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REPRODUCTIVE EFFICIENCY IN
TOWN SUPPLY DAIRY HERDS IN NEW ZEALAND

A thesis presented in partial fulfilment
of the requirements for the degree of
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ABSTRACT

The objective of the study was to examine the reproductive performance of dairy cattle in Town Milk Dairy Herds in New Zealand. Breeding and production data for parous animals were collected from the records of twenty herds which ranged in size from 75 to 300 cows. Herd owners were members of the Wellington Hawke's Bay Livestock Improvement Association which provided herd testing and artificial breeding services. There were 12,056 calvings recorded involving 4,050 cows. Of these 9,898 were for Friesian, 672 Jersey, 1,066 Friesian Jersey cross cows and the remaining 420 other breeds and crosses.

The parameters measured were calving interval, calving to first service interval, first service to conception interval, days open, inter-service interval, calving rate to first service and services per cow calving and were 383.7, 84.8, 11.3, 106.9, 43.7 days, 49.3% and 1.7 respectively for the pooled population. Data for calving interval and first service to conception interval were transformed for all analytical procedures - the unadjusted values for these parameters were 388.7 and 19.3 days respectively. The mean milk yield was 3,730 litres and the mean lactation length 291 days.

Age, herd, season and year had highly significant effects on both productive and reproductive performance although the amount of variation that could be explained by these variables was small as far as reproduction was concerned. Any breed differences which may have been present were confounded with herd effects and no significant relationship was found between herd size and reproductive efficiency. This may have been due to an inadequate number of smaller herds in the sample.

Significant negative correlations were found between average daily milk yield and calving, calving to first service and first service to conception intervals. Their values were so low as to be of little consequence.

Reproductive efficiency increased up to the age of four years and then gradually declined whereas milk production increased up to the age of eight years before it declined. The youngest cows, particularly two year olds, which comprise a high proportion of the herd, performed poorly in nearly all reproductive parameters studied.

The correlation between calving to first service and first service to conception intervals was -0.09 and the standard partial regression coefficients (β values) for calving to first service and first service to conception intervals on calving interval were 0.63 and 0.73 respectively. Thirty nine percent of the variation in calving interval was explained by days from calving to first service and 45% by days from first service to conception.

A high incidence of short (11.6%) and long (49.5%) returns, together with an average inter-service interval of 44 days, indicated that detection errors and heat detection efficiency were important problems contributing to delays in breeding and increased numbers of services per cow calving. Conscious management decisions to withhold cows from breeding to meet specific seasonal needs may have compounded this problem.

Significant seasonal effects were observed with superior results during the spring irrespective of whether cows calved or were being bred at that time. Year differences in both productive and reproductive performance were also noted with best results occurring during years which recorded climatic conditions as being most suitable for pasture growth.

The number of abortions recorded during the course of the investigation were few. Where aborting cows were retained their breeding performance during the year following abortion was poor but this effect did not appear to carry-over to their performance in subsequent years.

	v.
TABLE OF CONTENTS	<u>Page</u>
ACKNOWLEDGEMENTS	ii.
ABSTRACT	iii.
LIST OF TABLES	viii.
LIST OF FIGURES	x.
INTRODUCTION	1
LITERATURE REVIEW	3
CALVING INTERVAL	3
<u>Days Open</u> (Calving to conception interval)	4
Calving to First Service Interval	6
First Service to Conception Interval	7
Factors Affecting Days Open	8
a. Heat Detection	8
i. Intensity of heat	8
ii. Duration of heat	9
iii. Method of detection	9
iv. Frequency, length and time of observation	9
v. Ability and interest of observer	10
vi. Shed and yard design	10
vii. Herd size and number of cows per labour unit	12
viii. Accuracy of records and use of rectal palpation as a means of predicting heat	12
ix. Synchronisation procedures	12
b. Interval to First Post Partum Oestrus	13
i. Age	13
ii. Suckling and frequency of milking	15
iii. Season	15
iv. Level of production	15
v. Inbreeding	16
vi. Nutrition	16
vii. Abnormalities at parturition	17
viii. Post parturient disease conditions	17
<u>Live Calf Rate</u>	17
'Conception Rate'	18
a. First Service 'Conception Rate'	18
b. Number of Services per 'Conception'	20
c. Return to Service Interval	20

	<u>Page</u>
Factors Influencing 'Conception Rate'	
i. Post partum interval	20
ii. Semen quality and inseminator skill	22
iii. Correct time to breed	23
iv. Cow age	23
v. Season	24
vi. Nutrition	24
vii. Level of milk production	25
viii. Other individual cow factors	26
Losses During Pregnancy	26
a. Temperature	27
b. Ageing of the gamete	27
c. Nutrition	28
d. Endocrine disturbance	28
e. Disease	28
Losses During Parturition	28
MATERIALS AND METHODS	30
<u>Method of Analysis</u>	31
RESULTS	33
PERFORMANCE FOR ALL HERDS	33
PERFORMANCE OF THE DIFFERENT AGE GROUPS OF CATTLE	41
ASSOCIATION BETWEEN SEASON AND REPRODUCTIVE PERFORMANCE	45
ASSOCIATION BETWEEN YEAR AND REPRODUCTIVE PERFORMANCE	45
ASSOCIATION BETWEEN BREED AND REPRODUCTIVE PERFORMANCE	55
ASSOCIATION BETWEEN ABORTION AND REPRODUCTIVE PERFORMANCE	55
THE RELATIVE IMPORTANCE OF DAYS FROM CALVING TO FIRST SERVICE AND FIRST SERVICE TO CONCEPTION ON CALVING INTERVAL	55
THE RELATIONSHIP BETWEEN CALVING TO FIRST SERVICE AND FIRST SERVICE TO CONCEPTION INTERVALS	55
THE EFFECT OF HERD SIZE ON INTERCALVING INTERVAL, CALVING TO FIRST SERVICE AND FIRST SERVICE TO CONCEPTION INTERVALS	58
THE EFFECT OF MILK PRODUCTION ON INTERCALVING INTERVAL, CALVING TO FIRST SERVICE AND SERVICE TO CONCEPTION INTERVALS	58
THE IMPORTANCE OF HERD, AGE, SEASON, YEAR AND BREED ON THREE PARAMETERS OF REPRODUCTIVE PERFORMANCE AND ON MILK PRODUCTION	58

	<u>Page</u>
DISCUSSION	62
THE INTERCALVING INTERVAL	62
CALVING TO FIRST SERVICE INTERVAL	64
CALVING TO CONCEPTION INTERVAL (DAYS OPEN)	67
THE INTER-SERVICE INTERVAL	68
CALVING RATE	73
<u>Calving Rate to First Service</u>	74
<u>Services per Cow Calving</u>	77
<u>First Service to Conception Interval</u>	77
HERD DIFFERENCES	78
ASSOCIATION BETWEEN SEASON AND REPRODUCTIVE PERFORMANCE	79
ASSOCIATION BETWEEN YEAR AND REPRODUCTIVE PERFORMANCE	80
ASSOCIATION BETWEEN BREED AND REPRODUCTIVE PERFORMANCE	80
ASSOCIATION BETWEEN ABORTION AND REPRODUCTIVE PERFORMANCE	80
THE RELATIVE IMPORTANCE OF DAYS FROM CALVING TO FIRST SERVICE AND FIRST SERVICE TO CONCEPTION ON CALVING INTERVAL	81
THE RELATIONSHIP BETWEEN THE CALVING TO FIRST SERVICE AND FIRST SERVICE TO CONCEPTION INTERVALS	85
HERD SIZE	85
EFFECT OF PRODUCTION ON REPRODUCTIVE PERFORMANCE	86
THE IMPORTANCE OF HERD, AGE, SEASON, YEAR AND BREED ON THREE PARAMETERS OF REPRODUCTIVE PERFORMANCE AND ON MILK PRODUCTION	86
GENERAL CONCLUSIONS	89
REFERENCES	92
APPENDICES	

LIST OF TABLES

<u>Table</u>		<u>Page</u>
I.	ECONOMIC EFFECT OF CALVING INTERVAL IN A 40 COW HERD	3
II.	CALVING INTERVAL REPORTED BY NUMEROUS RESEARCHERS	5
III.	FIRST SERVICE TO CONCEPTION INTERVAL REPORTED BY VARIOUS RESEARCHERS	7
IV.	EFFICIENCY OF VARIOUS METHODS OF OESTROUS DETECTION OBSERVED BY DIFFERENT RESEARCHERS	11
V.	CALVING TO FIRST POST PARTUM OESTROUS INTERVAL IN DAIRY CATTLE REPORTED BY VARIOUS RESEARCHERS	14
VI.	FIRST SERVICE 'CONCEPTION RATE' REPORTED BY VARIOUS RESEARCHERS	19
VII.	SERVICES PER CONCEPTION REPORTED BY VARIOUS RESEARCHERS	21
VIII.	REPRODUCTIVE PERFORMANCE OF TWENTY TOWN SUPPLY DAIRY HERDS IN THE WELLINGTON HAWKE'S BAY LIVESTOCK IMPROVEMENT ASSOCIATION (1972-76)	34
IX.	RETURN INTERVALS AS A PERCENTAGE OF ALL FIRST SERVICE RETURNS FOR TWENTY TOWN SUPPLY DAIRY HERDS	35
X.	REPRODUCTIVE PERFORMANCE OF THE DIFFERENT AGE GROUPS IN TWENTY TOWN SUPPLY DAIRY HERDS IN THE WELLINGTON HAWKE'S BAY LIVESTOCK IMPROVEMENT ASSOCIATION (1972-76)	42
XI.	RETURN INTERVALS AS A PERCENTAGE OF ALL FIRST SERVICE RETURNS FOR THE DIFFERENT AGE GROUPS IN TWENTY TOWN SUPPLY DAIRY HERDS	46
XII.	ASSOCIATION BETWEEN SEASON AND REPRODUCTIVE PERFORMANCE IN TWENTY TOWN SUPPLY DAIRY HERDS	47
XIII.	ASSOCIATION BETWEEN YEAR AND REPRODUCTIVE PERFORMANCE IN TWENTY TOWN SUPPLY DAIRY HERDS	48
XIV.	ASSOCIATION BETWEEN BREED AND REPRODUCTIVE PERFORMANCE IN TWENTY TOWN SUPPLY DAIRY HERDS	56
XV.	ASSOCIATION BETWEEN ABORTION AND REPRODUCTIVE PERFORMANCE IN TWENTY TOWN SUPPLY DAIRY HERDS	57
XVI.	EXPECTED EFFECT OF BREEDING AT DIFFERENT POST PARTUM INTERVALS ON THE DEMAND FOR SERVICES, NUMBER OF COWS CALVING AND MEAN CALVING INTERVAL	84
XVII.	F VALUES AND TESTS OF SIGNIFICANCE FOR VARIOUS MEASURES OF REPRODUCTIVE PERFORMANCE AND THE EFFECTS OF HERD, YEAR, SEASON, AGE, BREED AND THEIR INTERACTIONS IN TWENTY TOWN SUPPLY DAIRY HERDS	59
XVIII.	ASSOCIATION OF HERD, AGE, SEASON AND YEAR WITH MEASURES OF REPRODUCTIVE AND PRODUCTIVE PERFORMANCE	60
XIX.	CALVING TO FIRST SERVICE INTERVAL REPORTED BY VARIOUS RESEARCHERS	65
XX.	THE RATE OF MATING RECORDED BY DIFFERENT RESEARCHERS AT VARIOUS POST PARTUM INTERVALS	65

<u>Table</u>	<u>Page</u>
XXI. PERCENTAGE OF LONG RETURN INTERVALS REPORTED BY VARIOUS RESEARCHERS	71
XXII. IN CALF, CALVING AND NON RETURN RATES (NRR) AT VARIOUS POST PARTUM INTERVALS RECORDED BY OTHER AUTHORS	75

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1.	Reproductive Performance in Twenty Town Supply Dairy Herds	36
2.	Distribution of Calving Intervals in Twenty Town Supply Dairy Herds	37
3.	Frequency Distribution for Four Breeding Parameters at Different Postpartum Intervals in Twenty Town Supply Dairy Herds	38
4.	Association of Postpartum Interval with Cows Mated and Calving to 1st Service in Twenty Town Supply Dairy Herds	39
5.	Return Interval Patterns to 1st Service in Twenty Town Supply Dairy Herds	40
6.	Association Between Age and Reproductive Performance in Twenty Town Supply Dairy Herds	43
7a.	Association Between Age and Postpartum Interval on Cows Submitted to 1st Service in Twenty Town Supply Dairy Herds	44
7b.	Association Between Age and Postpartum Interval on Calving Rate to 1st Service in Twenty Town Supply Dairy Herds	44
8.	Return Interval Patterns to 1st Service Between the Different Age Groups in Twenty Town Supply Dairy Herds	49
9.	Return Patterns to 1st Service in Two Year Old Cows in Twenty Town Supply Dairy Herds	50
10.	Return Patterns to 1st Service in Three Year and Older Cows in Twenty Town Supply Dairy Herds	51
11.	Return Pattern to 1st Service in Cows of All Ages in Twenty Town Supply Dairy Herds	52
12.	Association Between Season and Reproductive Performance When Corrected for Effect of Age and Herd in Twenty Town Supply Dairy Herds	53
13.	Year Differences in Reproductive Performance in Twenty Town Supply Dairy Herds	54
14.	Relationship Between Calving Interval and the Intervals from Calving to First Service and First Service to Conception	82

INTRODUCTION

Until the artificial induction of lactation can be carried out successfully and economically in dairy cattle, milk production will depend for its initiation on the establishment of pregnancy and the accomplishment of normal parturition. Reproductive efficiency thus plays a significant role in determining how ably, and economically, the herd is capable of producing milk, and New Zealand, with its all grass system of cattle husbandry, provides no exception to this.

Losses due to inefficient reproduction are reflected by:

- Lower annual milk production
- Lower annual calf crops
- Reduced selection pressure and slower genetic gains
- Increased culling rates and breeding costs
- Increased feed costs per unit of milk produced
- Increased animal health expenditure.

The magnitude of such losses have been suggested as approximately 660 million dollars in the United States of America (Pelissier, 1976) and while no authoritative estimate has been attempted in New Zealand, there can be little doubt that inefficient reproductive performance produces costs which are substantial and which cannot be ignored in a competitive milk production enterprise.

Extensive investigations have been made into reproductive performance in dairying in New Zealand, particularly seasonal factory supply dairying, by workers associated with the New Zealand Dairy Board. Much of this has been summarised in their annual Farm Production Reports, or in recent years, in scientific papers listed in these reports. Very little information, however, has been forthcoming concerning the performance of Town Supply Dairy Farmers and although their relative contribution to total dairy production in this country is small, it is nevertheless significant. Moreover it is a high cost, specialised sector of the farming industry deserving the attention of researchers as to methods which could lead to improvements in its efficiency.

It was with these points in mind that this pilot study concerned with reproductive efficiency in Town Supply Dairy Herds was undertaken, and it is the substance of this study that is reported in this thesis.

LITERATURE REVIEW

Although there are various methods that can be used to describe reproductive efficiency, calving interval is the most important and is the parameter influenced by all the other measures.

CALVING INTERVAL

Calving interval is defined as the period between two consecutive calvings for any one animal. There is now substantial evidence demonstrating that a calving interval of 365 days is ideal for yielding maximum profit from the dairy herd. The effect is on both milk and calf production as illustrated in Table I below:

TABLE I: ECONOMIC EFFECT OF CALVING INTERVAL IN A 40 COW HERD
(Zemjanis *et al.*, 1969)

	Average calving interval in months			
	12	13	14	15
Pounds of milk/cow/year	12,800	12,670	11,560	10,992
Profit				
Labour income/year	\$7,497	\$7,300	\$6,018	\$5,395
Hourly wage	2.52	2.49	2.10	1.89
Number of calves born/year	40	37	34	32

Similar findings have been reported by many other authors (Sanders, 1927; Milk Marketing Board (MMB), 1965, 1969a, 1969b, 1975; Speicher and Meadows, 1967; Louca and Legates, 1967, 1968; Blaxter, 1971; Pelissier, 1972, 1976; Esslemont, 1974b; Lauderdale, 1974; Britt, 1975). It is possible that even greater profit would be obtained with calving intervals shorter than one year; the Milk Marketing Board (1969b) for example reported a peak annual milk production with a calving interval of about 350 days and Esslemont (1974b) and Esslemont and Eddy (1976) described calving intervals of 355-365 days as giving the highest milk yields. In both reports however, calving intervals less than those mentioned above led to a depression in milk production. More

recently the Milk Marketing Board (1975) has reported that maximum 305 day milk yields were obtained where the calving interval was 365 days - with shorter calving intervals yield was depressed. Calving intervals longer than 365 days did not result in increased milk yields.

Several reports indicate that there is a wide range in calving intervals between different groups of animals surveyed (see Table II) and while a calving interval of 365 days (or slightly less) may be optimal, most studies indicate that the average level of performance being achieved is nearer to 395 days (Table II).

Seasonal Supply Dairy Herds in both New Zealand and Ireland are an exception since calving intervals of 364 and 363 days respectively have been reported (Macmillan and Moller, 1975, 1977; Cunningham et al., 1976).

Days Open (Calving to Conception interval)

This is the period between parturition and when the cow conceives. It is highly correlated with the calving interval (Everett et al., 1966; Olds and Cooper, 1970a; Slama et al., 1976) as the average gestation length of 281.9 days has a standard deviation of only ± 4.5 days (Macmillan and Curnow, 1976a). Since the calving interval is equal to the summation of days open and gestation length (Everett et al., 1966; Lineweaver and Spessard, 1975) it follows that the average cow should become pregnant on approximately the 83rd day after calving if a 365 day calving interval is to be maintained. Many reports however indicate that the number of days open is in excess of this (Everett et al., 1966 - 107 days; Morrow et al., 1969a - 109 days; Velasco, 1971 cited by Vaccaro, 1973 - 107 to 120 days; Spalding et al., 1975 - 116 days).

Days open is equal to the sum of the calving to first service interval and the interval from first service to conception. To estimate the date of conception either an accurate pregnancy test must be made or calving information obtained after the date(s) of service. Non return rate information could be used but has the

TABLE II: CALVING INTERVAL REPORTED BY NUMEROUS RESEARCHERS

Reference	Calving Interval (days)
Bozworth <u>et al.</u> , 1972	395
Carley, 1972 cited by Spalding <u>et al.</u> , 1975	395
Cunningham <u>et al.</u> , 1976	363
Esslemont, 1974a	395
Everett <u>et al.</u> , 1966	387
Gaines and Palfrey, 1931	395
Herschler <u>et al.</u> , 1964	395
Legates, 1954	406
Lewis and Horwood, 1950a	401
Louca and Legates, 1968	395
Macmillan and Moller, 1975	364
Matsoukas and Fairchild, 1975	401
Milk Marketing Board, 1976	395
Milk Marketing Board, 1971 and 1975	388
Miller cited by Morrow <u>et al.</u> , 1969a	382
Morrison and Erb, 1957	413
Morrow, 1970	395
Olds and Cooper, 1970a	382
Pelissier, 1972 and 1976	395
Rennie, 1956	413
Slama <u>et al.</u> , 1976	396
Spalding <u>et al.</u> , 1975	396
Spike, 1973	395
Spike and Meadows, 1973	395
Webb <u>et al.</u> , 1974	395
Whitmore <u>et al.</u> , 1974	395

serious disadvantage of introducing more errors (see later under section concerned with conception rate, page 13). Days open provides a relatively accurate measurement of reproductive performance before an animal calves but has the disadvantage of not taking account of losses which may occur during a pregnancy after the estimate is actually made. Calving interval however takes account of all such factors.

Calving to First Service Interval

This is the interval from when an animal calves until she is next bred. While basically this depends on the resumption of cyclical activity after parturition (see later - page 13) management decisions as to when first breeding should take place and the efficiency of oestrous detection can have a marked influence.

In the past a number of workers advanced the view that breeding problems resulted from mating early in the postpartum period (Hofstad, 1941; Van Demark and Salisbury, 1950; Morrison and Erb, 1957) and a common recommendation was not to breed until the sixtieth post partum day (Van Demark and Salisbury, 1950; Shannon et al., 1952; Trimberger, 1954; MMB, 1969b; Boyd, 1970; Morrow, 1970; Esslemont, 1974a, 1974b). Recent evidence however demonstrates no ill effects from early post partum breeding (Trimberger, 1954; Olds and Cooper, 1970b; Whitmore et al., 1974) and a number of researchers advocate breeding earlier than 60 days post partum in order to try and achieve a 365 day calving interval for the herd (Touchberry et al., 1959; MMB, 1969b; Olds and Cooper, 1970b; Bozworth et al., 1972; Lauderdale, 1974; Harrison et al., 1974, 1975; Britt, 1975; Matsoukas and Fairchild, 1975; Slama et al., 1976; Pelissier, 1976). Macmillan (1972a) in New Zealand, because of the current emphasis on concentrating calving under seasonal dairying conditions, has suggested that cows be bred, irrespective of the post partum period that has elapsed, if the mating season has commenced. Although it is well established that a lower conception rate will be obtained with cows bred during this early post partum period (Hofstad, 1941; Van Demark and Salisbury, 1950; Shannon et al., 1952; Trimberger, 1954; New Zealand Dairy Board (NZDB), 1961; Britt, 1975) individual animals in the herd will have more opportunities to become pregnant than if breeding is delayed.

A wide variation in calving to first service interval has been reported in the literature (see Table XIX, page 65). It is virtually impossible to achieve 365 day calving intervals when the initial breeding is as delayed as is shown in that table.

First Service to Conception Interval

This is the period from when a cow is first bred until she conceives. Many cows conceive to the initial breeding leading to a first service to conception interval of zero; the average for the herd, however, is inevitably longer than this. The first service to conception interval reported by a number of researchers is shown in Table III.

TABLE III: FIRST SERVICE TO CONCEPTION INTERVAL REPORTED BY VARIOUS RESEARCHERS

Reference	1st service to conception (days)
Carman, 1955	28.0
Chapman and Casida, 1935	30.0
Esslemont and Eddy, 1976	24.4
Everett <u>et al.</u> , 1966	29.0
Matsoukas and Fairchild, 1975	33.6
Olds and Cooper, 1970a	19.8
Pou <u>et al.</u> , 1953	52.0
Slama <u>et al.</u> , 1976	33.0
Sonderegger and Schurch, 1977	30.0
Touchberry <u>et al.</u> , 1959	36.1

There are problems in measuring the date of conception accurately when a cow conceives, as indicated earlier. Although this parameter reflects only one of the two components of days open, it is an important measure of fertility once breeding after parturition has begun. There is an inverse relationship between calving to first service and first service to conception intervals; thus Touchberry et al. (1959) and the Milk Marketing Board (1967a) recorded that as

the calving to first service interval increased up to 127 and 125 days respectively, the first service to conception interval decreased to a minimum with little change thereafter.

