58.7	75	80.9
4	TS	11	16	19	13	12	14	24	25	23	25	17	16	215
	SS	10	15	17	12	11	12	21	23	20	23	17	14	195
	FR	90.9	93.8	89.5	92.3	91.6	85.7	87.5	92	86.9	92	100	87.5	90.7
5	TS	80	104	111	93	118	82	103	100	116	101	90	101	1199
	SS	57	72	73	61	84	53	75	77	77	72	73	73	847
	FR	71.3	69.2	65.7	65.6	71.2	64.6	72.8	77	66.4	71.3	81.1	72.3	70.6

'Warm Region"

Month Farm		Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
1	TS	125	119	119	109	128	120	114	134	103	141	142	131	1485
	SS	87	88	92	83	106	90	89	105	73	101	104	86	1104
	FR	69.6	73.9	77.3	76.1	82.8	75	78.1	78.4	70.9	71.6	73.2	65.6	74.3
2	TS	27	23	24	18	29.	20	26	23	18	17	25	25	275
	SS	23	17	16	14	23	16	22	21	16	15	23	18	224
	FR	85.2	73.9	66.7	77.8	79.3	80	84.6	91.3	88.8	88.2	92	72	81.5
3	TS	41	39	26	26	29	23	44	42	38	34	29	33	404
	SS	20	25	19	19	20	13	27	27	17	17	10	12	226
	FR	48.8	64.1	73.1	73.1	68.9	56.5	61.4	64.3	44.7	50	34.5	36.4	55.9
4	TS	69	80	101	87	84	80	78	95	84	74	72	80	984
	SS	58	57	75	77	72	65	64	78	71	63	62	66	808
	FR	84.1	71.2	74.2	88.5	85.7	81.2	82.0	82.1	84.5	85.1	86.1	82.5	82.1
5	TS	24	17	32	33	33	24	33	36	34	44	17	30	357
	SS	20	13	27	25	25	23	24	27	25	36	14	25	284
	FR	83.3	76.5	84.4	75.8	75.8	95.8	72.7	75	73.5	81.8	82.4	83.3	79.6

'Cool Region'

Month Farm		Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
1	TS	29	20	26	27	20	20	33	45	29	25	26	16	316
	SS	21	10	23	20	17	16	20	32	22	20	20	13	234
	FR	72.4	50	88.5	74.1	85	80	60.6	71.1	75.9	80	76.9	81.3	74.1
2	TS	9	9	7	12	13	11	13	15	7	12	6	10	124
	SS	9	8	7	10	10	9	12	13	5	19	6	10	109
	FR	100	88.9	100	83.3	76.9	81.8	92.3	86.7	71.4	83.3	100	100	87.9
3	TS	48	34	54	36	51	49	32	43	47	43	44	48	529
	SS	35	17	44	20	44	41	29	30	39	32	24	29	384
	FR	72.9	50	81.5	55.6	86.3	83.7	90.6	69.8	83	74.4	54.5	60.4	72.6
4	TS	53	39	43	42	48	43	55	52	45	46	54	50	570
	SS	48	36	41	38	45	35	49	47	42	41	50	44	516
	FR	90.6	92.3	95.3	90.5	93.8	81.4	89.1	90.4	93.3	89.1	92.6	88	90.5
5	TS	6	1	27	24	29	10	5	25	19	23	18	6	193
	SS	5	0	14	17	20	6	3	16	13	19	16	5	134
	FR	83.3	-	51.9	70.8	69	60	60	64	68.4	82.6	88.9	88.3	69.4

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