Factors Affecting Days Open

a. Heat Detection

Many workers agree that accurate heat detection is of major importance for efficient reproduction (Chapman and Casida, 1934; Zemjanis et al., 1969; Boyd, 1970; David et al., 1971; Bozworth et al., 1972; Esslemont, 1974a, 1974b, 1974c; Foote, 1975; Barr, 1975; King et al., 1976; Macmillan, 1976a; Pelissier, 1976; Wood, 1976a). Poor heat detection may result from wrong identification of animals and errors in diagnosis so that heat is either missed or incorrectly thought to be present (Macmillan, 1976b). Recognition of stage of oestrus is also important if presentation for breeding is to take place at the most effective time. With the exception of animals which are incorrectly submitted for their first breeding when not in heat, and are then submitted when they are in heat, where no detrimental effect on fertility occurs according to Macmillan et al., (1977a), poor heat detection prolongs the days open and lengthens the inter-service interval. Efficient heat detection is associated with:

- i. Intensity of heat - cows showing marked behavioural changes during oestrus and standing readily for other cows to mount them are more easily recognised than those which show weak behavioural signs (Lee, 1953; Rollinson, 1963 cited by Esslemont and Bryant, 1974).

There are many references in the literature referring to the relatively high incidence of 'silent heat' in high producing cows (Murray, 1943; Meek, 1961 cited by Morrow, 1969a, 1969b), nursed cows (Wiltbank and Cook, 1958; Saiduddin et al., 1967a, 1967b; Moller, 1970b) and in cows early in the post partum period (Casida and Wisnicky, 1950; Kidder et al., 1952; Zemjanis, 1961; Labhsetwar et al., 1963; Marion et al., 1968; Morrow et al., 1969a; Morrow, 1969; Moller, 1970b). What is meant by 'silent heat'

however is not clearly defined and it seems probable that 'weak heat' and 'silent heat' are often being used in the same context. If this is the case difficulties in recognition of heat are likely to be considerable in cows under conditions mentioned above.

- ii. Duration of heat - this has been reported as being related to age, breed, level of feeding, presence of the bull and general state of health (Wishart, 1972). Clearly there is a greater chance of detecting oestrus where cows show signs of heat for a longer period (Macmillan and Watson, 1975b).
- iii. Method of detection - higher detection rates have been observed where marker bulls (Donaldson, 1968; Macmillan, 1972b, 1976b) or heat mount detectors (Baker, 1965; Boyd and Hignett, 1968; Elving, 1969; Thatcher et al., 1971 and Wells and Adams, 1972 cited by Esslemont 1974c; Foote, 1975) are used rather than depending on visual observation unless the latter can be carried out continuously (Williamson et al., 1972a). Testosterone treated cows (Kiser et al., 1977) and tail painting (Macmillan and Curnow, 1977b) have both been described as being as efficient as marker bulls for detecting cows in heat; the latter is a particularly convenient and low cost technique.

Various workers have cautioned that where devices to aid heat detection are used they must be used correctly (Macmillan, 1972b, 1976b; Williamson et al., 1972a; Foote, 1975); continuous observation by farm workers on the other hand has serious practical limitations.

- iv. Frequency, length and time of observation - more cows can be detected by increasing the frequency at which observations are made (Hall et al., 1959; Donaldson, 1968; Esslemont, 1974c; Fielden et al., 1976) and by increasing the time spent at each observation period (Williamson et al., 1972a; Esslemont, 1974c; Fielden et al., 1976). The time

during the day when observations are carried out is also important; Donaldson (1968), Lauderdale (1974), Esslemont (1974c) and Esslemont and Bryant (1976) for example found that early morning and late evening resulted in a higher level of detection than when observations were made at other times. Esslemont (1974a) stressed the importance of not only the selection of the correct time and duration but also the spread of observation periods if short heats were not to be missed. The intensive feeding period which follows milking, particularly under pasture grazing conditions, is not a satisfactory time for observations to be made, and inspections are better carried out at times that follow periods of intensive grazing activity (Williamson et al., 1972b; Foote, 1975; Esslemont and Bryant, 1976).

Many of the points outlined in (iii) and (iv) are shown in Table IV.

- v. Ability and interest of observer - the observer must be both skilled and conscientious in recognising the signs of heat in animals under his care, and it has been suggested that some form of incentive for the observer increases the interest and the efficiency of detection (Esslemont, 1974c; Fielden et al., 1976).

- vi. Shed and yard design - this should be arranged in such a way that the observer(s) can readily identify animals in heat (Edgson, 1970; Esslemont, 1974c; Fielden et al., 1976). Even under pasture grazing conditions as in New Zealand, where cows spend only relatively short periods in the milking unit, certain milking shed designs, particularly where a pit is involved and labour is working at a lower level than the animals, lead to difficulties in recognising cows which have been marked by a bull as being in heat (Fielden, E.D. - personal communication).

TABLE IV: EFFICIENCY OF VARIOUS METHODS OF OESTROUS DETECTION
OBSERVED BY DIFFERENT RESEARCHERS

Method of detection	Percentage correctly identified in oestrus	Reference
Continuous 24 hour observation	98-100)	Donaldson, 1968
Observed thrice daily	81-91)	
Observed twice daily	81-90)	
Marker bulls	98-100)	
Continuous 24 hour observation	98-100)	Williamson <u>et al.</u> , 1972a
Heat mount detector	90)	
Observed during daily routine activities	56)	
Observed four times daily for $\frac{1}{2}$ hour	84)	Esslemont, 1974c
Observed three times daily for $\frac{1}{2}$ hour	81)	
Observed three times daily for $\frac{1}{4}$ hour	69)	
Marker bulls (continuous exposure to cows on pasture)	80)	Foote, 1975
Marker bulls (2) exposed to cows yarded for one hour at 0600 and 1800 hours daily	87)	
Observed by herdsman for $\frac{1}{2}$ hour at 0800 and 1700 hours daily	72)	

- vii. Herd size and number of cows per labour unit - with increasing herd size heat detection errors become more prevalent (Hewett, 1968; Macmillan and Watson, 1971; Lauderdale, 1974; Esslemont, 1974c; Macmillan, 1975b). This is probably associated with the increase in cows per labour unit that tends to occur in larger herds (Smith, 1969; Bevan, 1970 cited by Esslemont, 1974c; King, 1972; Hodgson, 1973 cited by Lauderdale, 1974) and to some degree to the quality of the hired help necessary in such large herds.
- viii. Accuracy of records and use of rectal palpation as a means of predicting heat - careful recording of pre-mating heats (Zemjanis, 1961; Zemjanis et al., 1969; Morrow, 1969; Lineweaver and Spessard, 1975) and prediction of heat by rectal palpation of the ovaries and genital tract during routine examinations (Morrow, 1969; Zemjanis et al., 1969) both act as a guide to the farmer for more careful observation of animals for heat over specified periods of time.
- ix. Synchronisation procedures - enucleation of the corpus luteum was formerly used as an aid to both induction and detection of heat in cows when such a structure was present (Zemjanis et al., 1969; Vandeplassche, 1976). Because of problems associated with haemorrhage and adhesions this procedure has now gone out of favour (Vandeplassche, 1976). Of recent years luteolytic substances such as the prostaglandins or their analogues have been used to synchronise oestrus in cycling cows (Rowson et al., 1972; Lauderdale, 1974; Macmillan, 1976b; Macmillan and Curnow, 1976b; Day, 1976; Roche, 1976). Progestagens have been used for a similar purpose (Zimbleman et al., 1970) but generally with less success. Although there is a cost associated with these procedures there may be husbandry situations under which their use as an aid to heat detection could be justified (Macmillan, 1976b; Esslemont et al., 1977). In certain circumstances synchronisation procedures

such as these, followed by fixed time inseminations, have been suggested as a means of overcoming heat detection problems entirely (Esslemont et al., 1977; Wishart et al., 1977).

While many non visual methods for detecting heat in cows have been described e.g. fern leaf patterns in vaginal and cervical mucus (Lamond and Shanahan, 1969; Linford, 1974 cited by Foote, 1975), vaginal cytology (Hansel, 1959 cited by Foote, 1975), hormonal changes in blood and milk (Hansel and Echterkamp, 1972; Heap et al., 1973; Laming and Bulman, 1976; Bulman, 1976), and endoscopy (Wishart, 1972; Esslemont and Bryant, 1974), these have generally been confined to research investigations and have to date not become available for practical field use.

b. Interval to the First Post Partum Oestrus

Although factors which affect puberty have an important influence as to when an animal can be first bred, the literature in respect to puberty has not been surveyed since the investigation which was undertaken and reported in this thesis was confined to cattle which were all parous and had entered the milking herd. The period between calving and the first post partum oestrus (return to heat) however is of the utmost importance because of its effect on days open (Bozworth et al., 1972; Lauderdale, 1974; Pelissier, 1976; Wood, 1976b). A wide variation in the period before cows return to heat after calving has been described (Table V).

Useful reviews which consider uterine involution and post partum ovarian activity in cattle have been contributed by Morrow et al., (1969b) and Moller (1970a). Return to heat is influenced by:

- i. Age - although some authors have reported no significant effect of age on return to post partum oestrus (Clapp, 1937; Butch et al., 1955; Warnick, 1955; Morrow et al., 1966, 1969a; Morrow, 1969), many authors indicate that the post partum oestrous interval is comparatively longer in younger growing animals than in their older herd mates (Casida and

TABLE V: CALVING TO FIRST POST PARTUM OESTROUS INTERVAL IN
DAIRY CATTLE REPORTED BY VARIOUS RESEARCHERS

Reference	Post partum oestrous interval (days)
Butch <u>et al.</u> , 1955	33.0
Carman, 1955	55.4
Casida and Venzke, 1936	40.7
Casida and Wisnicky, 1950	60.4
Chapman and Casida, 1935	59.0
Clapp, 1937	46.4
Foote and Petersen, 1968	28.0
Graves <u>et al.</u> , 1968	54.0
Hall <u>et al.</u> , 1959	38.4
Herman and Edmundson, 1950	57.0
Higaki <u>et al.</u> , 1959 cited by Morrow <u>et al.</u> , 1969b	76.3
Hurst, 1959	21.0
Labhsetwar <u>et al.</u> , 1963	21.0
Menge <u>et al.</u> , 1962	32.4
Moller, 1970b	36.0-52.0*
Morrow, 1969	15.0
Olds and Seath, 1953	32.1
Olds <u>et al.</u> , 1949	30.0
Trimberger, 1956	50.2
Whitmore <u>et al.</u> , 1974	39.0
Wiltbank and Cook, 1958	54.0
Wickersham and Schultz, 1963	43.3
Velasco, 1971 cited by Vaccaro, 1973	43.0-69.0 (range)

*Refers to first post partum ovulation (not necessarily accompanied by overt heat); the longer interval refers to two year and three year old cows, the shorter to adult cows.

- Wisnicky, 1950; Herman and Edmundson, 1950; Wiltbank and Cook, 1958; Menge et al., 1962; Young, 1965; Tennant et al., 1967). Under New Zealand conditions Moller (1970b) reported that the first post partum ovulation occurred in four year and older milking cows at around 36 days post partum and in two and three year old cows at around 52 days post partum. It is likely that the interval to the first post partum oestrus also shows a similar variation between these age groups.
- ii. Suckling and frequency of milking - suckling tends to lengthen the interval to first oestrus compared with cows milked twice daily (Clapp, 1937; Wiltbank and Cook, 1958; Lyn et al., 1966; Saiduddin et al., 1967a, 1967b; Graves et al., 1968; Moller, 1970b; Morrow et al., 1969a; Oxenreider and Wagner, 1971; Randel et al., 1976); multiple suckling (i.e. more than one calf suckled per cow) and increasing the frequency of milking delays the return to heat even further (Moller, 1970b; Bellows et al., 1974; Kaiser, 1976; Wettemann et al., 1976).
- iii. Season - while Herman and Edmundson (1950), Warnick (1955), Wiltbank and Cook (1958) and Morrow (1969) found no significant influence of season on return to heat, other authors reported delays in return to heat, both where hot humid (Carman, 1955; Branton et al., 1961; Stott and Williams, 1962; Hafez, 1965; Gangwar et al., 1965; Vaccaro, 1973; Thatcher, 1974) and cold winter (Joubart, 1954b; Butch et al., 1955; Branton et al., 1974) conditions prevailed. Although in some instances this seasonal effect could be related to scarcity of feed (Joubart, 1954a) or lowered food consumption (Kelly and Hurst, 1963; Van Heerden, 1963; Gangwar et al., 1965) the mechanism by which season influences reproductive activity in this way in cattle is not clear.
- iv. Level of production - many workers have recorded that high producing cows take longer to return to heat following calving than do lower producing animals (Lewis and Horwood, 1950a;

Olds and Seath, 1954; Marion and Gier, 1968; Morrow, 1969; Oxenreider and Wagner, 1971; Whitmore et al., 1974). Gaines (1927), Eckles (1929), Clapp (1937), Herman and Edmundson (1950) and Carman (1955) however found no significant correlation between the interval from calving to first heat and milk production. More equivocal is the relationship between production and fertility which is dealt with later in this literature review.

- v. Inbreeding - several authors have described the depressing effect of inbreeding on reproductive performance, including a lengthening of the interval from parturition to the first post partum heat (Hawk et al., 1955; Mares et al., 1961; Gaines et al., 1966). Outbreeding can be used to overcome such problems (Robertson, 1949; Rollinson, 1955; Bonadonna et al., 1966; Pearson and McDowell, 1968).

- vi. Nutrition - there are a large number of reports indicating that low levels of nutrition (Joubart, 1954b; McTaggart, 1961; McClure, 1961, 1965, 1968; Saiduddin et al., 1968; McDonald, 1969; Rakha and Igboeli, 1971; Davey, 1976; Halford, 1976), especially during the periparturient period, delay the time to the first post partum oestrus (Turman et al., 1964; McClure, 1970; Falk et al., 1975). Under New Zealand conditions a clear association has been established between liveweight just before calving (or just before breeding in the case of maiden heifers) and submission rate (submission rate is generally defined as the percentage of cows mated within the first 28 days of the breeding season); thus animals of low body weights have poorer submission rates largely as a result of their slow return to heat after calving (Fielden et al., 1976; Moller, 1978).

Both pre and post partum levels of nutrition seem to be important in causing such delays in return to heat (Whitman, 1977) although there is some evidence to suggest that pre partum nutrition and condition of the animal have a dominant effect on the post partum interval whereas early

post partum levels of nutrition, while influencing this interval, have a more significant effect on conception rate (Wiltbank et al., 1962, 1964; Dunn et al., 1969; Grainger, 1978).

While quantitative and qualitative nutritional levels clearly appear to influence return to heat after calving (Reid, 1949; Morrow, 1976; Kaiser, 1976; Whitman, 1977) as well as other aspects of reproductive performance, the exact relationship between these levels and liveweight, liveweight change, blood glucose levels, body condition and reproduction are as yet poorly defined in cattle (Broster, 1973; Downie and Gelman, 1976).

- vii. Abnormalities at parturition - many workers have described an increase in the interval between calving and return to heat when cattle have experienced difficulties such as dystocia, retained foetal membranes and other peri parturient diseases (Butch et al., 1955; Morrow et al., 1966, 1969a; Morrow, 1969; Pelissier, 1976).

- viii. Post parturient disease conditions - infectious conditions of the tubular genital tract, ovarian tumours and cystic ovarian disease may all prolong the period before an animal returns to normal cyclical activity after calving (Hancock, 1948; Morrow, 1969; Roberts, 1971).

Live Calf Rate

Under New Zealand dairy husbandry conditions it is usual to leave the calf with the mother until the second day. While it is possible for calves to die 48 hours or more after birth as a result of problems that have occurred before or at the time of parturition, the majority of losses after 48 hours appear to be due to environmental factors unassociated with the mother (Fielden, E.D. - personal communication). Under dairying conditions in this country therefore, the proportion of calves alive at 48 hours per 100 cows mated, is a reasonable measure of reproductive efficiency. Defined in this way the live calf rate is equal to the conception rate less losses during gestation, parturition and the first 48 hours post partum.

'Conception Rate'

Non return rates (NRR) are frequently used as a measure of 'conception rate' on the basis that animals which have been served and do not return for a further service within a specified period of time are assumed to be pregnant. The specified period of time varies from country to country e.g. in New Zealand a 49 day non return period is used (NZDB, 1961, 1963; Macmillan and Watson, 1973, 1975c; Macmillan, 1975b, 1976a) while in the U.S.A. and Great Britain the period is 60-90 days (Slama et al., 1976; Pelissier, 1976). Although NRR are highly correlated with 'conception rates' NRR are always higher (Spalding et al., 1975; Pelissier, 1976) because of such problems as post service anoestrus in the absence of a conceptus or incomplete records of return to service (Macmillan et al., 1977b).

Pregnancy examinations at an appropriate period after service (often 6-12 weeks) have been used as another method of determining whether 'conception' has occurred. While pregnancy tests in skilled hands are likely to give a more accurate prediction of cows that will actually calve than a NRR, they cannot take account of embryonic losses that occur between the time of fertilisation and the time when the pregnancy examination is actually made. If 'conception rate' is used in the sense that it really means fertilisation has taken place, pregnancy rates underestimate 'conception rates'. Because the rate of embryonic loss differs at the different stages of gestation, being much greater during the first 34 days (Hawk et al., 1955; Hanly, 1961; Olds, 1969), the degree of underestimate of 'conception rates' as judged by pregnancy tests will depend on the time at which the pregnancy examination is made.

'Conception rate' therefore, although widely used in the literature, is a poorly defined term and would be better replaced by terms which describe the technique actually being used in making the estimate e.g. NRR, pregnancy rate, calving rate, etc. A clear illustration of this occurs in Table VI.

a. First service 'Conception rate'

The percentage of animals 'conceiving' to first service for dairy

TABLE VI: FIRST SERVICE 'CONCEPTION RATE' REPORTED BY VARIOUS RESEARCHERS

Reference	Conception rate	Method used
Barret <u>et al.</u> , 1948	58.9%	60-90 day NRR
Bozworth <u>et al.</u> , 1972	56.0%	Not reported
Britt <u>et al.</u> , 1972	55.9%	Pregnancy rate
Crowley <u>et al.</u> , 1967	60.0%	Calving rate
Dale and Smith, 1968	61.6%	Not reported
Donald and Russel, 1968	54.5%	Calving rate
Eckles, 1929	42.7%	Pregnancy rate
Esslemont and Eddy, 1976	52.5%	Pregnancy rate
Esslemont <u>et al.</u> , 1977	54.9%	Pregnancy rate
Foote, 1952 cited by Spalding <u>et al.</u> , 1975	72.3%	60-90 day NRR
Gwazdauskas <u>et al.</u> , 1975	37.9%	Pregnancy rate
Macmillan <u>et al.</u> , 1977a	62.0%	49 day NRR
Milk Marketing Board (MMB), 1967	62.4%	NRR
Milk Marketing Board (MMB), 1969a	63.5%	NRR
Milk Marketing Board (MMB), 1976	68.3%	NRR
Morrow <u>et al.</u> , 1966	58.5%	Pregnancy rate
NZDB, 1961	58.3%	49 day NRR
Olds, 1969	65.0%	Fertilisation rate
Pelissier, 1972, 1976	44.2%	Calving rate
Spalding <u>et al.</u> , 1975))	50.0% 58.0%	Calving rate 60-90 day NRR
Sonderegger and Schurch, 1977	62.0%	Not reported
Stewart, 1973 cited by Esslemont, 1974b	50-55.0%	Pregnancy rate
Tanabe and Salisbury, 1946	48.2%	5 months NRR
Touchberry <u>et al.</u> , 1959	42.5%	Calving rate
Trimberger, 1954	48.7%	Calving rate
Van Demark and Salisbury, 1950	50.8%	Calving rate
Ward, 1940	63.7%	Not reported
Whitmore <u>et al.</u> , 1974	52.0%	Pregnancy rate

cattle, using various methods of estimating 'conception', are summarised in Table VI. This is a very common parameter used for measuring reproductive efficiency. A serious disadvantage is that it gives no further information about the performance of those animals which do not conceive at the initial service.

b. Number of services per 'Conception'

Formerly this was considered as an excellent measure of reproductive efficiency (Carman, 1955; Johansson, 1961; Everett et al., 1966). Since the number of services per 'conception' is inversely related to the post partum interval before breeding commences (Trimberger, 1954; Touchberry et al., 1959; Perkin and Kidder, 1963; Olds and Cooper, 1970b; Britt, 1975) it is possible for a herd with a low services per 'conception' index to have a longer intercalving interval than one with a higher services per 'conception' index. Thus calving interval would seem to be the more appropriate measure. The number of services per 'conception' recorded in the literature is summarised in Table VII.

c. Return to service interval

In most instances it is the return interval to the first service of the breeding period that is analysed, usually for the purposes of diagnosing a fertility problem, although an analysis can be made of all interservice intervals within a breeding period if required. Return to service information is of most value as an aid to identifying the source of a problem e.g. a high incidence of short return intervals (1-17 days) suggests heat detection errors, a high percentage of long return intervals (25 days or more) either heat detection errors or embryonic death, and a high percentage of normal return intervals (18-24 days) failure of fertilisation associated with semen quality, technician incompetence or incorrect time of breeding (Macmillan, 1970, 1975a, 1975b; Moller, 1976).

'Conception' rate is influenced by many factors:

- i. Post partum interval - it is now universally accepted that the ability of a cow to conceive increases as the post partum period before service lengthens. The rate of increase is

TABLE VII: SERVICES PER CONCEPTION REPORTED BY VARIOUS RESEARCHERS

Reference	Services/conception
Boyd <u>et al.</u> , 1954	1.68
Bozworth <u>et al.</u> , 1972	1.68
Carman, 1955	1.80
Esslemont and Eddy, 1976	1.70
Everett <u>et al.</u> , 1966	1.84
Hollon <u>et al.</u> , 1967 cited by Bozworth <u>et al.</u> , 1972	1.73
Legates, 1954	1.80
Matsoukas and Fairchild, 1975	2.12
Milk Marketing Board (MMB), 1969b	1.59
Milk Marketing Board (MMB), 1967	1.64
Morrison and Erb, 1957	2.01
Morrow <u>et al.</u> , 1969a	1.84
Norwood, 1963	2.11
Olds and Cooper, 1970b	1.68
Olds <u>et al.</u> , 1949	2.26 (cows) 2.57 (heifers)
Pelissier, 1972, 1976	2.44
Slama <u>et al.</u> , 1976	1.95
Tanabe and Salisbury, 1946	2.07
Touchberry <u>et al.</u> , 1959	2.28
Trimberger, 1954	1.69
Van Demark and Salisbury, 1950	1.97

greatest up to the 60th post partum day and only small improvements are generally noted after that point e.g. cows inseminated at less than 30 days had a first service NRR of 31.3% increasing to 62.0% when inseminated at 60-90 days post partum and to 62.9% above 120 days post partum (NZDB, 1961). Many other authors describe similar types of results (Van Demark and Salisbury, 1950; Touchberry et al., 1959; Graves et al., 1968; MMB, 1969b; Britt, 1975).

There appears to be an important relationship between 'conception' rate and the number of open heats a cow has had before she is bred (Whitmore et al., 1974). Animals which had only one heat and then were bred after 74 days post partum had a pregnancy rate of 35.3%, those with two open heats 50% and those with three open heats 73.1%. Trimmerger (1954) reported that for animals bred within 60 days post partum, there was a distinct fertility advantage if they had an open heat before service; for animals bred after 60 days post partum an open heat appeared to have little effect. The number of animals on which the conclusions were based however, was small. While the NZDB (1963) has stated that length of time since calving rather than the number of pre-mating heats is more important in obtaining high non return rates, the definitive experiment to determine which has the most effect, post partum interval before breeding or open heats before breeding, does not yet appear to have been done.

There also appears to be an age effect in respect to the relationship between post partum interval and fertility since two year old cattle had better non return rates when mated within a relatively short period after calving than did the older cows (NZDB, 1963).

- ii. Semen quality and inseminator skill - clearly the quality of the semen inseminated, either by the bull or by an inseminating technician, will affect 'conception rate'. While many factors such as the health of the sire and methods used in collecting, processing and storage of semen all affect its quality (Salisbury and Van Demark, 1961), the major differences between sires in 'conception rate', at least under

conditions where disease control is at a high level as in an Artificial Breeding Centre, appear to be associated with sperm survival and fertilisation rate (Macmillan and Watson, 1975c; Macmillan and Curnow, 1977a).

Although the incidence of technical incompetence in New Zealand appears to be low, instances do occur where very poor 'conception rates' are attributable to the inseminating technician. Generally however the differences in 'conception rates' observed between inseminators are associated with factors beyond their control (Macmillan, 1975a).

- iii. Correct time to breed - several studies have indicated that highest 'conception rates' are obtained when cows are bred in standing heat (Hahn, 1959; Whitmore et al.; 1974, Macmillan and Watson, 1976). Macmillan (1976b) found that the quality of semen being used was also important; with high quality semen best results were obtained when breeding took place during mid and late oestrus (still standing heat) whereas with low quality semen best results were obtained with breedings during the late and post oestrous periods. Thus efficient heat detection and recognition of the stage of oestrus are necessary to present the animal for breeding at the correct time if high 'conception rates' are to be achieved.

- iv. Cow age - although Slama et al. (1976) reported no effect of age on fertility as determined by intercalving interval, other authors reported lowest 'conception rates' in younger cows (two and three years of age), and highest conception rates have been recorded in cows four to seven years of age (Jones et al., 1941; Lasley and Bogart, 1943; Trimberger and Davis, 1945; Tanabe and Salisbury, 1946; Olds et al., 1949, 1952; Herman, 1956; Morrison and Erb, 1957; Boyd and Reed, 1961; NZDB, 1961; Salisbury and Van Demark, 1961; Everett et al., 1966; MMB, 1970, 1971; Spike and Meadows, 1973; Spalding et al., 1975; McDowell et al., 1976). After the age of seven years 'conception rates' show a tendency to decline. Koger et al. (1962) and Young (1965) working with beef cattle, suggested that the poor fertility

observed with young animals was associated with inadequate feeding and poor body condition brought about by their continued requirements for growth as well as the demands for lactation.

- v. Season - many workers report an effect of season on 'conception rate'. Poor 'conception rates' have been associated with hot humid conditions (Seath and Staples, 1941; Branton et al., 1955, 1956, 1974; Fryer et al., 1958; Hillen and Rupel, 1960; Stott, 1961; Stott and Williams, 1962; Poston et al., 1962; Labhsetwar et al., 1963; Gangwar et al., 1965; Hafez, 1965; Ulberg and Burfening, 1967; Britt and Ulberg, 1970; Stott et al., 1972; Gwazdauskas et al., 1973, 1975; Ingraham et al., 1974; Thatcher, 1974; Thatcher et al., 1974) while thermal stress has been reported to delay puberty, cause anoestrus and depress the length, duration and intensity of oestrus (Branton et al., 1961; Van Heerdin, 1963; Hafez, 1965; Dunlap and Vincent, 1971; Vaccaro, 1973; Thatcher, 1974; Gwazdauskas et al., 1975). Salisbury and Van Demark (1961) reported that temperature and humidity were particularly deleterious in tropical areas whereas increasing daylight length, according to Mercier and Salisbury (1947a and 1947b), became more important as a stimulus to fertility in cooler regions. Morrison and Erb (1957) and Kelly and Hurst (1963) have suggested a similar relationship.

Not all authors have reported significant effects on fertility that could be associated with season (Wiltbank and Cook, 1958; Armstrong, 1964 cited by Everett et al., 1966; Slama et al., 1976). In the case of the report by Slama et al. (1976) the herd was managed to calve between the months of July and January thus limiting the opportunity for recognition of any seasonal effect.

- vi. Nutrition - while overfeeding associated with obesity has been reported to increase breeding difficulties (Reid, 1959; Hansen and Steensberg, 1950 cited by Olds, 1953) there is a

more substantial body of evidence demonstrating that low levels of nutrition preceding and during the breeding period depress 'conception rate' (McClure, 1961, 1964, 1968, 1970; Wiltbank et al., 1962, 1964; Warnick et al., 1967; King, 1968; Ward, 1968; Schilling and England, 1968; Dunn et al., 1969; Lamond, 1970; Moller and Shannon, 1972; Axelsen and Morely, 1976; Rowlands et al., 1977; Youdan and King, 1977; Grainger, 1978).

Considerable interest has been shown in many countries in dietary supplementation to enhance fertility (McClure, 1968 in Australia; Payne et al., 1970 in Great Britain; Oxenreider and Wagner, 1971 in the USA; Scales, 1974 in New Zealand; Garden and MacDonald, 1975 in Scotland). Never-the-less, provided the normal demands for growth and production are being met, there is little evidence to suggest that dietary supplements over and above those needed to meet these demands increase fertility in any way (Reid, 1949; Boyd, 1970). Level of nutrition is clearly related to liveweight, liveweight change, blood glucose levels and body condition and while many attempts have been made to relate these factors to fertility (Speth et al., 1962; King, 1968; McClure, 1968; Lamond, 1970; Payne et al., 1970; Oxenreider and Wagner, 1971; Downie and Gelman, 1976; Rowlands et al., 1977; Youdan and King, 1977; Grainger, 1978) the inter-relationships are complex and as yet poorly defined in cattle (Boyd, 1972; Broster, 1973; Downie and Gelman, 1976; Whitman, 1977).

- vii. Level of milk production - there is marked disagreement between authors concerning the relationship between production and 'conception rate'. A number of workers have reported an inverse relationship between level of production and fertility (Lewis and Horwood, 1950a; Rennie, 1956; Miller et al., 1967; Steele et al., 1967; Hewett, 1968; Morrow, 1969; Dawson, 1972; Spike and Meadows, 1973; Wagner, 1974; Spalding et al., 1975). Many of these reports however have been concerned with total

milk production rather than with the level of production prior to and during the actual breeding period. Total production could be significantly influenced by lactation length and by the presence or otherwise of a conceptus (Sanders, 1927; Touchberry et al., 1959; Lee et al., 1961; Smith and Legates, 1962). If this is so, it is conceivable that high production recorded in cows which have poor 'conception rates' is the result rather than the cause of such breeding difficulties. A number of other reports, where 'conception rate' has been related to level of production prior to and during the breeding period, have indicated that any relationship that exists is very small and of little consequence (Gaines, 1927; NZDB, 1961; Boyd et al., 1954; Touchberry et al., 1959; Smith and Legates, 1962; Everett et al., 1966).

viii. Other individual cow factors - apart from those influences that have already been reviewed, developmental abnormalities (some segmental aplasias), functional disorders (delayed ovulation, anovulation and cystic ovarian disease) and infectious diseases of the ovaries and tubular genital tract will all depress 'conception rate'. The incidence of such conditions in New Zealand Dairy Herds, however, has been reported to be low (Fielden et al., 1973).

Losses During Pregnancy

Prenatal losses can have a marked influence on the live calf rate. Very early losses (up to about 16 days after service) have little influence on the interoestrous interval whereas losses after this time result in a prolongation of this interval (Roberts, 1971). The majority of losses occur during the first 34 days after 'conception' (Hawk et al., 1955; Tanabe and Casida, 1949; Casida, 1953 cited by Hanly, 1961; Olds, 1969) and as gestation proceeds the rate of loss decreases markedly. Thus losses between 34-50 days and parturition have been estimated by Casida et al., (1946) cited by Erb and Flerchinger (1954); Fosgate and Smith (1954) cited by Hanly (1961) and Roberts (1971) to be of the order of 6%

whereas total loss, most of which has occurred by the 34th day of gestation, has been reported as being 20-60% (Hawk et al., 1955; Hanly, 1961; Bishop, 1964; Ayalon et al., 1967; David et al., 1971). Reviews of prenatal loss in farm animals have been contributed by Hanly (1961); Bishop (1964); Boyd (1965) and David et al. (1971).

Prenatal loss may be brought about by either genetic or environmental factors (Boyd, 1965). Genetic factors include chromosomal abnormalities (Johansson, 1961; Pakes and Griesmer, 1965; Gustavsson, 1969), incompatibility of zygotes as well as lethal and sub-lethal effects brought about by mutation (Johansson, 1961; Bishop, 1964; Gustavsson, 1969; David et al., 1971) and the results of inbreeding (Hawk et al., 1955; Mares et al., 1961; Conneally et al., 1963; Gaines et al., 1966). The technology of recognising genetic aberrations is still in its infancy, particularly in the larger animals where material for study is difficult to obtain, and the extent to which genetic aberrations contribute to low fertility has yet to be defined (Bruere, A.N. - personal communication). Much of the prenatal loss for which no cause can be ascribed has been suggested by Bishop (1964) as being nature's way of disposing of genetic material which was poorly fitted for survival.

Environmental factors which have been attributed to causing an increase in prenatal loss include:

- a. Temperature - various studies (Hillen and Rupel, 1960; Stott and Williams, 1962, see page 24) indicate that 'conception rates' are lower under hot humid conditions although it is not clear whether the effect is due to failure of fertilisation or embryonic loss. Van Heerden (1963) and Ulberg and Burfening (1967) reported that spermatozoa subjected to high temperatures before fertilisation resulted in non viable embryos after fertilisation had taken place.
- b. Ageing of the gamete - while ageing of sperm in the female reproductive tract leads to failure of fertilisation (Lanman, 1968) the use of aged sperm for insemination has been reported to increase the level of embryonic death (Bishop, 1964; Lanman, 1968). Salisbury

(1967) claimed that sperm which were stored for artificial insemination purposes for five days at 5°C not only lost their fertilising capacity but also increased the incidence of embryonic death.

c. Nutrition - while some specific dietary deficiencies have been reported to be associated with prenatal losses (selenium - Mace et al., 1963; vitamin A - Thomas, 1968; iodine - Allcroft et al., 1954; and copper - Munro, 1957), and ingestion of specific toxic materials in feed such as 'oestrogenic compounds' (Thain, 1967; Dawson, 1970), ergot (Roberts, 1971) and other plant toxins has led to abortion, the effect of plane of nutrition on prenatal loss in cattle remains unclear. Restricted nutrition may influence calf viability at the time of birth (Hight, 1968) as can very high levels of nutrition; in the latter case the problem is generally one of dystocia (Reid et al., 1964; Laster et al., 1973). Edey (1976) reported an increased level of prenatal loss in ewes following both severe under-nutrition and also after very high level feeding.

d. Endocrine disturbance - progesterone deficiency has been suggested as a cause of prenatal loss (Wiltbank et al., 1956; Johnston et al., 1958 cited by Roberts, 1971; Morrow, 1968) and of recent years, the exogenous administration of glucocorticoids for other purposes has inadvertently led to abortion (Welch et al., 1973).

e. Disease - bacterial diseases such as vibriosis, trichomoniasis, brucellosis and leptospirosis, some of the mycoses and a number of viruses (Afshar, 1965; Roberts, 1971) can all interfere with the viability of a developing conceptus. While still present in New Zealand their total contribution to fertility problems in the national dairy herd appears to be small (Fielden, E.D. - personal communication).

Losses During Parturition

Dystocia can be an important cause of calf loss during parturition and in the immediate post partum period. However, since calving difficulties per se were not a part of the investigation reported in this thesis, the literature relevant to dystocia in cattle has not been reviewed.

Peri parturient disease, so commonly associated with difficult parturition, not only results in losses during the peri parturient period (Roy, 1973; Sloss, 1974; Young and Blair, 1974; Appleman and Owen, 1975), but also can have serious implications on subsequent reproductive performance (Morrow et al., 1969a; Kelly and Holman, 1975; Pelissier, 1976). Cows experiencing such problems usually take longer to return to their first post partum oestrus, have a slower rate of uterine involution, require more services per conception and end up with longer calving intervals than herd mates which have not experienced such difficulties (Butch et al., 1955; Morrison and Erb, 1957; Moller et al., 1967; Morrow, 1969; Morrow et al., 1969a; Pelissier, 1972, 1976; Kelly and Holman, 1975; Galton et al., 1977a, 1977b).

MATERIALS AND METHODS

A sample of twenty Town Supply Dairy herds was selected for the study. Herd owners were members of the Wellington Hawke's Bay Livestock Improvement Association which provided herd testing and artificial breeding services. The owners of these herds had indicated their interest and willingness to co-operate in an investigation of reproductive efficiency. Herd size ranged from 75 to 300 cows.

Data were collected from the breeding and production records of these herds held in the Livestock Improvement Association Office spanning a period from 1 January 1972 to 31 October 1976. All information collected was from parous animals. There were 12,056 calvings recorded involving 4050 cows. Of these 9898 were for Friesian, 672 Jersey, 1066 Friesian x Jersey cross cows and the remaining 420 other breeds and crosses.

Copies of the forms onto which the data were extracted appear in Appendix 1. Data were then punched onto cards with one card for each cow.

Abnormal calvings such as abortions were based on the judgement of and record kept by the farmer. The date of 'conception' was estimated by subtracting 282 days from the calving date if service records were not available. In the case of a single service followed by a calving, the service date was accepted as the date of 'conception' provided gestation length fell within the range of 270 - 290 days. Where more than one service had been given, the service to which the animal 'conceived' was taken as that date which fitted closest to a 282 day gestation length. In the case of successive services less than 10 days apart no satisfactory decision could be made and an entry for service to which 'conceived' was not made. That a cow had 'conceived' in this study depended on her calving (whether the calf was live, dead or premature was immaterial). The parameter used was called calving rate,

Apart from the above estimates, where data were missing for the

calculation of a particular parameter the case record was excluded from the analysis. Milk yields where the lactation length was less than 200 days were also excluded. Average daily milk yield was calculated from the total milk yield divided by lactation length.

Age was recorded as at the time of calving; each year was considered as a calendar year except for 1976 when records were only available up to 31 October. Years were divided into four seasons as follows:

Autumn - 1 March to 31 May
Winter - 1 June to 31 August
Spring - 1 September to 30 November
Summer - 1 December to 28 February

Method of analysis

Data collected were placed on individual punch cards (one per cow). A Burroughs B6700 computer was used to categorise and analyse the information. All analyses were carried out using a standard computer programme as described by Nie et al., (1975).

Prior to statistical analysis frequency distributions using raw and transformed data (log and double log transformations) were examined for the following parameters - calving interval, calving to first service, first service to conception and calving to conception intervals.

The method selected for handling the data during analytical procedures was that which gave the distribution which was closest to normal; thus double log transformation was used for calving interval data, and log transformation for first service to conception data. All other analyses were carried out using unadjusted data.

The effect of herd, age, season, year, an abortion and breed on the different breeding parameters, and the effect of herd and age on the lactation yield and length, were investigated by one way analyses of variance.

Since no programme was available which would analyse all variables at the one time (the degrees of freedom varied widely depending on the parameter measured) a series of two way analyses of variance were carried out to determine the percentage of variation contributed by the individual variables (to see the main effects and interaction of the two variables on the different breeding parameters) in that analysis.

The intercalving interval (ICI) is a summation of days from calving to first service (ICSMI), plus days from first service to conception (SCON), plus gestation length. Variation in gestation length was not measured in this study.

An assumption was made that gestation length was unlikely to be as variable a parameter as the other two components. Macmillan and Curnow (1976a) found that the normal gestation length in cows in New Zealand herds mated to Jersey, Friesian and Angus sires averaged 281.9 days with a range of 272 - 293 days. It was therefore treated as a constant (282 days) when an estimate of the relative importance of ICSMI and SCON was made. A path analysis was carried out on these parameters to determine their relationship to each other. The model can be illustrated as follows:



Similarly, the relationship between average daily milk yield, total milk yield and herd size were estimated on days from calving to first service, on first service to conception and on calving intervals.

Chi-square tests as described by Snedecor (1962) were used for the analyses of return intervals, calving rates and submission rates at various post partum intervals (see Tables IX, XI and Figures 4, 5, 7a, 7b and 8). Services per cow calving were calculated from the above conception rate analysis.

RESULTS

The initial section of the results outlines the performance of all twenty herds examined throughout the course of the investigation. Effects of age, year, season, breed and abnormal events in gestation such as abortion are next considered individually. This is followed by an analysis of the relationship and interaction between pairs of the above variables where considered appropriate and finally the inter-relationships between the more important breeding parameters are described.

PERFORMANCE FOR ALL HERDS

The reproductive performance for the sample of twenty Town Supply Dairy Herds together with their average milk yield and lactation is shown in Table VIII. A simplified form of analysis of returns to first service is included in this table. Three of the more important measures of reproductive performance (interval between calvings, interval from calving to first service and number of services per cow calving) have been extracted from Table VIII and shown in the form of a modified histogram in Fig. 1. There were marked differences between herds in all parameters studied ($p < 0.001$).

The distribution of calving intervals from the pooled population of all cows studied is shown in Figs. 2 and 3. Approximately 60% of cows had inter-calving intervals less than 390 days (the mean inter-calving interval for all cows was 383.7 - see Table VIII) with 10% being less than 330 days and 10% more than 460 days.

The rate at which the cows were mated according to the period which had elapsed from calving, together with the first service calving rate obtained at that particular post partum period, is illustrated in Fig. 4. Although the mean interval between calving and first service was 85 days (Table VIII) for all animals in this study, 25.3% of cows had their first breeding by the sixtieth day post partum and 40.3% of them calved to this mating (see Fig. 3).

A detailed analysis of return intervals to first service for all cows recorded and for individual herds is shown in Table IX. While

TABLE VIII: REPRODUCTIVE PERFORMANCE OF TWENTY TOWN SUPPLY DAIRY HERDS IN THE WELLINGTON HAWKE'S BAY LIVESTOCK IMPROVEMENT ASSOCIATION (1972-76)

Breeding parameter	Total count	Total mean	S.D.	Individual herd means																				Significance
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Calving interval (days)**	4537	383.7	335 to 441**	371	388	383	378	380	381	377	394	384	389	392	375	398	395	374	366	378	388	366	391	P < 0.001
Calving to 1st service interval (days)	3613	84.78	40.56	76	93	86	87	81	89	78	80	85	105	89	80	85	98	76	72	83	103	78	84	P < 0.001
Inter service interval (days)	2039	43.68	46.74	26	39	44	36	33	38	44	44	39	37	38	65	60	41	46	48	62	50	27	36	P < 0.001
Days open (days)	4501	106.9	58.57	91	112	106	100	102	103	98	121	107	110	113	101	125	121	99	89	100	110	87	115	P < 0.001
First service to conception interval (days)*	3005	11.34	-2 to +47*	9	11	9	7	7	9	10	18	9	11	14	16	22	10	13	8	7	11	15	25	P < 0.001
Calving rate (1st service)	1783	49.34	-	50	53	56	55	55	52	45	43	55	66	49	38	34	54	44	61	56	48	35	29	P < 0.001
Services per cow calving	3700	1.71	-	1.4	1.7	1.6	1.4	1.2	1.6	1.5	2.4	1.6	1.4	1.8	1.7	2.2	1.5	1.8	1.4	1.5	1.4	1.6	2.1	P < 0.001
Milk yield (litres)+	5960	373	121	311	358	386	291	386	499	349	438	379	407	427	431	361	365	386	388	345	372	290	355	P < 0.001
Lactation length (days)	5960	291	69	296	290	288	297	274	307	292	315	273	280	291	291	297	296	284	289	255	290	277	304	P < 0.001
Percentage of returns to first service																								
1 - 17 days	236	11.6	-	18	18	9	7	0	6	11	16	9	16	5	4	15	8	14	2	6	10	12	24)
18 - 24 days	794	38.9	-	55	35	36	45	48	49	39	40	39	37	49	37	19	47	31	44	38	37	51	37	P < 0.001)
25 - 49 days	488	23.9	-	19	25	29	31	39	23	24	20	26	22	27	25	22	22	23	24	23	19	30	21)
More than 49 days	521	25.6	-	8	22	26	17	13	22	26	23	26	25	20	34	44	23	31	30	33	33	6	18)

+ To obtain milk yield, figures in Table should be multiplied by 10

** Double log transformation used (S.D. - one standard deviation on each side of the mean represents a range from 335 to 441 days)

* Log transformation used (S.D. - one standard deviation on each side of the mean represents a range from -2 to +47 days)

Herd sizes: 75-100 cows - Herds 5, 16, 19, 20.

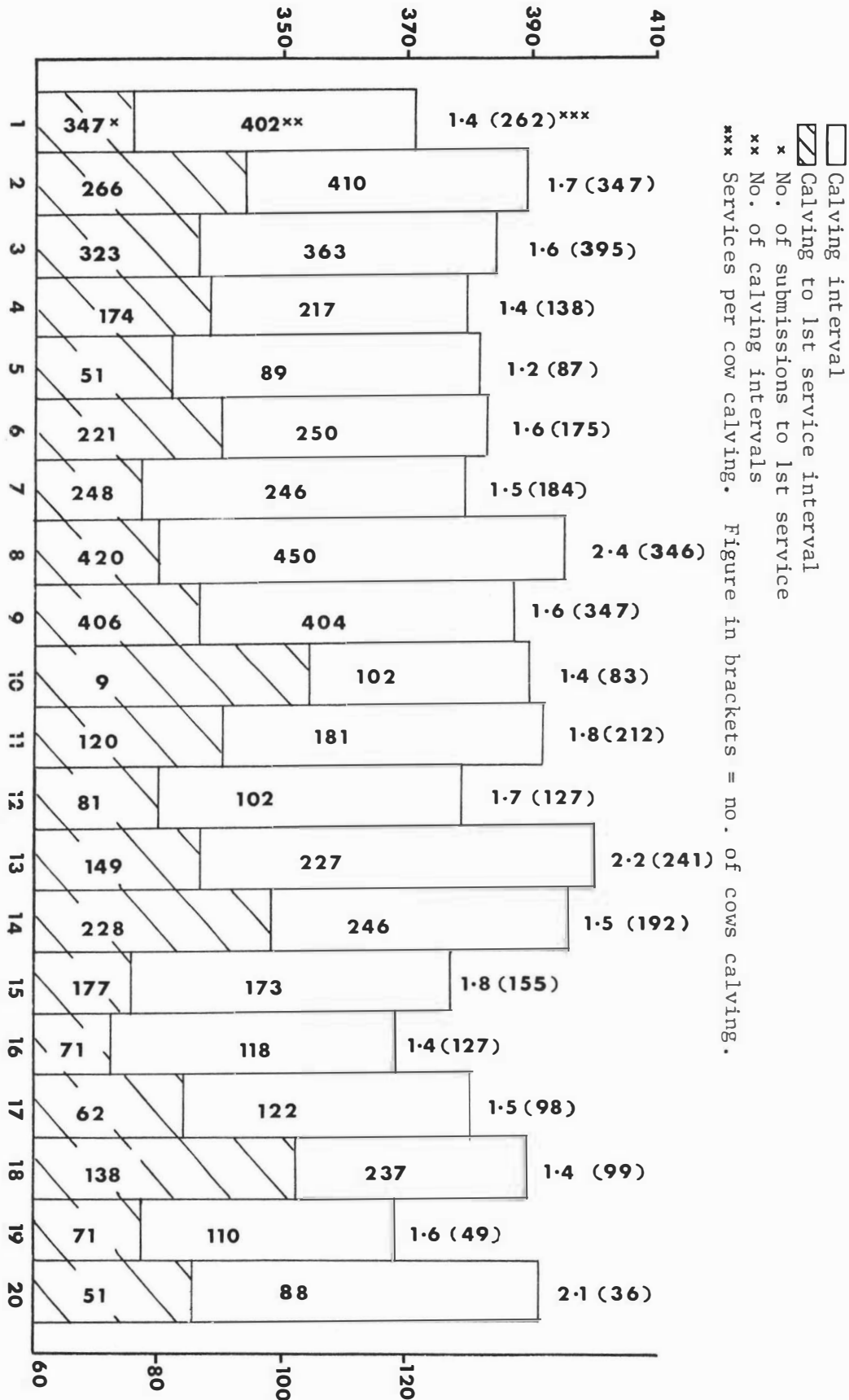
101-200 cows - Herds 4, 6, 7, 8, 9, 10, 11, 12, 14, 15, 17, 18.

201-300 cows - Herds 1, 2, 3, 13.

TABLE IX: RETURN INTERVALS AS A PERCENTAGE OF ALL FIRST SERVICE RETURNS FOR TWENTY TOWN SUPPLY DAIRY HERDS

Return interval (in days)	Total count	Total mean	Herd identification																				Significance
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1 - 7	67	3.3	5	10	2	2	0	0	2	5	3	0	2	0	2	2	3	0	0	2	9	5)
8 - 10	75	3.7	6	3	4	2	0	4	5	4	2	9	3	0	3	3	8	2	2	4	0	8)
11 - 13	33	1.6	1	1	1	0	0	0	2	3	1	6	0	2	4	1	1	0	2	0	3	3)
14 - 17	61	3.0	5	3	2	3	0	3	2	4	3	0	0	1	6	1	2	0	2	4	0	8)
1 - 17	236	11.6	18	18	9	7	0	6	11	16	9	16	5	4	15	8	14	2	6	10	12	24)
18 - 19	191	9.4	12	7	8	15	9	13	8	10	11	9	6	9	7	13	8	6	11	8	12	13)
20 - 21	341	16.7	28	17	15	21	26	23	21	17	16	22	20	14	6	13	14	26	8	15	28	16	P<0.001)
22 - 24	262	12.8	14	12	12	9	13	13	10	14	13	6	22	15	7	22	10	12	19	15	12	8)
18 - 24	794	38.9	55	35	36	45	48	49	39	40	39	37	49	37	19	47	31	44	38	37	51	37)
25 - 33	145	7.1	8	7	5	7	26	1	11	8	11	9	9	0	7	5	8	8	4	4	6	5)
34 - 49	343	16.8	11	18	24	24	13	22	12	12	14	12	17	25	15	17	16	16	19	15	24	16)
25 - 49	488	23.9	19	25	29	31	39	23	24	20	26	22	27	25	22	22	23	24	23	19	30	21)
>49	521	25.6	8	22	26	17	13	22	26	23	26	25	20	34	44	23	31	30	33	33	6	18)

Calving interval in days



□ Calving interval
 ▨ Calving to 1st service interval
 * No. of submissions to 1st service
 ** No. of calving intervals
 *** Services per cow calving. Figure in brackets = no. of cows calving.

Fig. 1: Reproductive Performance in Twenty-Town Supply Dairy Herds

Calving to 1st service in days

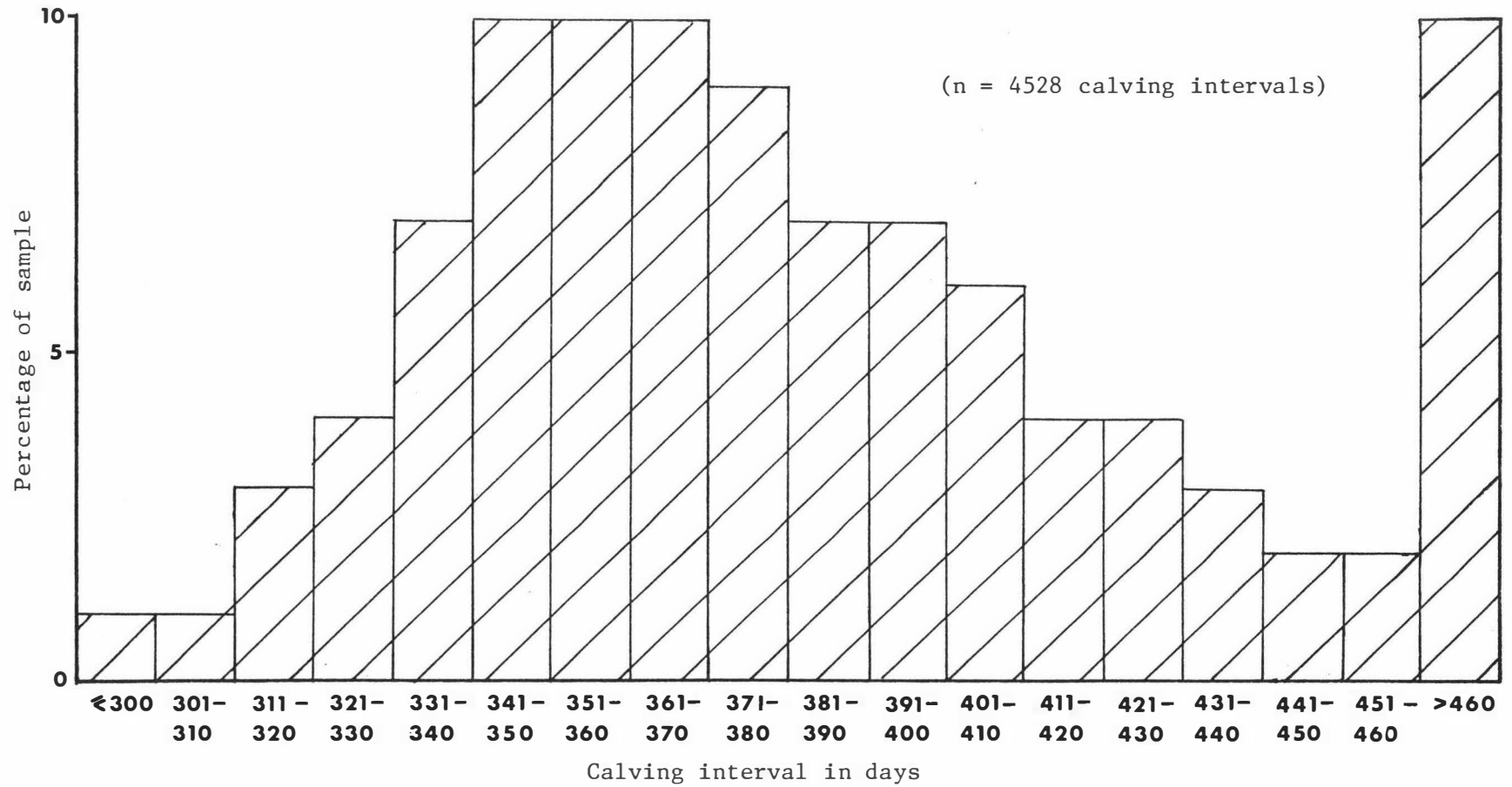


Fig. 2: Distribution of Calving Intervals in Twenty Town Supply Dairy Herds.

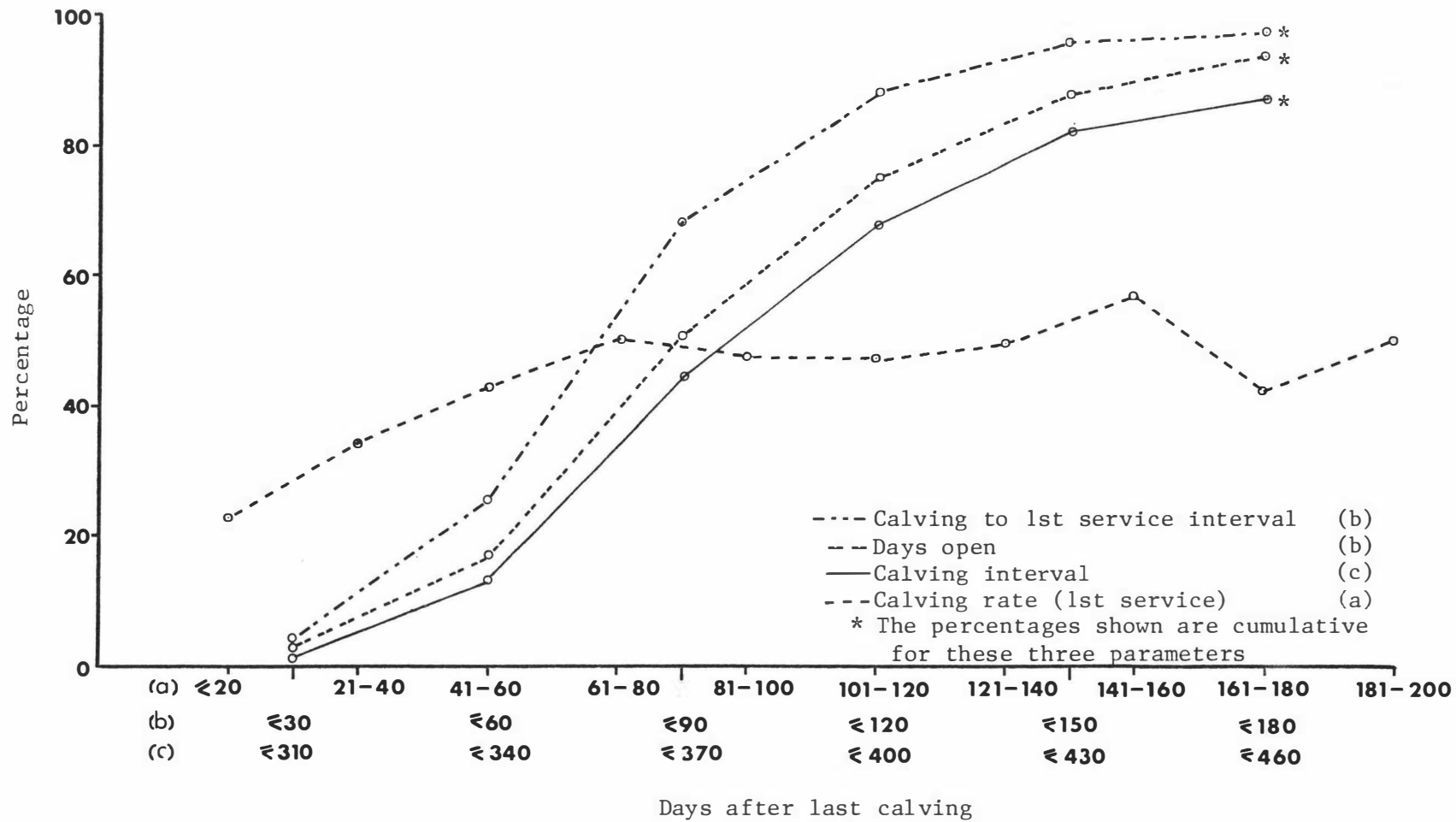


Fig. 3: Frequency Distributions for Four Breeding Parameters at Different Postpartum Intervals in Twenty Town Supply Dairy Herds

▨ % of cows mated (1st service only)
 *Calving rate (1st service only)
 (n = 3544 records)

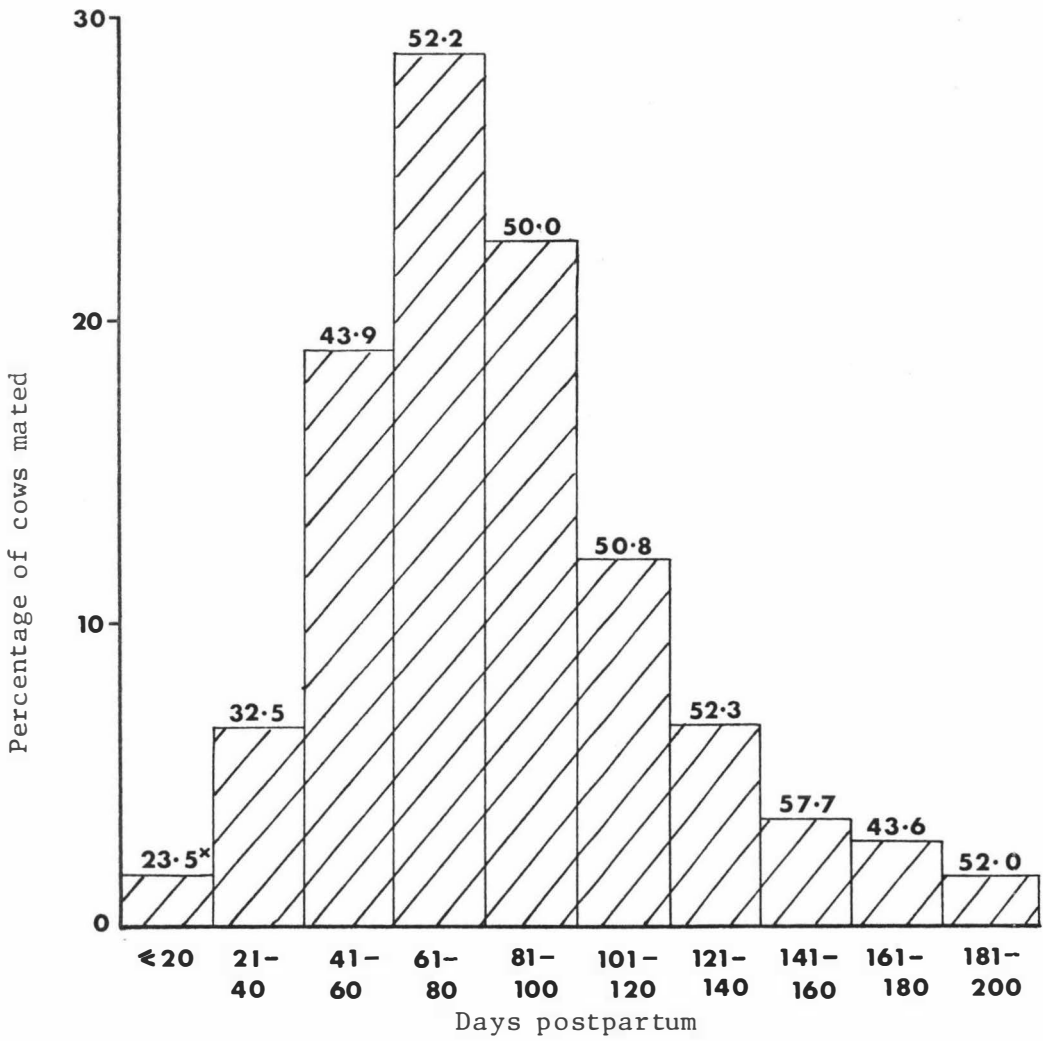
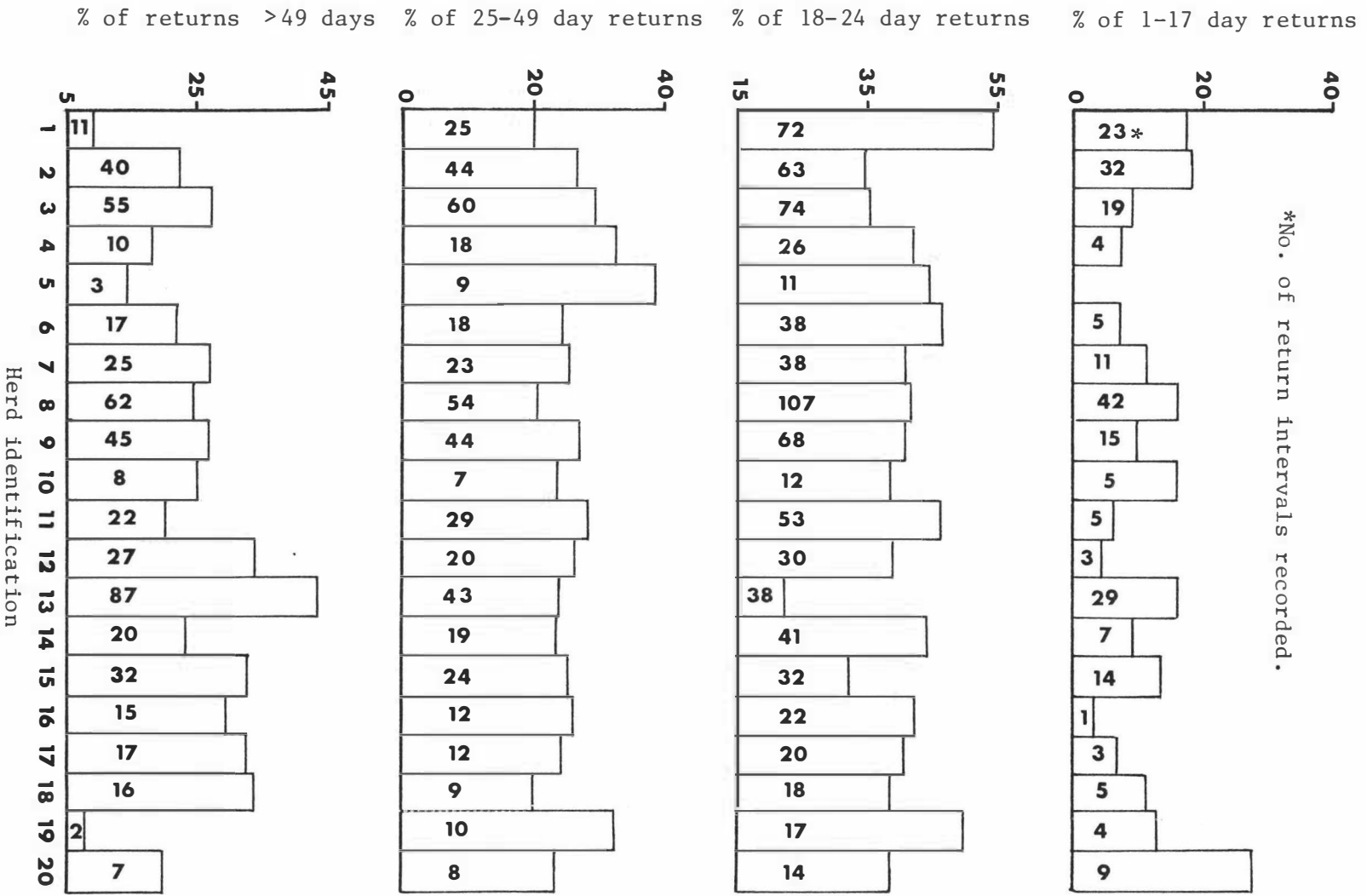


Fig. 4: Association of Postpartum Interval with Cows Mated and Calving to 1st Service in Twenty Town Supply Dairy Herds.

Fig. 5: Return Interval Patterns to 1st Service in Twenty Town Supply Dairy Herds.



*No. of return intervals recorded.

the percentage of short (1-17), normal (18-24) and long returns (25 days or more) for the population was 11.6, 38.9 and 49.5 respectively, the most striking features are the very large between herd differences observed in return interval patterns (Table IX and Fig. 5).

PERFORMANCE OF THE DIFFERENT AGE GROUPS OF CATTLE

The reproductive performance for the different age groups of cattle together with their average milk yield and lactation length is shown in Table X. A simplified form of analysis of returns to first service is included in the table and three of the more important measures of reproductive efficiency, as in the previous section of results, have been extracted and illustrated in Fig. 6. Although milk yield was highest in the older age groups (six years and older) the most efficient reproductive performance occurred with the four year old cows, as determined by the breeding parameters measured, and the least efficient were the two year old cows. There was a tendency for reproductive performance to decline with increasing age after five years of age. Significant differences occurred between ages with all parameters evaluated except for the interservice interval (for levels of significance see Table X).

When the rate at which the different age groups of cows were submitted to first service during the post partum period was analysed significant differences between age differences were found ($p < 0.001$). This rate of submission is illustrated in Fig. 7a in which all cows four years of age and older have been combined into one group (mature cows). Although the pattern of submission for two year old, three year old and mature cows was similar (Fig. 7a) it is noticeable that 78.6% of cows in the mature group had been bred by 100 days post partum compared with 71.8% and 65.8% for the three year and two year old cows respectively.

First service calving rates at different post partum periods were significantly different for the various age groups of cattle examined ($p < 0.01$). The calving rate increased as the post partum interval before breeding became longer (Fig. 7b). Eighty percent of mature cows, submitted for breeding by the hundredth post partum day, were pregnant

TABLE X: REPRODUCTIVE PERFORMANCE OF THE DIFFERENT AGE GROUPS IN TWENTY TOWN SUPPLY DAIRY HERDS IN THE WELLINGTON HAWKE'S BAY LIVESTOCK IMPROVEMENT ASSOCIATION (1972-76)

Breeding parameter	Total count	Total mean	S.D.	Age in years								Significance
				2	3	4	5	6	7	8	≥ 9	
Calving interval (days)**	4477	383.7	335 to 441**	394	385	376	378	381	380	386	386	P < 0.001
Calving to first service interval (days)	3479	84.88	40.55	95	88	83	82	81	81	84	82	P < 0.001
Interservice interval (days)	1972	43.49	46.14	41	46	41	42	49	46	43	42	P < N.S.
Days open (days)	4442	106.80	58.57	117	109	98	102	105	103	110	108	P < 0.001
First service to conception interval (days)*	2979	11.36	-2 to +47*	13	12	9	10	12	10	12	14	P < 0.005
Calving rate (first service)	1765	50.70	-	49	50	56	55	51	52	50	45	P < 0.01
Services per cow calving	3665	1.71	-	1.8	1.8	1.6	1.6	1.7	1.7	1.8	1.8	P < 0.01
Milk yield (litres)+	5786	373	121	323	348	367	379	396	406	416	392	P < 0.001
Lactation length (days)	5786	291	69	293	291	288	285	288	290	295	298	P < 0.005
Percentage of returns to first service												
1 - 17 days	226	11.50	-	16	13	12	16	9	13	6	8	P < 0.01
18 - 24 days	774	39.20	-	35	39	39	39	32	36	47	44	
25 - 49 days	472	23.90	-	25	22	24	19	29	21	21	26	
More than 49 days	500	25.40	-	24	26	24	26	29	29	26	22	

+ To obtain milk yield, figures in Table should be multiplied by 10.

** Double log transformation used (S.D. - one standard deviation on each side of the mean represents a range from 335 to 441 days)

* Log transformation used (S.D. - one standard deviation on each side of the mean represents a range from -2 to +47 days).

- Calving interval
- ▨ Calving to 1st service interval
- x No. of submissions to 1st service
- ** No. of calving intervals
- *** Services per cow calving. Figure in brackets = no. of cows calving

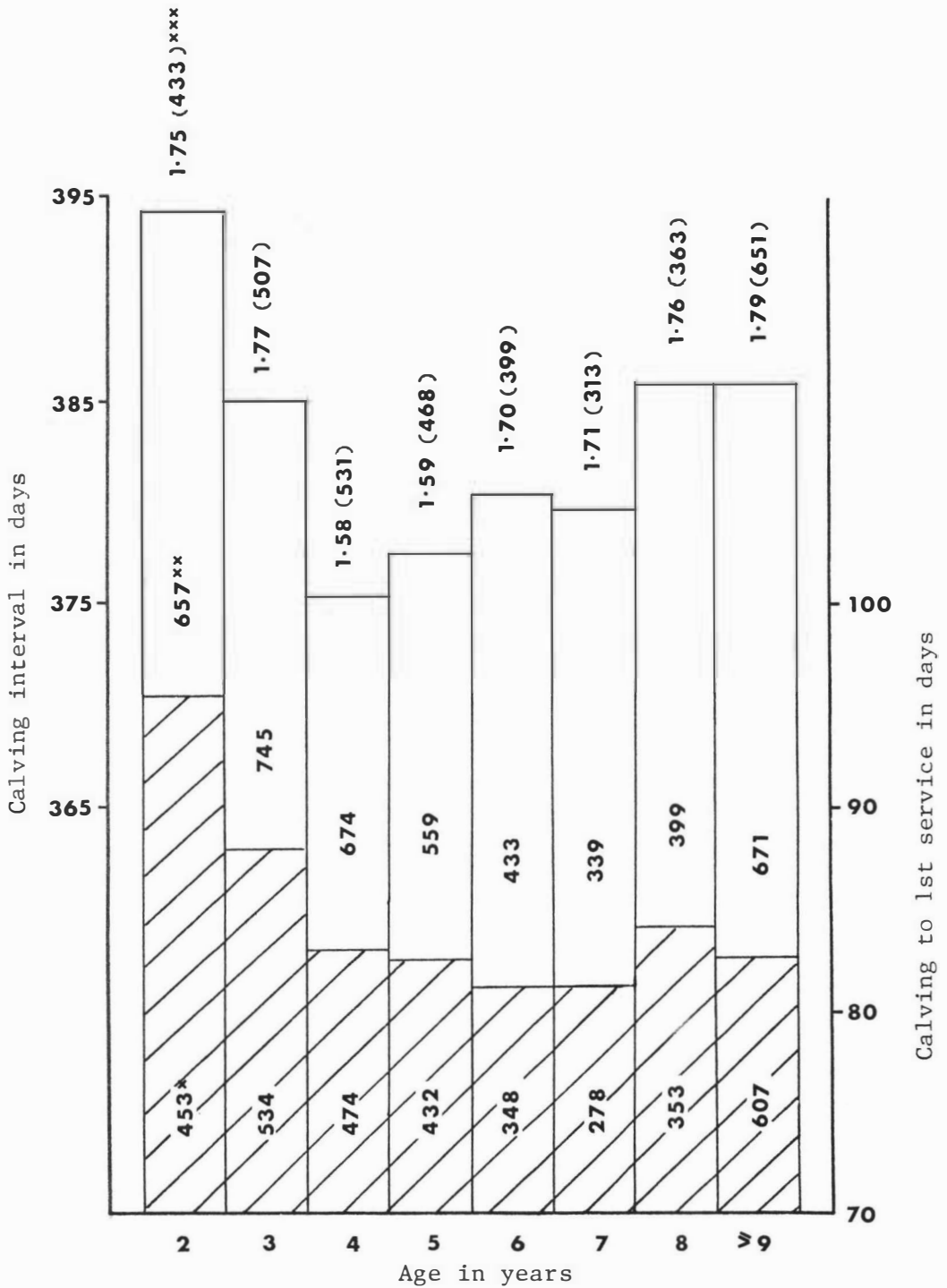


Fig. 6: Association Between Age and Reproductive Performance in Twenty Town Supply Dairy Herds.

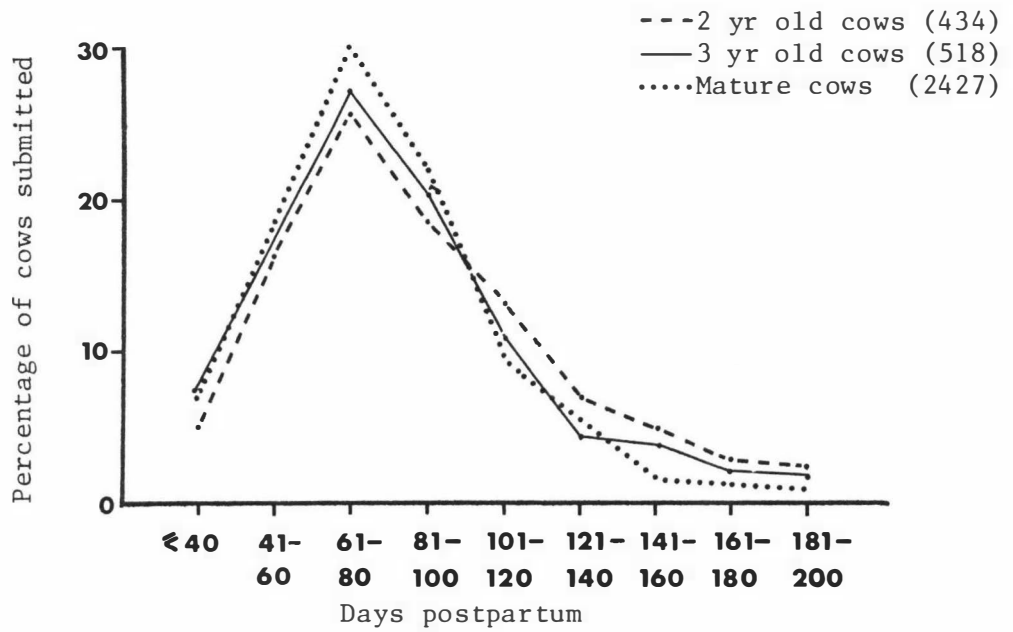


Fig. 7a: Association between Age and Postpartum Interval on Cows Submitted to 1st Service in Twenty Town Supply Dairy Herds.

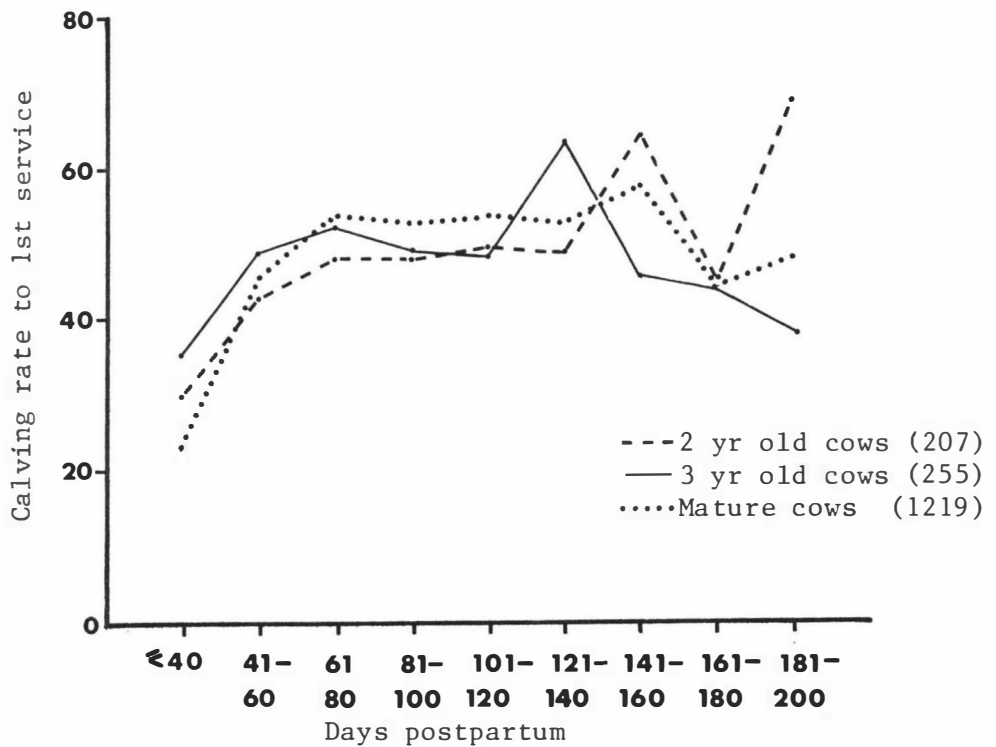


Fig. 7b: Association between Age and Postpartum Interval on Calving Rate to 1st Service in Twenty Town Supply Dairy Herds.

compared with 73% and 65% for three year old and two year old cows respectively.

A detailed analysis of return intervals to first service for the different ages of cattle in the study is shown in Table XI and Fig. 8. Although the younger age groups had a tendency to have a higher percentage of short returns (1-17 days) than the older cattle, while the reverse was the case for normal returns (18-24 days), the most interesting feature was that 49.3% of all returns were greater than 25 days irrespective of age.

The frequency distribution for return intervals to first service for two year old cows is shown in Fig. 9 and for older cows in Fig. 10. The majority of returns occurred in the 18-24 day period with a second and more spread peak at about 37-45 days after the initial mating. Secondary peaks occurred on days eight and nine and again 20-22 days later. There was little difference between the two age groups in the pattern of returns observed. Fig. 11 shows return intervals for all cows.

ASSOCIATION BETWEEN SEASON AND REPRODUCTIVE PERFORMANCE

The relationship between the four seasons of the year and reproductive performance is shown in Table XII and Fig. 12. Irrespective of whether the animals calved or were being bred, performance during the spring months (September-November inclusive) was better than during any other season. Poorest performance was observed during the summer for most parameters in most years although there was variation between summer, autumn and winter in calving rates to first service, services per cow calving and the days elapsing between first service and conception. Season differences were significant except for interservice interval (Table XII).

ASSOCIATION BETWEEN YEAR AND REPRODUCTIVE PERFORMANCE

Significant differences were observed between years in most parameters measured (Table XIII and Fig. 13) with 1974 being particularly poor in respect to reproductive performance.

TABLE XI: RETURN INTERVALS AS A PERCENTAGE OF ALL FIRST SERVICE RETURNS FOR THE DIFFERENT AGE GROUPS IN TWENTY TOWN SUPPLY DAIRY HERDS

Return intervals (in days)	Total count	Total mean	Age in years								Signi- ficance
			2	3	4	5	6	7	8	≥9	
1 - 7	65	3.3	4	3	3	6	1	5	3	2)
8 - 10	74	3.8	4	6	3	5	3	4	1	4)
11 - 13	28	1.4	2	1	1	2	2	1	1	1)
14 - 17	59	3.0	6	2	6	2	3	3	1	1)
1 - 17	226	11.5	16	13	12	16	9	13	6	8)
18 - 19	187	9.5	11	12	8	8	7	9	14	7)
20 - 21	331	16.8	15	14	18	16	16	12	19	21	P < 0.005)
22 - 24	256	13.0	9	13	12	15	8	14	15	16)
18 - 24	774	39.2	35	39	39	39	32	36	47	44)
25 - 33	139	7.0	7	6	10	5	6	8	4	8)
34 - 49	333	16.9	18	16	14	15	23	13	17	18)
25 - 49	472	23.9	25	22	24	19	29	21	21	26)
> 49	500	25.4	24	26	24	26	29	29	26	22)

TABLE XII: ASSOCIATION BETWEEN SEASON AND REPRODUCTIVE PERFORMANCE IN TWENTY TOWN SUPPLY DAIRY HERDS

Breeding parameter	Total count	Total mean	S.D.	1972				1972/73				1973/74				1974/75				Significance
				S+	A	W	Sp	S	A	W	Sp	S	A	W	Sp	S	A	W	Sp	
Calving interval (days)**	4537	383.7	335 to 441**	391	380	380	372	387	386	387	370	394	386	393	389	387	381	366	335	P < 0.001
Calving to 1st service interval (days)	3613	84.78	40.56	124	81	81	72	83	82	87	73	93	89	89	84	-	-	-	-	P < 0.001
Inter service interval (days)	1480	40.21	38.75	35	45	34	48	47	39	37	34	42	45	39	36	-	-	-	-	P < N.S.
Days open (days)	4501	106.88	58.57	120	102	102	96	114	112	110	93	118	109	116	113	110	102	87	56	P < 0.001
First service to conception interval (days)*	3005	11.34	-2 to +47*	15	9	8	11	12	16	11	8	11	12	13	12	-	-	-	-	P < 0.01
Calving rate*** (1st service)	1711	63.10	-	52	67	70	63	63	54	61	76	61	59	59	67	-	-	-	-	P < 0.01
Services per cow calving	2712	1.73	-	2.2	1.6	1.5	1.6	1.8	1.9	1.6	1.5	1.8	2.1	1.7	1.5	-	-	-	-	P < 0.001

S+ Summer i.e. December-February inclusive except 1972 (January and February only)

A Autumn i.e. March-May inclusive

W Winter i.e. June-August inclusive

Sp Spring i.e. September-November inclusive

** Double log transformation used (S.D. - one S.D. on each side of the mean represents a range from 335 to 441 days).

* Log transformation used (S.D. - one S.D. on each side of the mean represents a range from -2 to +47 days).

*** Calving rate to first service which in this analysis has excluded all cows with calving intervals greater than 500 days, cows which were not bred within 200 days of their last calving and cows which did not conceive at all.

TABLE XIII: ASSOCIATION BETWEEN YEAR AND REPRODUCTIVE PERFORMANCE IN TWENTY TOWN SUPPLY DAIRY HERDS

Breeding parameter	Total count	Total mean	S.D.	Different year means				Significance
				1972	1973	1974	1975	
Calving interval (days)**	4537	383.70	335 to 441**	379	382	391	375	P < 0.001
Calving to 1st service interval (days)	3613	84.78	40.56	82	82	88	64	P < 0.001
Inter service interval (days)	1480	40.21	38.77	41	39	41	-	P < N.S.
Days open (days)	4501	106.88	58.57	102	107	114	97	P < 0.001
1st service to conception interval (days)*	3005	11.34	-2 to +47*	10	11	12	-	P < 0.01
Calving rate (1st service)***	1711	63.10	-	66	63	61	-	P < N.S.
Services per cow calving	2712	1.68	-	1.60	1.70	1.74	-	P < N.S.
Milk yield (litres) ⁺	5958	373	121	390	367	369	371	P < 0.001
Lactation length (days)	5956	291	69	294	288	295	288	P < 0.001

+ To obtain milk yield, figures in table should be multiplied by 10.

** Double log transformation used (S.D. - one S.D. on each side of mean represents a range from 335 to 441 days).

* Log transformation used (S.D. - one S.D. on each side of mean represents a range from -2 to +47 days).

*** Calving rate to first service which in this analysis has excluded all cows with calving intervals greater than 500 days, cows which were not bred within 200 days of their last calving and cows which did not conceive at all.

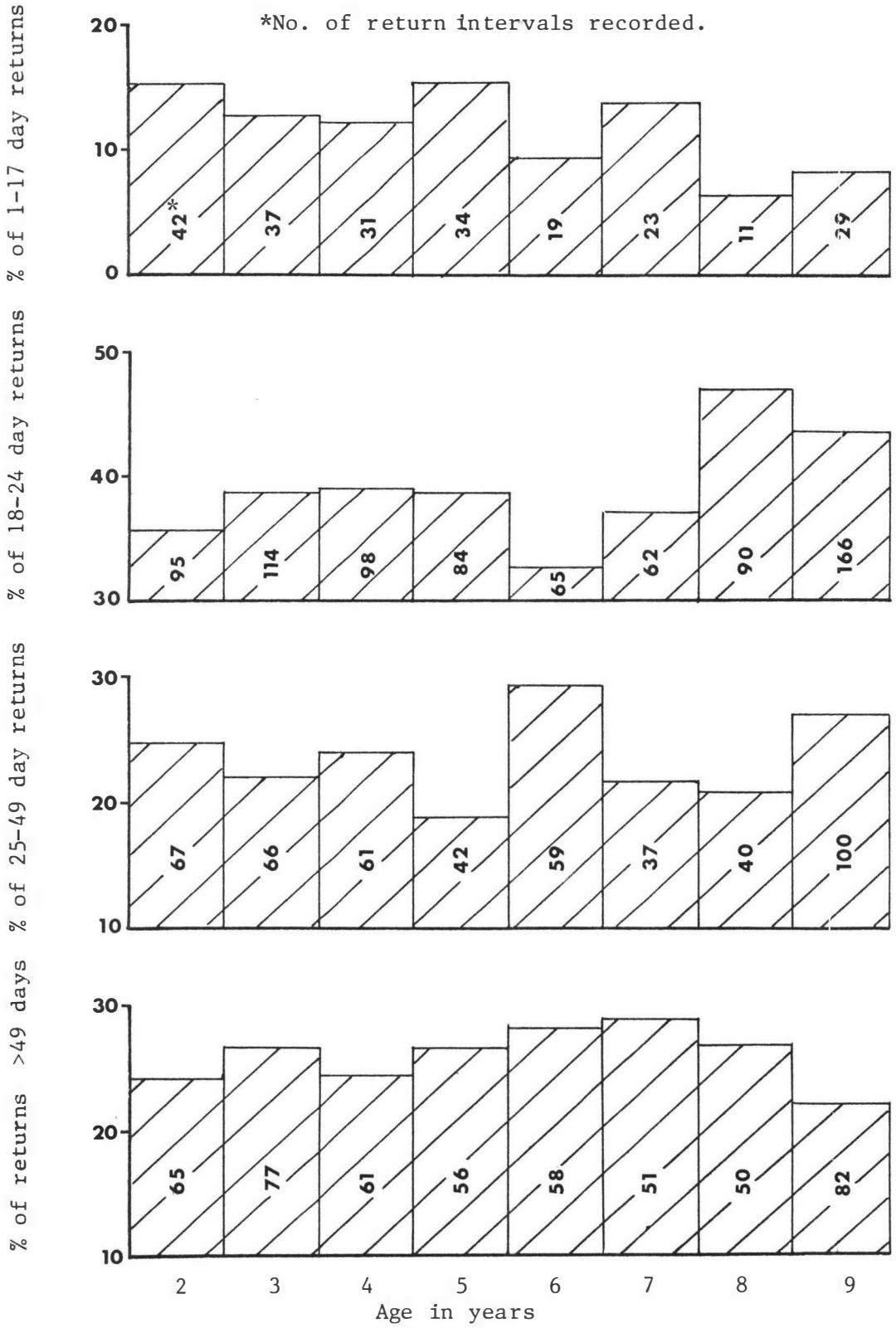


Fig. 8: Return Interval Patterns to 1st Service Between the Different Age Groups in Twenty Town Supply Dairy Herds.

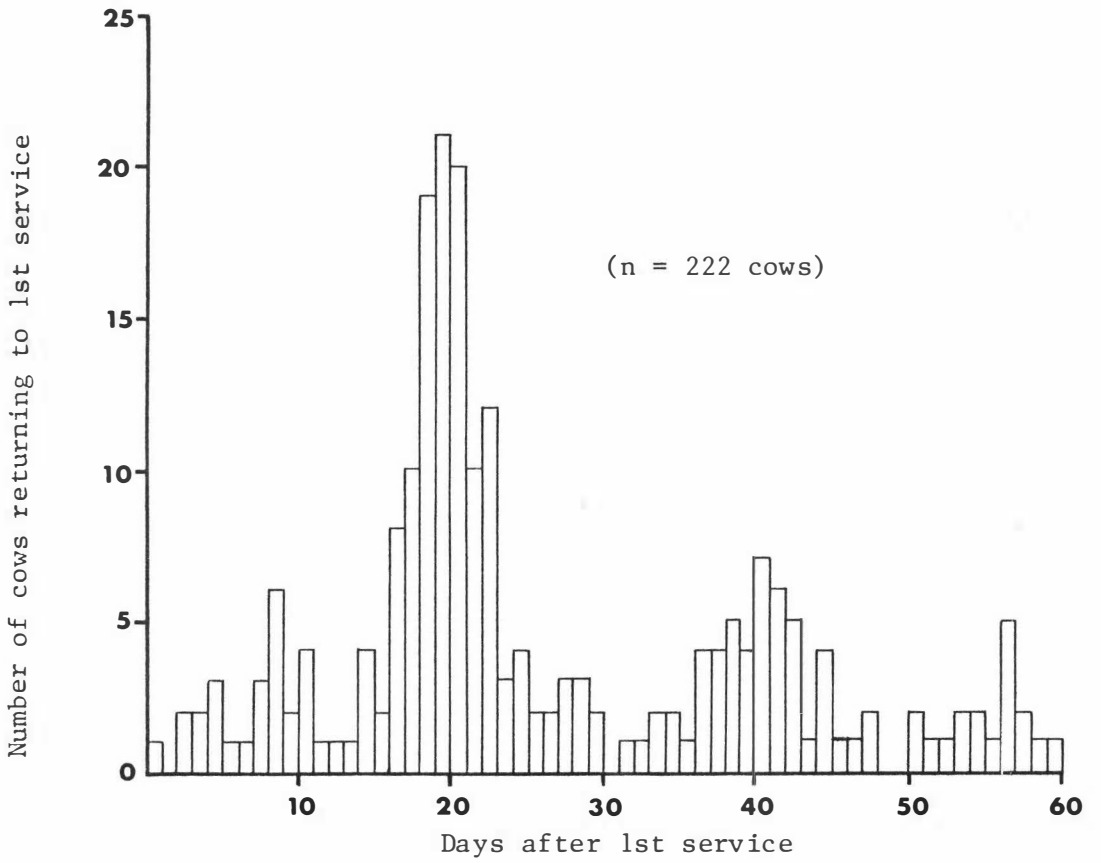


Fig. 9: Return Patterns to 1st Service in Two year old Cows in Twenty Town Supply Dairy Herds.

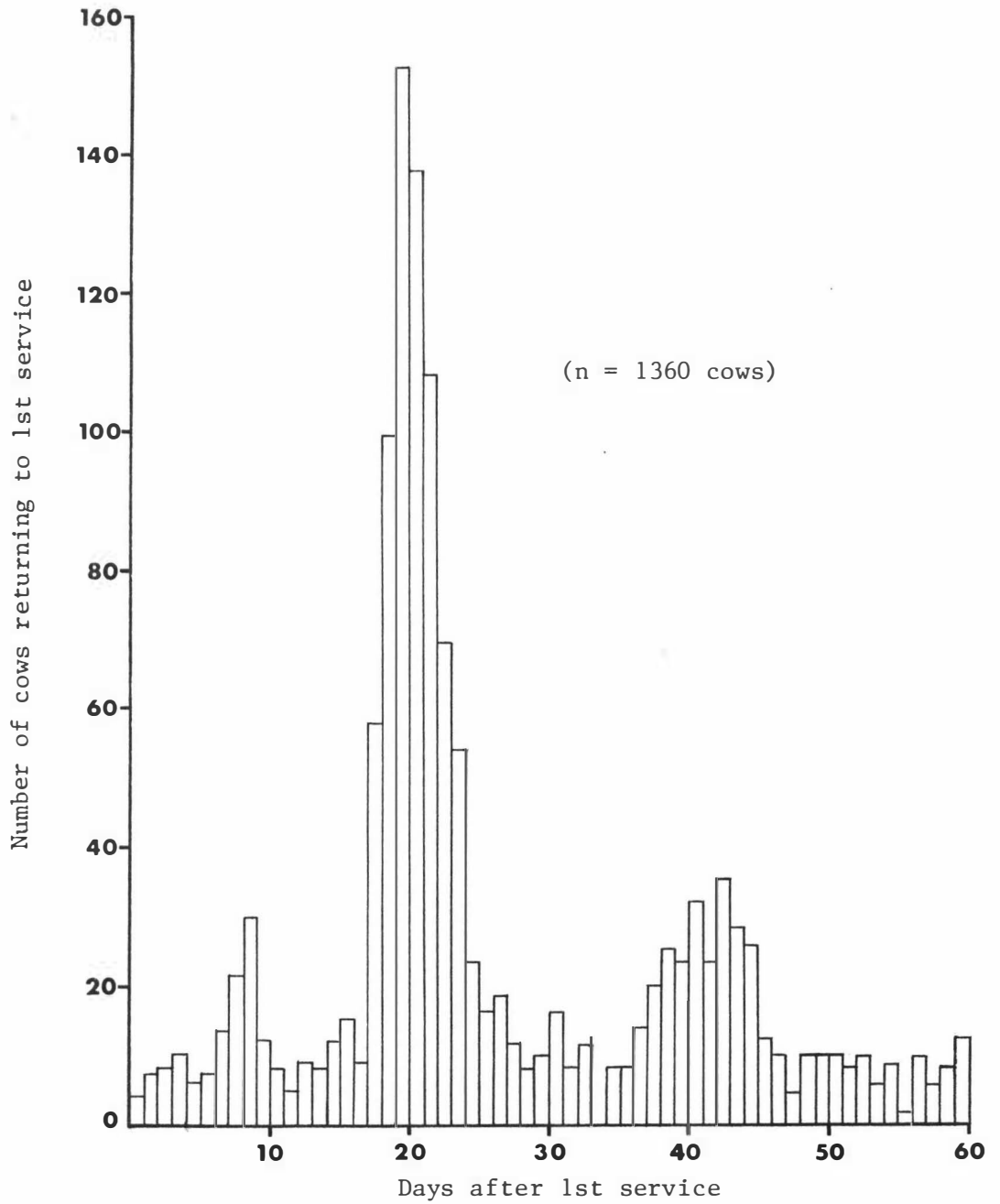


Fig. 10: Return Patterns to 1st Service in Three year and Older Cows in Twenty Town Supply Dairy Herds.

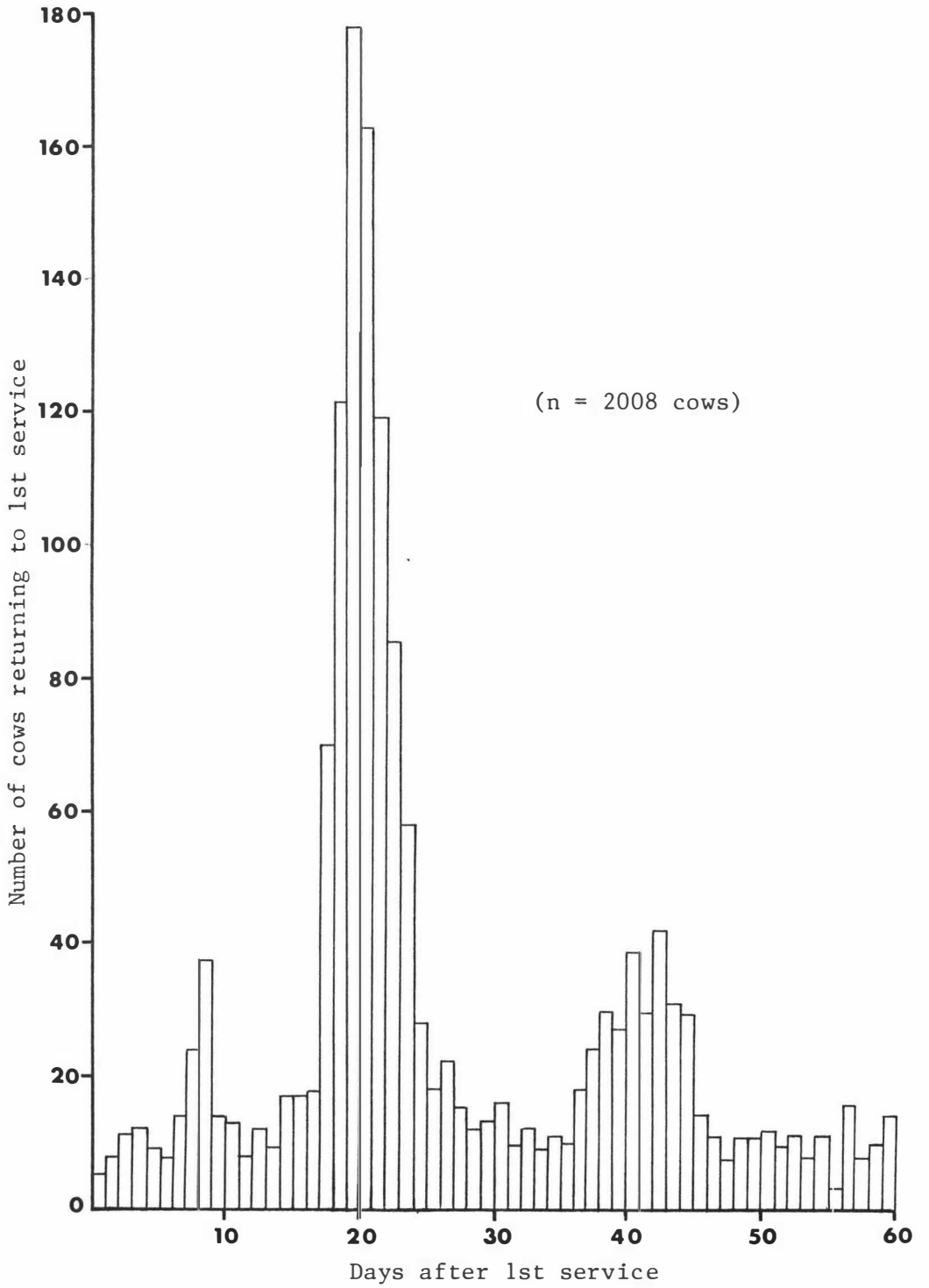


Fig. 11: Return Pattern to 1st Service in Cows of All Ages in Twenty Town Supply Dairy Herds.

Calving interval
 Calving to 1st service interval
 1st service to conception interval
 x No. of 1st service to conception intervals
 xx No. of submissions to 1st service
 xxx No. of calving intervals

 S = Summer A = Autumn
 W = Winter Sp = Spring

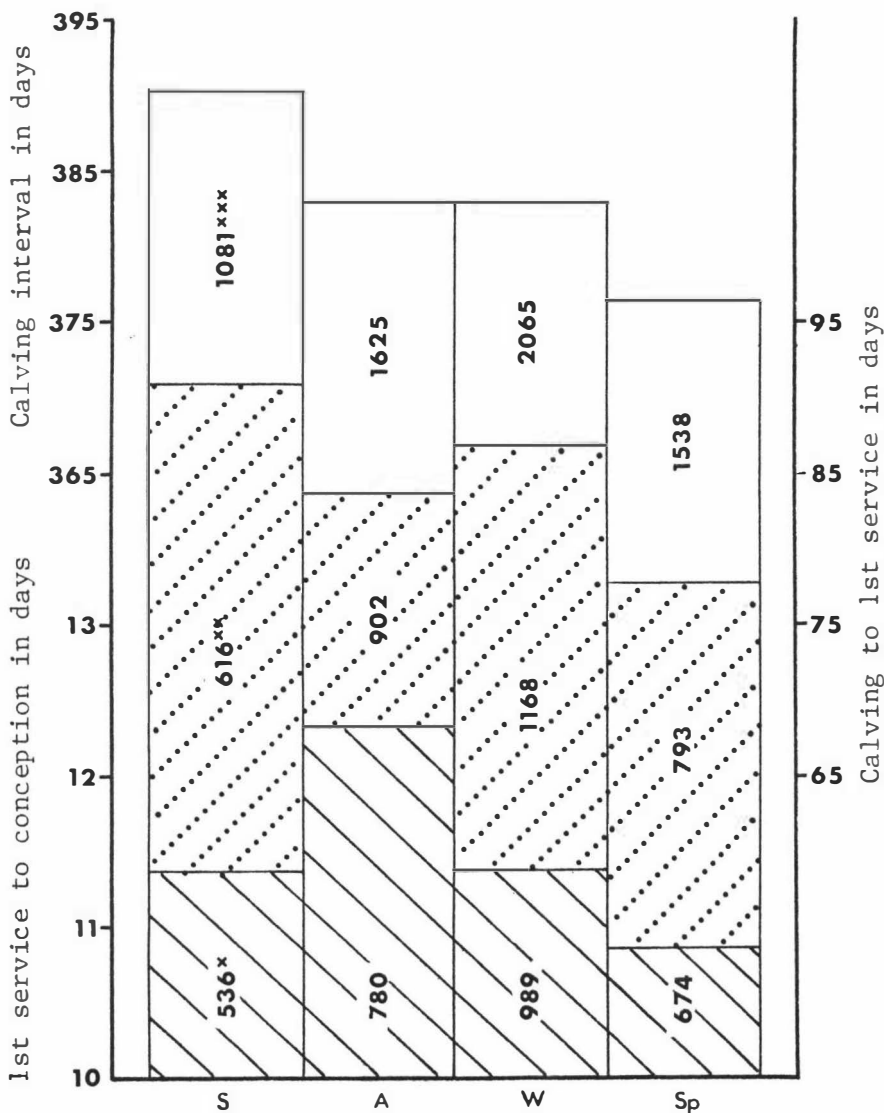


Fig. 12: Association Between Season and Reproductive Performance
 When Corrected for Effect of Age and Herd in Twenty
 Town Supply Dairy Herds

Calving interval
 Calving to 1st service interval
 * No. of submissions to 1st service
 ** No. of calving intervals
 *** Services per cow calving. Figures in brackets = number of cows calving

Note: Insufficient data to estimate services per cow calving and calving to 1st service interval in 1975

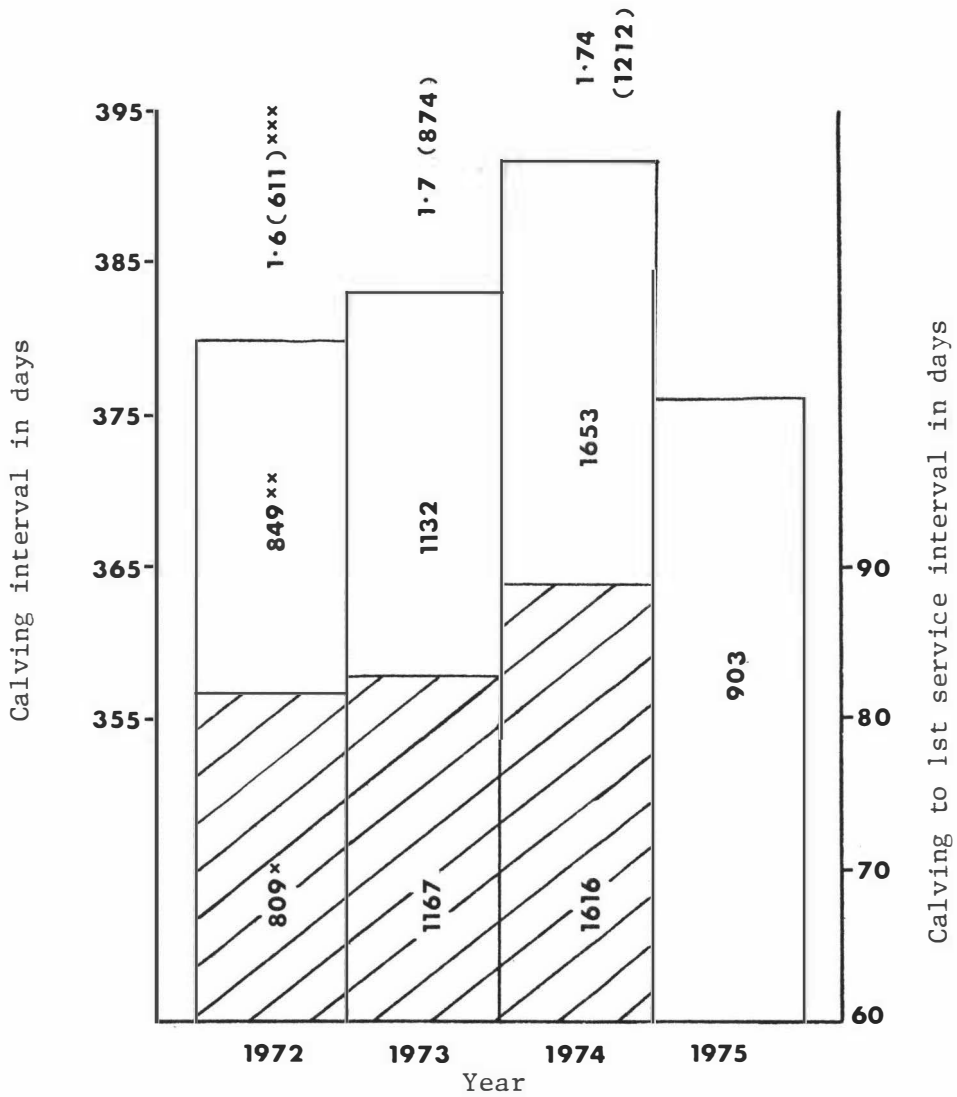


Fig. 13: Year Differences in Reproductive Performance in Twenty Town Supply Dairy Herds

ASSOCIATION BETWEEN BREED AND REPRODUCTIVE PERFORMANCE

Significant differences were found for some of the parameters of breeding performance between the different breeds when a one way analysis was carried out (Table XIV); this apparent difference, however, was due to herd effects (see Tables XVII and XVIII, pp59-60).

ASSOCIATION BETWEEN ABORTION AND REPRODUCTIVE PERFORMANCE

Fifty two cases of abortion were recorded during the course of this investigation and of these 35 were recorded as having had a subsequent pregnancy. The performance of aborting animals during the gestation before abortion and during the two breeding periods following the abortion has been compared with the breeding parameters for all normal gestations in Table XV. Following abortion the intercalving interval for the 35 cows averaged 437 days compared with 384 days for cows undergoing a normal gestation. Sixteen cows had breeding records associated with a second pregnancy following abortion - fertility appeared to be little different from the normal indicating that there was unlikely to be any carryover effect in these cows.

THE RELATIVE IMPORTANCE OF DAYS FROM CALVING TO FIRST SERVICE AND FIRST SERVICE TO CONCEPTION ON CALVING INTERVAL.

When the effect of days from calving to first service and of days from first service to conception on intercalving interval were considered in a multiple regression analysis the standard partial regression coefficients were 0.631 and 0.732 respectively ($p < 0.001$). Thirty nine percent of variation in calving interval was explained by days from calving to first service and 45% by days from first service to conception.

THE RELATIONSHIP BETWEEN CALVING TO FIRST SERVICE AND FIRST SERVICE TO CONCEPTION INTERVALS

The standard partial regression coefficient obtained, when the days from first service to conception were regressed on the days from calving to first service, was -0.099 ($p < 0.001$): less than 1% of the variation in days from first service to conception was explained by the calving to first service interval.

TABLE XIV: ASSOCIATION BETWEEN BREED AND REPRODUCTIVE PERFORMANCE IN TWENTY TOWN SUPPLY DAIRY HERDS

Breeding parameter	Total count	Total mean	S.D.	Breeds			Significance
				Friesian	Friesian x Jersey	Jersey	
Calving interval (days)**	4497	383.70	335 to 441**	385	378	371	P < 0.001
Calving to 1st service interval (days)	3588	84.81	40.60	86	81	76	P < N.S.
Inter service interval (days)	2027	43.46	45.81	44	39	32	P < 0.01
Days open (days)	4497	106.86	58.58	108	99	91	P < 0.001
1st service to conception interval (days)*	3002	11.34	-2 to +47*	11	9	14	P < N.S.

** Double log transformation used (S.D. - one S.D. on each side of the mean represents a range of 335 to 441 days).

* Log transformation used (S.D. - one S.D. on each side of the mean represents a range of -2 to +47 days).

TABLE XV: ASSOCIATION BETWEEN ABORTION AND REPRODUCTIVE PERFORMANCE IN TWENTY TOWN SUPPLY DAIRY HERDS

Breeding parameter	Total count	Total mean	S.D.	Class of cow				Significance
				A	B	C	D	
Calving interval (days)**	4519	383.70	335-441**	344(52)+	437(35)	388(16)	384(4416)	P < 0.001
Calving to 1st service interval (days)	3596	84.82	40.58	91(35)	110(34)	105(9)	84(3518)	P < N.S.
Days open (days)	4483	106.92	58.59	93(14)	165(35)	108(16)	105(4418)	P < 0.001

A = breeding parameter associated with the gestation before abortion took place

B = breeding parameter associated with gestation immediately after abortion took place

C = breeding parameter associated with the second gestation after abortion took place

D = breeding parameter for all normal gestations

+ no. of observations made

** double log transformation used (S.D. - one S.D. on each side of the mean represents a range of 335 to 441 days)

THE EFFECT OF HERD SIZE ON INTERCALVING INTERVAL, CALVING TO FIRST SERVICE AND FIRST SERVICE TO CONCEPTION INTERVALS

Although there was a tendency for reproductive performance to decline with increasing herd size (Table VIII) the standard partial regression coefficients for intercalving interval, calving to first service and first service to conception intervals on herd size, were 0.220, -0.046 and 0.092 respectively - these values were not statistically significant.

THE EFFECT OF MILK PRODUCTION ON INTERCALVING INTERVAL, CALVING TO FIRST SERVICE AND SERVICE TO CONCEPTION INTERVALS

When the intercalving interval, calving to first service and first service to conception intervals were regressed on the average daily yield, the standard partial regression coefficients were -0.093, -0.007 and -0.067 respectively ($p < 0.001$) whereas when total yield was considered in the same way the values were 0.326, 0.172 and 0.211 ($p < 0.001$).

THE IMPORTANCE OF HERD, AGE, SEASON, YEAR AND BREED ON THREE PARAMETERS OF REPRODUCTIVE PERFORMANCE AND ON MILK PRODUCTION

The relative importance of herd, age, season, year and breed on calving interval, calving to first service, first service to conception, lactation length and milk yield, together with some of their interactions is shown in Tables XVII and XVIII.

While there were significant interactions between herd and age, herd and season, and season and age on some of the breeding parameters the influence of the interaction was small compared with the influence of herd, season and age on all breeding parameters (see F values and tests of significance in Table XVII). Year also had a significant influence on breeding performance (Table XVII).

Breed appeared to have a highly significant influence on calving interval, but when examined in a two way analysis with herd, the effect was shown to be due to the influence of the latter (Tables XVII and XVIII).

TABLE XVII: F VALUES AND TESTS OF SIGNIFICANCE FOR VARIOUS MEASURES OF REPRODUCTIVE PERFORMANCE AND THE EFFECTS OF HERD, YEAR, SEASON, AGE, BREED AND THEIR INTERACTIONS IN TWENTY TOWN SUPPLY DAIRY HERDS

Source	Type of analysis	d.f.	ICI**	ICSMI	SCON*	Lactation Length	Lactation Length
Herd	One way analysis	19	6.79a	6.34a	5.09a	10.24a	61.77a
Age	One way analysis	7	6.59a	6.81a	3.07b	3.29b	52.40a
Age	One way analysis (Herd & Season Cov.)	7	6.48a	6.94a	3.49a	-	-
Season (within year)	One way analysis	12	7.97a	11.55a	0.77NS	-	-
Breed	One way analysis	2	10.86a	1.69NS	1.25NS	-	-
Year	One way analysis	3	19.26a	9.19a	4.04c	-	-
Herd	Two way analysis with Age	19	7.82a	6.24a	8.46a	9.98a	60.99a
Age	Two way analysis with Herd	7	9.66a	8.09a	4.49a	3.61a	47.22a
Herd x Age	Interaction	125	1.26d	1.27d	1.06NS	1.38b	1.83a
Herd	Two way analysis with Breed	19	5.38a	5.87a	8.03a	-	-
Breed	Two way analysis with Herd	2	1.33NS	1.17NS	2.79d	-	-
Herd x Breed	Interaction	18	0.76NS	1.23NS	1.35NS	-	-
Herd	Two way analysis with Season (Age Cov.)	19	5.55a	6.42a	4.84a	-	-
Season	Two way analysis with Herd (Age Cov.)	12	9.16a	13.98a	2.66b	-	-
Herd x Season (Age Cov.)	Interaction	133	1.79a	2.65a	1.29c	-	-
Age	Two way analysis with Season (Herd Cov.)	7	6.57a	6.32a	3.49a	-	-
Season (pooled)	Two way analysis with Age (Herd Cov.)	3	10.58a	14.23a	0.67NS	-	-
Age x Season (Herd Cov.)	Interaction	21	1.80c	1.76c	0.79NS	-	-
Herd	Two way analysis with Year	19	-	-	-	9.76a	63.94a
Year	Two way analysis with Herd	4	-	-	-	4.02b	7.24a
Herd x Year	Interaction	-	-	-	-	4.49a	6.66a

a = P < 0.001, b = P < 0.005, c = P < 0.01, d = P < 0.05, NS = Not Significant, ** Double log transformation, * Single log transformation, ICI = Intercalving interval, ICSMI = Calving to 1st service interval, SCON = First service to conception interval.

TABLE XVIII: ASSOCIATION OF HERD, AGE, SEASON AND YEAR WITH MEASURES OF REPRODUCTIVE AND PRODUCTIVE PERFORMANCE

Independent variables	Calving interval**			Calving to 1st service interval			1st service to conception interval*			Milk yield		
	R	β	R ²	R	β	R ²	R	β	R ²	R	β	R ²
Herd and Age	.20a	.18a .12a	4.2a	.21a	.18a .13a	4.6a	.23a	.21a .09a	5.2a	.46a	.40a .22a	21.5a
Herd and Breed	.16a	.16a .03NS	2.7a	.18a	.18a .03NS	3.4a	.20a	.20a .05NS	4.4a	-	-	-
Herd and Season (Age covariate)	.24a	.15a .17a	5.7a	.28a	.18a .21a	8.0a	.21a	.18a .10b	4.3a	-	-	-
Season pooled and Age (Herd covariate)	.13a	.08a .10a	1.8a	.16a	.11a .11a	2.6a	.11b	.03NS .09a	1.3b	-	-	-
Herd and Year	-	-	-	-	-	-	-	-	-	.41a	.41a .07a	16.9a
Age (Herd and Season covariates)	.11a	.10a	1.1a	.12a	.12a	1.5a	.11a	.09a	1.3a	-	-	-
Season	.17a	.17a	3.0a	.21a	.21a	4.3	.08NS	.08a	.07a	-	-	-
Year	.11a	.11a	1.3a	.09a	.09a	0.8a	.6c	.6c	.4c	-	-	-
Age	-	-	-	-	-	-	-	-	-	.24a	.24a	6.0a

a = P < 0.001

b = P < 0.005

c = P < 0.01

R = Multiple correlation coefficient

β_2 = Standard partial regression coefficient

R² = % of variation explained by independent variables

NS = Not significant

** Double log transformation used

* Log transformation used

Herd x age and herd x year interactions were significant in respect to both lactation length and milk yield but these interactions were small compared with the influence of herd and age on these production parameters (Table XVII).

The amount of variation in the three measures of reproductive performance examined that could be ascribed to the effects of herd, age and season was small (Table XVIII). Herd and age, herd and year, and age explained 21.5, 16.9 and 6.0% respectively of the variation observed in milk yield.

DISCUSSION

High production and efficient reproduction are very necessary for a cow to maintain a long economically productive life and the importance of a 365 day calving interval, in this context, has already been discussed (see page 3 Literature Review).

Dairying under Town Supply conditions in New Zealand requires a rather different management approach to dairying for Seasonal Factory Supply. For example the Town Milk Producer operates on a 'quota' system whereby he must produce a nominated volume of milk each day for whole milk consumption and is paid at a higher rate for this relative to the rate received by the Seasonal Producer. Surplus production over and above the quota is normally sold to a Dairy Company for processing to a variety of milk products at normal non subsidised rates. Costs for whole milk production during the winter period, when natural pasture growth is low, are highest and it is particularly important that the most efficient use is made of all resources (particularly food resources) during this period. Calving management, used in its widest sense, is particularly important to the Town Supply Producer at this time of year whereas the time and rate at which cows calve during periods of high natural pasture growth is much less critical from a financial point of view. The Seasonal Supplier on the other hand, who is endeavouring to fit the demands of the herd closely to the period of greatest natural pasture growth, is more concerned with a concentrated late winter / early spring calving, then drying off at a fixed time in the autumn with no milking taking place during the winter period.

THE INTERCALVING INTERVAL

From the survey of twenty Town Supply Herds in the Wellington Hawke's Bay area, the mean calving interval was found to be 383.7 days. This mean has been calculated from transformed data (see section on Materials and Methods) and one standard deviation on each side of this mean represents a range from 335 to 441 days. The arithmetic mean and standard deviation, which has been the method of reporting results used by other authors, was 388.7 \pm 59 days.

Either method gives values which are in relatively close agreement with the findings of Everett et al. (1966), Miller, cited by Morrow et al. (1969a) and Olds and Cooper (1970a and 1970b) who reported calving intervals of 387 \pm 59.7, 381.5 and 382.2 \pm 54 days respectively for American dairy herds. The Milk Marketing Board (MMB 1970, 1971 and 1975) reported similar calving intervals for British dairy herds. The majority of reports concerning dairy herds in the United Kingdom and United States of America however indicate that calving intervals are usually of the order of 395 days (Louca and Legates, 1968; Morrow, 1970; Bozworth et al., 1972; Pelissier, 1972; Spike, 1973; Spike and Meadows, 1973; Esslemont, 1974a; Webb et al., 1974; Matsoukas and Fairchild, 1975; Spalding et al., 1975; MMB, 1976; Slama et al., 1976; Esslemont et al., 1977), while Macmillan and Moller (1975 and 1977) and Cunningham et al. (1976), working with Seasonal Supply Herds, note that the intercalving intervals were 364 and 363 days for New Zealand and Ireland respectively.

It is interesting to note in Fig. 2 that 10% of calving intervals in the herds sampled were longer than 460 days in duration. This is often associated with failure to cull animals in the herd which have difficulties in getting pregnant for a number of reasons; such cows can continue to be milked readily in the Town Supply Herd whereas they would frequently be eliminated from a herd under Seasonal Dairy conditions where 85% of cows calve in six weeks of the calving period (New Zealand Dairy Board, 1951) and 95% within twelve weeks (Moller, 1976). In addition, because Town Supply Farmers tend to have set breeding periods at least twice per year, they sometimes hold animals over from one breeding period to the next, thus prolonging the intercalving interval.

A limited number of abortions (less than 1% of all calvings) account for the very short intercalving intervals recorded e.g. 221-300 days.

When age differences in reproductive performance were considered it was clearly established that the four year old animals, i.e. animals that have completed three calvings, had the shortest intercalving intervals and superior reproductive performance in most of the parameters measured (see Table X and Fig. 6). Least efficient

were the two year old cattle followed by three year olds; there was then little change until cows had reached the age of eight years. Similar findings have been reported by almost all other groups of workers in the United States of America (Trimberger and Davis, 1945; Tanabe and Salisbury, 1946; Olds et al., 1949, 1952; Herman, 1956; Morrison and Erb, 1957; Salisbury and Van Demark, 1961; Everett et al., 1966; Spike and Meadows, 1973; Spalding et al., 1975; McDowell et al., 1976), Great Britain (Boyd and Reed, 1961; MMB, 1970; MMB, 1971) and New Zealand (NZDB, 1961). Matsoukas and Fairchild (1975) and Lewis and Horwood (1950b) found no consistent age effect until the fifth and ninth pregnancy respectively. In the former case, however, results for the first five pregnancies were pooled and only relatively small numbers of records were included for older age groups while in the second report the calving interval between first and second calvings was in fact longer than for between any subsequent calving until nine calvings had been recorded. Although not statistically significant, this still represented a difference of at least 0.2 months (i.e. approximately six days) when these animals were compared with the next poorest performing age group.

It does not seem unreasonable that there should be a deterioration in reproductive efficiency in older cattle associated with the ageing process and the hazards which occur with repeated pregnancies. Other explanations, however, must be found for the relatively poor performance of the younger group, particularly those undergoing their first lactation. These are considered during succeeding parts of the discussion (see Calving to first service interval below).

The intercalving interval provided a key measure of performance in the investigation reported here. A number of the other parameters of breeding efficiency which were recorded also have a direct association with this interval - these are considered in the following sections.

CALVING TO FIRST SERVICE INTERVAL

The mean calving to first service interval was 84.8 ± 40.6 days (see Table VIII) which is comparable to intervals recorded by other workers (see Table XIX). This is longer than the calving to first

service intervals in Seasonal Supply Herds reported by Macmillan and Moller (1977) which was estimated to be 76 days.

TABLE XIX : CALVING TO FIRST SERVICE INTERVAL REPORTED BY VARIOUS RESEARCHERS

Reference	Calving to 1st service interval (days)
Bozworth <u>et al.</u> (1972)	79-107
Esslemont <u>et al.</u> (1977)	87.8
Everett <u>et al.</u> (1966)	78.0
Macmillan and Moller (1977)	76.0
Olds and Cooper (1970a, 1970b)	82.2
Oxender and Mellenburger (cited by Britt, 1975)	85.0
Slama <u>et al.</u> (1976)	84.8
Sondoregger and Schurch (1977)	80.0
Spalding <u>et al.</u> (1975)	87.0
Van Demark and Salisbury (1950)	117.0

Examination of Fig. 3 shows that 26% of cows in the Town Supply Herds had been bred by 60 days, 69% by 90 days and 88% by 120 days post partum, an observation which is in close agreement with the findings of other authors (see Table XX).

TABLE XX : THE RATE OF MATING RECORDED BY DIFFERENT RESEARCHERS AT VARIOUS POST PARTUM INTERVALS

Reference	Post partum intervals		
	60 day	90 day	120 day
Bozworth <u>et al.</u> (1972)	24%	50-73%	74-92%
Olds and Cooper (1970b)	23.5%	69.5%	89.9%
NZDB Survey (1961)	27.2%	65.3%*	
Pelissier (1976)	16.2%	67.2%	91.6%

*99 days post partum

There were, however, noticeable differences between the different age groups (Table X and Figs. 6 & 7a) -a smaller proportion of younger cows were presented for breeding in the earlier post partum

periods compared with the mature animals in the herd e.g. by 60 days post partum, 26% of mature cows had been bred compared with 25% and 21% for three year old and two year old cows respectively. Comparable figures for breedings by 100 days post partum were 79%, 72% and 66% for these same three age groups (Fig. 7a).

Such age differences can be accounted for by the fact that the two year old animals in particular require a longer interval between calving and their first post partum ovulation and/or oestrus than older herd mates as shown by Herman and Edmundson (1950), Wiltbank and Cook (1958), Riesen (1968), Hammond and Sanders (1923) cited by Morrow (1969) and Moller (1970b). Furthermore, a much higher incidence of pre-service anoestrus has been reported in younger age groups by Fielden *et al.* (1976) and Boyd (1977). It has been suggested by Fielden *et al.* (1976) that this age effect can be attributed to such factors as the continuing demands for growth as well as lactation together with the disadvantages the younger animal has when competing for available food under a competitive pasture grazing situation.

The net result of this delay before breeding is that the younger animals have fewer open heats thus depressing fertility (see later section on Services per cow calving p 77).

Direct comparison of these results for calving to first service in Town Supply Herds cannot be made with Seasonal Supply Herds since submission rate (SR) is a more useful and frequently quoted statistic in the latter group (SR is generally defined as the percentage of cows mated within the first 28 days of the breeding season). It has been reported that 88% of cows in New Zealand Seasonal Supply Herds are mated within the first 28 days of the breeding period (Macmillan *et al.*, 1975). If the breeding season for these herds commences approximately 60 days after the median calving date for the herd this suggests that 88% of these cows have had their first service by 88 days post partum i.e. a much higher proportion of cows in Seasonal Supply Herds have been bred by 90 days post partum than the 69% recorded in the Town Supply Herds.

Delays in breeding in Town Supply Herds will clearly be a contributing factor, whatever their cause, to the prolonged inter-calving interval seen in these herds. While the reasons for this delay between calving and first service in Town Supply Herds could not be determined from the information obtained in this investigation, two of the most likely possibilities would be an increased length of post partum anoestrus in Town Supply Herds associated for example with seasonal factors (seasonal differences were observed - see Table XII), and/or deliberate management decisions related to when animals would best be mated to fit in with the demands of the quota milk supply system.

Heat detection errors and/or missed heats could also be implicated as an important contributing factor to prolonged calving to first service intervals. Differences in short returns (usually associated with heat detection errors) between the Town Supply Farms examined in this study and Seasonal Supply Farms in New Zealand appeared to be approximately the same although the pattern of long returns (which can also be associated with heat detection problems) did vary between these two farming systems. (This is to be discussed later - see page 72).

Apart from the preponderance of Friesian cattle in Town Supply Herds it seems unlikely that there are any major genetic differences between cattle running within the Town Supply and Seasonal Dairying systems that would lead to major fertility differences. There is for example, a relatively free interchange of cows between Town Supply and Seasonal Supply Herds, and more importantly, a similar semen service (normally bulls standing at the NZDB Artificial Breeding Centres) is drawn from during the breeding periods. This suggests that management and other environmental factors are largely responsible for any differences that are seen.

CALVING TO CONCEPTION INTERVAL (DAYS OPEN)

The calving to conception interval consists of two components:

- a. The calving to first service interval as discussed in the previous section.

b. The in-calf rate achieved when breeding takes place. Where animals do not conceive to the initial breeding for whatever reason, the calving to conception interval will be prolonged. The rate at which these animals become pregnant to subsequent services, and the interservice intervals, will also have a considerable influence on this parameter.

Assuming that gestation length for Friesian cattle is relatively constant at 282 days, animals must conceive by the 83rd day post partum if a 365 day intercalving interval is to be maintained. Since the conception rate at any one oestrous cycle is not 100%, breeding must commence before 83 days post partum to achieve this objective.

Sixty percent of the animals in this study were in fact bred by the 83rd day post partum but only 45% of them calved following breeding within this period (see Fig. 3). The mean calving to conception interval however was 107 days (Table VIII) resulting in a prolongation of the intercalving interval; this 107 day calving to conception interval is comparable to the 107, 109, 116 and 109 days reported by Everett *et al.* (1966), Morrow *et al.* (1969a), Spalding *et al.*, (1975) and Sonderegger and Schurch *et al.*, (1977) respectively. Significant age differences in the number of days open were observed (Table X) largely, but not entirely, due to differences in the interval from calving to first service (pp 65,66).

THE INTER-SERVICE INTERVAL

The majority of returns to first service occurred 18-24 days after the first breeding (Fig. 11) with a peak at day 20. This corresponds with the generally accepted interval for normal interservice periods and is comparable to 20 days reported by NZDB (1963), 21 days reported by Møller and Van Demark (1951), Flerchinger and Erb (1954), Pelissier (1972, 1976) and Wood (1976a) and 22 days reported by Olds and Seath (1954). Examination of Fig. 9 for the two year old cattle, however, shows a slight variation from that of the other age groups (Figs. 10 and 11) in that the majority of returns occurred 17-23 days later, a finding which supports the slightly shorter return interval described in younger animals (Hammond, 1927; Chapman and Casida, 1937; Asdell, 1946 cited by Salisbury and Van Demark, 1961).

Using the frequency distribution for service interval information shown in Figs. 9, 10 and 11 it is possible to make an estimate of heat detection efficiency during the first 45 days after first service. During the 45 day period 1476 cows returned to service and were mated again with the majority of second matings occurring during the 18-24 day (794 cows) and 37-45 day (271 cows) periods. It is reasonable to assume that the former group represents animals which were correctly detected and mated when in oestrus at their initial mating but failed to conceive either because of lack of fertilisation or some other problem - they have then undergone a normal inter-oestral interval. The latter group of 271 cows are likely to be animals that have had two oestrous cycles the first of which was missed at 18-24 days after breeding. It is possible that such cycles went unobserved because of lack of signs of oestrus (so called 'silent heat'); a more likely explanation however is failure to observe heat by the farmer since the incidence of 'silent heat' is low in the late post partum period (Kidder et al., 1952; Labhsetwar et al., 1963; Morrow et al., 1969 a).

One estimate of detection efficiency could be calculated as follows:

$$\frac{\text{Cows correctly detected at 18-24 days after first breeding} \times 100}{\text{*Cows cycling at 18-24 days after first breeding}}$$

$$= \frac{794 \times 100}{794 + 271} = 74.6\%$$

Errors inherent in such an estimate and unaccounted for are those associated with embryonic loss and other causes of aberrant oestrous cycles at present not understood. These are more likely to be associated with the 37-45 day period rather than with the 18-24 day period; if these factors could be taken into account they would improve the estimate of detection efficiency. There was little difference in heat detection efficiency between the two year old (71.4%) and older cattle (75.4%) when estimated in the same way (Figs. 9 and 10).

*This is estimated from the cows correctly detected at 18-24 days after first breeding plus cows detected at 37-45 days after first breeding and assumed to have been missed at the 18-24 day period.

The mean interval elapsing between first and second services was 43.7 days which is similar to the 41 day interval reported by Spalding et al. (1975) but considerably longer than the 32.4 and 35 day intervals reported by Olds and Seath (1954) and Flerchinger and Erb (1954) respectively.

Olds and Cooper (1970b) noted that the mean number of days between first and second service varied according to the post partum interval when the first service took place; thus for cows bred less than 36 days post partum the interservice interval was 38.6 days while cows bred after 35 days post partum had an interservice interval of 45.7 days. The difference was apparently due to the high number of short returns (1-17 days) in the former group. While this interaction was not looked for in the present study, it is noteworthy that only 5% of animals were bred up to and including the 36th post partum day.

The percentage of long return intervals (more than 25 days) in this investigation was 49.5% out of all returns between the first and second services (Table VIII). While the overall incidence of long returns to first service is thus comparable to information published in North America, it is very different from that reported for New Zealand Seasonal Supply Dairy Herds in respect to returns longer than 49 days (see Table XXI).

A high incidence of long returns will clearly lengthen the inter-calving interval. Though it is not possible from the information available to determine the exact cause for this high incidence of long returns it is most likely to be associated with poor heat detection (Erb and Flerchinger, 1954; Pelissier, 1972, 1976). Other possibilities include conscious management decisions to withhold animals from breeding after the first service, and embryonic death or other genital diseases. Erb and Flerchinger (1954) have previously suggested that long returns to service are an important source of loss to dairymen for similar reasons.

TABLE XXI: PERCENTAGE OF LONG RETURN INTERVALS REPORTED BY VARIOUS RESEARCHERS

Reference	Percentage of Long Returns (25-49 days) (\geq 49 days)	
<u>N.Z. Seasonal Herds</u>		
Castle (1963)	24.7	
NZDB Survey (1963)	23.6	
Macmillan (1970)	22.7	in Auckland HIA
Macmillan (1970)	20.4	in Taranaki HIA
Macmillan <u>et al.</u> (1977b)		2.7
<u>American Herds</u>		
Olds & Cooper (1970b)	34.8*	16.9*(a)
Olds & Cooper (1970b)	32.3**	28.1**(b)
Study reported in this thesis	23.9	25.6

* Calving to first service interval less than 36 days

** Calving to first service interval more than 35 days

(a) Percentage of long returns 25-47 days only

(b) Percentage of long returns more than 47 days

If, as Salisbury and Van Demark (1961) and Macmillan and Watson (1975a) suggest, 25-33 day returns are the most appropriate indirect measure of early embryonic death in cattle, then this would not appear to be of great significance as a cause of long returns in the animals investigated in these herds since only 7.1% of all returns to first service fell into the 25-33 day category (see Table IX). Approximately 17% of returns however were in the 34-49 day period which is more likely to be explained by missed heats.

In addition to the major peak of returns at 17-23 and 18-24 days for two year old and other age groups respectively, an important secondary peak of returns occurs 8-10 days after first breeding; this tends to show some irregularity for the two year old cattle probably

because of the limited number of animals in the sample (Fig. 9). This secondary peak occurs again 18-21 days later with some slight variation according to the age of cattle concerned e.g. 28-29 days after first breeding for two year old cows and 31 days later for the three year old and older cows. It is probable that this short inter-service interval after the initial breeding represents an actual oestrous cycle of short duration; it is a phenomenon that was first noted in the 1959 and 1961 fertility surveys carried out by the NZDB (1963) and which was described by Macmillan and Watson (1971) in cattle in New Zealand. According to this report the phenomenon was associated particularly with three year old cows in large herds. The incidence of 8-10 day returns was highest among three year old cows in the present study (Table XI).

It is generally considered that a high incidence of short return intervals (1-17 days) is indicative of a heat detection problem although fertile short cycles of 8-10 days have been reported as mentioned above. If this is the case, the incidence of short returns in the Town Supply Herds investigated (11.6%) was no worse than reports for Seasonal Supply Herds in this country (see NZDB Survey, 1963 - 11.7%; Castle, 1963 - 10.5%; Macmillan, 1970 - 18% in the Auckland Herd Improvement Association and 16.3% in the Taranaki Herd Improvement Association). They do, however, compare unfavourably with reports for American and British dairy herds where the incidence of short returns has been recorded as 3.5% in American herds (Flerchinger and Erb, 1954; Moeller and Van Demark, 1951) and 5% in British herds (cited by Macmillan 1976b). The major reason for the between country differences seems to be associated with a policy of liberal heat detection in New Zealand dairy herds brought about by the strong emphasis being placed on concentrated calving in these herds (Macmillan, 1976a). Town Supply Farmers operating in the same environment are probably influenced to some extent by these policies. Furthermore, until recently there appears to have been a strong emphasis in the U.S.A. and U.K. on not breeding an animal until 60 days post partum, thus leading to a reduction of short returns (particularly of 8-10 days) which are generally seen in the earlier post partum period (Olds *et al.*, 1949; Morrow, 1969; Macmillan, K.L., 1978 - personal communication).

Although Macmillan and Watson (1971, 1975b) described a higher incidence of 1-17 day returns in younger cows, older age groups (5 and 7 year olds - Table X), as well as the younger age groups, showed a high incidence of short returns in this study. One would expect a higher incidence of short returns associated with detection errors in younger cows due to the high level of anoestrus seen with these ages (Fielden *et al.*, 1976), their tendency to have a shorter duration of oestrus (Hammond, 1927; Trimberger, 1948), and the phenomenon of a high incidence of genuine 8-10 day returns as described above. Why some of the older cows had a high incidence of short returns in the current investigation (Table X) remains unknown.

In view of the high incidence of long returns in the Town Supply study (49.5%) it is clear that the incidence of normal returns (18-24 days) will be low compared to that observed by Castle (1963), NZDB (1963) and Macmillan (1970, 1975b). The ratio between the 18-19, 20-21 and 22-24 day returns for the two farming systems is however approximately the same as shown below:

	<u>Town Supply Herds</u>	<u>Seasonal Supply Herds*</u>
18-19 day returns to 1st service	24%	22%
20-21 day returns to 1st service	43%	44%
22-24 day returns to 1st service	33%	33%

* Data from Macmillan (1975b).

It thus seems reasonable to conclude that, in addition to the delays from calving to first service described in this thesis, a high incidence of long return intervals was also an important component affecting the intercalving interval in Town Supply Herds.

CALVING RATE

In this particular investigation the relevant parameters studied were calving rate to first service, services per cow calving and the interval from first breeding to a conception resulting in calving.

Calving Rate to First Service

The most appropriate measure of the calving rate to first service in this study was derived from a cross tabulation programme where every cow that was bred was examined in relation to the period that had elapsed after a previous calving and before this first breeding took place. A mean first service calving rate of 49.3% was obtained. This compares with calving rates of 50.8%, 48.7%, 42.5%, 44.2% and 50% recorded by Van Demark and Salisbury (1950), Trimmerger (1954), Touchberry et al. (1959), Pelissier (1972) and Spalding et al. (1975) respectively but is lower than the pregnancy rates of 58.5%, 55.9%, 52.0%, 58% and 61.8% recorded by Morrow et al. (1966), Britt et al. (1972), Whitmore et al. (1974), Macmillan (1974) and Macmillan et al. (1977b). In-calf or pregnancy rates however are generally based on pregnancy diagnosis examinations at different stages of gestation - actual calving rates are likely to be less than the pregnancy rates because of losses between the time of examination and the date of calving. e.g. The average difference between pregnancy examinations at 60-90 days post service and actual calving rates was about 6% for American cattle (see Literature Review p 26) for further details). If this is taken into consideration the 49.3% calving rate obtained for the Town Supply Herds in this study is only marginally lower than the pregnancy rates of 58% and 61.8% recorded by Macmillan (1974) and Macmillan et al. (1977b) respectively in Seasonal Supply Herds in New Zealand.

A major factor influencing calving rate to first service was the number of post partum days that had elapsed before first breeding took place. This effect is clearly seen in Figs. 3, 4 and 7b. There was an increase in calving rate to first service during the early post partum period, reaching a level of 52.2% at 61-80 days (Fig. 4). From this point only little change occurred except at 161-180 days post partum. Since only 31 cows were represented in the 161-180 day sample however, it is unlikely that the depression seen at that time represented a true measure of performance. Table XXII shows the results reported by other workers for comparison.

When the performance of the various age groups was examined differences were apparent in the calving rate to first service with

TABLE XXII: IN-CALF, CALVING AND NON RETURN RATES (NRR) AT VARIOUS POST PARTUM INTERVALS RECORDED BY OTHER AUTHORS (Figures expressed as percentages)

Reference	Post partum intervals in days														Remarks								
	0	10	20	30	40	50	60	70	80	90	100	110	120										
NZDB Survey (1961)	←	31.3	←	43.7	←	50.4	←	55.6	←	62	←	62.9	←	-----	49 days NRR								
MMB (1966-67)	←	40	←	55	←	62	←	65	←	68	←	→	→	→	4 month NRR								
Shannon et al. (1952)	←	20.8	←	37.7	←	51	←	51.2	←	51.5	←	54.6	←	→	5 month NRR								
Van Demark & Salisbury (1950)	←	35	←	41	←	44	←	50.8	←	53.2	←	57.8	←	→	Calving rate								
Ods & Cooper (1970b)	←	26.8	←	→	→	→	→	→	→	→	→	→	→	-----	Calving rate								
Touchberry et al. (1959)	←	→	→	→	←	27.2	←	34.1	←	37.5	←	47.6	←	43.6	←	43.5	←	46.1	←	38.3	←	→	Calving rate
Britt (1975)	←	25	←	40	←	49	←	58	←	60	←	61	←	→	In calf rate								
Graves et al. (1968)	←	39.3	←	→	→	→	→	→	→	→	→	→	→	→	In calf rate								
Whitmore et al. (1974)	←	0	←	6	←	28	←	43	←	50	←	46	←	→	In calf rate								
Study reported in this thesis	←	23.5	←	32.5	←	43.9	←	52.2	←	50	←	50.8	←	→	Calving rate								

best performances generally being achieved by the mature cows (Table X). There also appeared to be an interaction between the particular age group concerned and the post partum period at which cows in that age group were first bred (Fig. 7b). In the early post partum period (up to 60 days) more three year old cows became pregnant than in the other age groups but after 60 days post partum the mature group performed at the highest level. (The marked fluctuations observed in Fig. 7b after 100 days post partum probably reflects the relatively small numbers bred at this time). Reports that young cows conceive more readily than mature cows in the early post partum period have also been published by the NZDB (1961, 1963) from studies carried out in Seasonal Supply Herds. Why such interactions exist is not at all clear; one explanation is suggested by the findings of Rasbech (1950), Butch et al. (1955) and Morrow (1969) who indicated that more rapid involution of the uterus in younger cows led to improved fertility.

In spite of the fact that younger cows bred in the early post partum period appeared to have better fertility, their overall calving rate performance was generally less than that of their older herd mates (Table X). This apparent anomaly could be accounted for by the fact that fewer young cows were submitted for breeding in the early post partum period as discussed earlier (p 65) and the majority of them, because of their delay in returning to heat after calving, had fewer open heats with a resulting depression in fertility. This point is further elaborated under services per cow calving (next section).

When cows reach the age of nine years or more they are more difficult to get in calf - in this particular study for example the calving rate to first service for cows nine years of age or more was 45% (Table X) which was lower than that for any other age group. To have remained in the herd as long as this usually means that these cows are highly selected milk producers and fertility considerations, while important, are generally secondary provided some replacement calves can be bred from them. Low calving rates to first service in old cows have been reported by many authors (see

Literature Review page 23); increased embryonic death rates in older cows may provide an explanation for this (Ball, 1976).

Services per Cow Calving

The mean number of services per cow calving of 1.71 measured during this study compares favourably with figures published by most other workers (see Table VII). However, cows which did not conceive, irrespective of how many times they were bred, were excluded from this particular analysis and hence more services than the 1.71 recorded were actually required for each calving obtained.

As with the other breeding parameters age differences occurred with respect to the number of services required per cow calving. The two year and three year old cattle and animals eight years of age and over required more services than the other age groups in the herds surveyed. Lowered fertility in older animals is not unexpected (see earlier discussion on page 64) - poor performance in the younger animals however deserves further comment. That more services per conception are required by cows which have had only one lactation, compared with mature cattle which have had three to five lactations, has been reported before by a number of other workers (Jones et al., 1941; Olds et al., 1949; Ehlers et al., 1954; Morrison and Erb, 1957; Everett et al., 1966; Hewett, 1968; Spike and Meadows, 1973; Boyd, 1977). The important question is why? One likely explanation is that younger animals have fewer open heats before breeding than their older contemporaries because of the relatively long period before they return to heat following calving - thus more services per cow calving are required. Trimberger (1954) and Whitmore et al. (1974) have both described the advantages of one or more open heats on subsequent fertility. Heat detection errors, which are more likely in the younger age groups (Macmillan and Watson, 1971, 1975b) further compound the problem.

First Service to Conception Interval (The Conception Resulting in a Calving).

The mean first service to conception interval of 11.3 days is considerably shorter than the same parameter reported by other workers

(see Table III).

It should be noted, however, that the data for first service to conception was subjected to a logarithmic transformation to improve the normality of the distribution. The detransformed information thus cannot be directly compared with the results from other workers who used arithmetic data. The unadjusted mean for the first service to conception interval was 19.3 days.

Since the first service to conception interval is closely related to the number of services per cow calving, similar differences were observed between the different age groups as were seen with the former measurement (Table X). Reasons for these differences have already been discussed (see pages 64, 66, 77).

HERD DIFFERENCES

While there are many factors which could contribute to the variation in performance noted between the twenty Town Supply Herds, e.g. geographical location, herd size, genetic quality of stock and level of management, a detailed analysis of these differences was not planned as part of this particular investigation. However, it is worth noting that some of the analyses could give a lead as to where particular problems were occurring. For example the high percentage of short returns in herds 1,2,8,10 and 20 (see Table IX) suggest a problem of heat detection (Macmillan, 1970; Macmillan and Watson, 1975a) while in Herd 5, with 26% of 25-33 day returns, a pattern of early embryonic loss may be indicated (Salisbury and Van Demark, 1961). In this second case the fact that no short returns at all were recorded, however, brings the overall recording system in use in that herd under suspicion and clearly further investigation would be warranted. It is possible that the owner of Herd 5 ignores all returns from 0-10 days and consequently records a falsely high level of 25-33 day interservice periods.

Marked differences were found between herds in milk yield and lactation length - while the reasons for this were beyond the scope of this study, similar factors to those indicated above are likely to explain the differences observed.

ASSOCIATION BETWEEN SEASON AND REPRODUCTIVE PERFORMANCE

It has been generally established that high temperature and humidity have a detrimental effect on fertility (see Literature Review). Within some temperate and colder climates however, where high temperatures are not prevalent, increasing daylight hours rather than temperature has the greater effect on fertility with improved reproductive performance occurring during the summer and fall (Mercier and Salisbury, 1947a and 1947b).

In the present investigation when calving interval, calving to first service and first service to conception intervals in days were corrected for age and herd effects the best reproductive performance occurred during the spring period (Fig. 12). The most effective measurement for determining whether any seasonal effect existed however was the calving interval because the other two parameters described may have been derived from cows calving in the immediate preceding season e.g. many cows calving during the spring period would be submitted for breeding during the summer and would therefore become a component of the statistic for calving to first service in that summer period.

Although many workers have described seasonal effects similar to those seen here not all regard season as an important cause of variation in fertility (see Literature Review). Even the results described in this study could be regarded as equivocal since New Zealand Town Supply Farmers may, by conscious management decisions, influence the type of result that can occur during any one period of the year. They, for example, tend to have two major breeding periods (late autumn / early winter and late spring / early summer) and cows which calve out of phase may be deliberately with-held for longer periods than is physiologically necessary so that they will conform with this pattern. Cows calving during the summer therefore, while they could be victims of high temperature and poor nutrition leading to impairment of fertility, could equally be victims of farming decisions of this nature.

ASSOCIATION BETWEEN YEAR AND REPRODUCTIVE PERFORMANCE

The between year differences observed in this study (Table XIII and Fig. 13) were not unexpected in view of the general dependence of Town Supply Farmers on grass grazed in situ for food supplies for their herds. In 1972 and 1975 favourable seasons for grass production occurred (New Zealand Meteorological Service Misc. Pub. 109, 1972 to 1975) and this was reflected by both higher milk production and relatively better reproductive performance than that recorded in the other two years surveyed; 1974 in particular was a poor year for pasture growth with an exceptionally wet winter during which sunshine hours were low and drought conditions prevailing during the summer and autumn periods.

ASSOCIATION BETWEEN BREED AND REPRODUCTIVE PERFORMANCE

The majority of Jersey cattle in this investigation were in Herd 19 which was in fact a pedigree Jersey Herd. Because of this very uneven distribution of breeds it was not possible to carry out an appropriate analysis of the data to determine whether real breed differences in performance existed. Herd effects in fact were responsible for the differences observed (see Tables XVII and XVIII).

Nevertheless there appeared to be a trend indicating better reproductive performance by Jerseys than by Friesians with crosses between these two breeds occupying an intermediate position (Table XIV). Jersey cattle have been reported to be reproductively more efficient in both tropical countries (Narvaez Ramirez, 1951; Wijeratne, 1970; Velasco, 1971 cited by Vaccaro, 1973) and also in temperate regions (Lewis and Horwood, 1950a; Everett et al., 1966; McDowell et al., 1974; Gwazdouskas et al., 1975; Matsoukas and Fairchild, 1975; Slama et al., 1976), although survivability of Jersey calves has been recorded as inferior to Friesian calves in the New Zealand environment (Macmillan, 1973).

ASSOCIATION BETWEEN ABORTION AND REPRODUCTIVE PERFORMANCE

Although the number of animals which were recorded as having an abortion was small the evidence suggests that the reproductive performance of these cows was considerably impaired when they were compared with cows having normal gestations (Table XV). While

the period between abortion and when these cows were first served appeared to be prolonged (110 days for abortion cows compared with 84 days for normal cows) their ability to become pregnant once breeding commenced (see under B class cow, Table XV), as can be seen by comparing the days open for each group, was substantially reduced. Similar effects of abortion on fertility have been recorded by other workers (Morrison and Erb, 1957; Morrow, 1969; Morrow *et al.*, 1969a; Kelly and Holman, 1975; Galton *et al.*, 1977a, 1977b).

THE RELATIVE IMPORTANCE OF DAYS FROM CALVING TO FIRST SERVICE AND FIRST SERVICE TO CONCEPTION ON CALVING INTERVAL

The interval from first service to conception had a slightly greater effect on the calving interval than did the interval from calving to first service since a change of one standard deviation unit in either interval led to a calving interval change of 0.73 and 0.63 standard deviation units respectively (see standard partial regression coefficients, p 55 of results). Olds and Cooper (1970b) reported similar results in their study of dairy cattle fertility in Kentucky, USA where the correlation coefficients for first service to conception and calving to first service on calving interval were 0.8 and 0.6 respectively.

Because 'conception' rate tends to be more variable in cows mated during the first sixty days post partum than in cows mated after this time (see Figs 4 and 7b) a second analysis was carried out excluding records of animals bred before the sixtieth post partum day (this resulted in 26% of records being discarded). The standard partial regression coefficients obtained were 0.73 for the interval from first service to conception and 0.59 for the interval from calving to first service, a result which was little different from that obtained in the first analysis when all records were included.

The predicted values for calving interval (\hat{y}) from the multiple regression analysis where two of the variables were transformed were difficult to interpret. Results of the analysis were therefore displayed (see Fig. 14) by obtaining the predicted values of \hat{y} (calving interval - converted to the original arithmetic scale) for separate factual ranges for each of the two (χ) variables (days from calving to

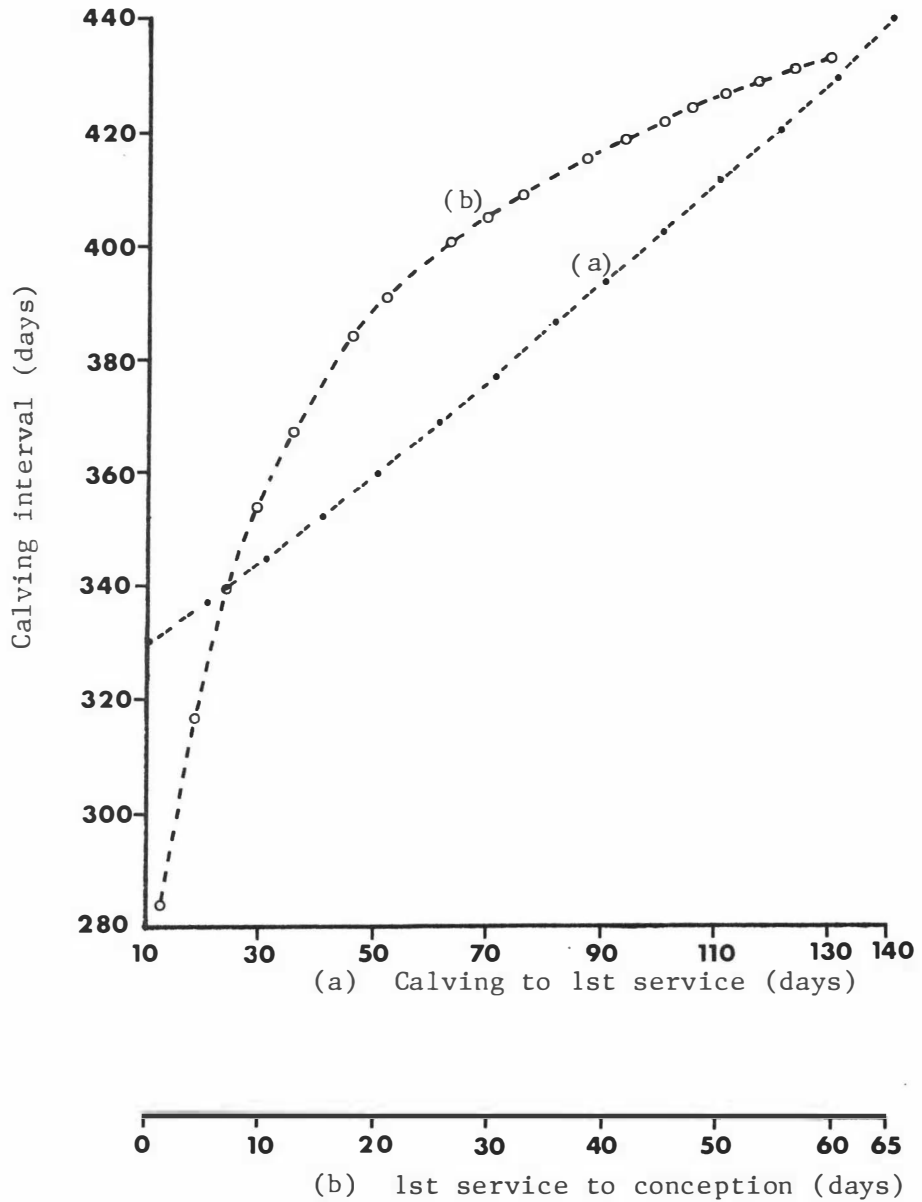


Fig 14: Relationship Between Calving Interval and the Intervals from Calving to First Service and First Service to Conception.

first service (χ_1) and first service to conception (χ_2).

The estimates for the regression coefficients were used to estimate the effects separately for each of the two independent variables by dividing the overall equation:

$$(\hat{y} - \bar{y}) = b_1 (\hat{\chi}_1 - \bar{\chi}_1) + b_2 (\hat{\chi}_2 - \bar{\chi}_2)$$

into two parts

$$(\hat{y} - \bar{y})_1 = b_1 (\hat{\chi}_1 - \bar{\chi}_1) \text{ and } (\hat{y} - \bar{y})_2 = b_2 (\hat{\chi}_2 - \bar{\chi}_2)$$

where \bar{y} is the log log value for calving interval

χ_1 is the arithmetic value for the interval from calving to first service

χ_2 is the log value for the interval from first service to conception

b_1 is the partial regression coefficient relating \hat{y}_1 to χ_1

b_2 is the partial regression coefficient relating \hat{y}_2 to χ_2

Using the information from Fig. 14 and the calving rate values obtained in this study for breeding at different post partum periods (Fig. 4), it is possible to predict the number of services required per cow calving, the number of cows which should calve after a defined service period, and the mean calving interval for these cows (see Table XVI).

From this table it can be seen that while calving intervals of less than 350 days are theoretically possible (by breeding early in the post partum period), large numbers of services are required. Furthermore there are two practical limitations to such early breeding, a below optimum level of milk production (see Literature Review p 3) and the fact that New Zealand dairy cattle on average do not have their first post partum ovulation, let alone show overt heat, until 36 days after calving in the case of mature animals and 52 days after calving in the case of two year old heifers (Moller, 1970b). If breeding is delayed until after the sixtieth post partum day, it is not possible to achieve the desired 365 day intercalving interval unless 'conception' rates can be improved.

It would appear desirable therefore to commence breeding, in the Town Supply Dairy Herds studied here, shortly after the fortieth post

TABLE XVI: EXPECTED EFFECT OF BREEDING AT DIFFERENT POST PARTUM INTERVALS ON THE DEMAND FOR SERVICES, NUMBER OF COWS CALVING AND MEAN CALVING INTERVAL*

Interval from calving to 1st service (days)	Probability of cow calving (see Fig. 4)	Interval from calving to 1st service (days)							
		1-20	21-40	41-60	61-80	81-100	101-120	121-140	141-160
1-20	0.24	100.00							
21-40	0.33	76.00	100.00						
41-60	0.44	50.92	67.00	100.00					
61-80	0.52	28.52	37.52	56.00	100.00				
81-100	0.50	13.69	18.01	26.88	48.00	100.00			
101-120	0.51	6.85	9.08	13.44	24.00	50.00	100.00		
121-140	0.52	3.36	4.41	6.59	11.76	24.50	49.00	100.00	
141-160	0.58	2.61	2.12	3.16	5.65	11.76	23.52	48.00	100.00
No. of cows that will calve after the service period		98.9	99.1	98.7	97.6	95.1	91.1	88.7	
Total services required for the cows that calve		281.95	238.04	206.07	189.41	186.26	172.52	148.00	
Mean calving interval (predicted from Fig. 14)		330	345	360	375	393	411	430	

*Predictions calculated on basis of 100 cows submitted for breeding.

partum day if a 365 day intercalving interval is to be achieved. Only in those herds where 'conception' rates are higher than the mean recorded in this investigation, should a longer post partum period before breeding commences be contemplated. Olds and Cooper (1970b) have suggested a similar approach based on their results in Kentucky.

The author appreciates that another approach to reducing the calving interval is that of shortening gestation length; this has been taken as constant at 282 days in the calculations discussed in this thesis (see p 32). Techniques for the induction of parturition before term in cattle have been described (Welch et al., 1973) and quite widely used in New Zealand dairy herds. However, because of the costs and other potential hazards associated with this procedure (Moller, 1978) it seems unlikely, at the present state of technology, that this approach will be used extensively enough to have any significant influence on calving intervals in the national dairy herd.

THE RELATIONSHIP BETWEEN THE CALVING TO FIRST SERVICE AND FIRST SERVICE TO CONCEPTION INTERVALS

There was a negative correlation between these two parameters ($R = -0.099$ see p55); Touchberry et al. (1959) have reported similarly. This is understandable in view of the fact that the number of services per 'conception' tends to decrease as the post partum interval before breeding increases, at least up to the sixtieth post partum day. Because of the importance of both parameters on calving interval, however, as indicated in the previous section, a management compromise must be reached by breeding earlier and accepting a slightly higher number of services per 'conception' if a 365 day intercalving interval is to be achieved.

HERD SIZE

A number of authors have reported a decline in 'conception' rate with increasing herd size (Hewett, 1968; Spike and Meadows, 1973; Lauderdale, 1974; Macmillan, 1975b; Spalding et al., 1975). Macmillan (1975b) explained this decline in New Zealand dairy herds as being due to an increase in the number of 'genuine' short cycles (8-10 days) in larger herds (Macmillan and Watson, 1971) and largely to an increase in the incidence of errors during heat detection (Macmillan et al., 1973).

While there was a tendency for the calving interval and first service to conception interval to increase in the larger herds in this investigation, the result was not statistically significant (p 58). It is likely that the number of herd studied did not yield an adequate sample within various size ranges to allow any conclusive interpretation to be made. Moreover, even the smallest herd in this study consisted of 75 cows.

EFFECT OF PRODUCTION ON REPRODUCTIVE PERFORMANCE

When yield per cow per lactation was considered there was a significant positive correlation with calving interval (0.326), calving to first service interval (0.172) and first service to conception interval (0.211). This agrees with the reports of many other authors (Lewis and Harwood, 1950a; Rennie, 1956; Miller et al., 1967; Morrow, 1969; Dawson, 1972; Spike and Meadows, 1973; Wagner, 1974; Spalding et al., 1975). High milk yields, however, are influenced markedly by lactation length (McDowell et al., 1976). An increased length of lactation is likely to be found in animals which remain open for long periods because there will be no depressant effect associated with gestation. Under these circumstances the high yield may be a result rather than a cause of the poorer breeding performance of these cows.

It seems more reasonable therefore, to examine the relationship between production prior to and/or during the breeding period and reproductive performance rather than considering the relationship with total yield. The authors who have done this (see p 26 Literature Review) have reported that any relationship that exists is small and of little consequence. In the current investigation it was the average daily yield throughout lactation that was considered; the negative correlations found were so small as to have little effect. Since the information examined was from data pooled from all the herds there were many other variables which could not be taken into consideration which may have confounded this result.

THE IMPORTANCE OF HERD, AGE, SEASON, YEAR AND BREED ON THREE PARAMETERS OF REPRODUCTIVE PERFORMANCE AND ON MILK PRODUCTION

While it was not possible to study all the variables in one

analysis for reasons outlined earlier (see Materials and Methods, p 32) a series of two way analyses were carried out to determine whether effects observed were due to the main effects of the variables or to their interactions (see Tables XVII and XVIII).

Herd, age, season and year have all had significant effects on the three breeding parameters studied and while there were significant interactions between herd and age, herd and season, and age and season on most of these parameters the effect of the interaction was relatively small compared to the effect of the two main variables (see F values and tests of significance - Table XVII). More important, however, is the fact that the amount of variation in breeding performance that could be ascribed to any of these variables was remarkably small (see Table XVIII). This is not unexpected in view of the vast array of factors that can influence the reproductive performance of each individual animal as outlined in the Literature Review at the beginning of this thesis.

The value of undertaking this series of two way analyses was best illustrated in respect to the findings relating breed effects to reproductive performance. On initial examination it appeared that there was a very clear case in favour of the Jersey breed having better reproductive efficiency than the Friesians in the population studied. As explained in an earlier section of the discussion (p 80) the majority of Jersey cattle were in one herd which proved to be one of the better herds as far as reproductive efficiency was concerned. The superiority of the Jersey cows therefore could simply be explained by this herd effect.

As far as milk yield was concerned significant interactions were found between herd and age, and herd and year, but again they were small compared with the main effects of herd, year and age (Table XVIII). Production differences between properties can be explained by many factors such as level of management, local topography and climate, and stage of development, while age differences in production have been recognised for many years. Furthermore, under a farming system that depends largely on grazing pasture in situ, favourable years for pasture growth are inevitably reflected by higher levels of milk production and

this proved to be the case in this investigation (see earlier discussion, p 80).

It is not surprising therefore, that much more of the variation in yield could be explained by the variables investigated (Table XVIII) than was the case for calving interval and other measures of reproductive performance.

GENERAL CONCLUSIONS

1. Available evidence points strongly to a 365 day intercalving interval as being optimal for economic production in dairying. Since the average value for this interval was 384 days in the study reported in this thesis, it is desirable that methods for improving reproductive efficiency in Town Supply Herds be sought.

The target of a 365 day calving interval was nearly achieved by two of the herds investigated (see Herds 16 and 19, Table VIII) although at what cost, in terms of animals culled for infertility, is not known. Calving interval does not take account either of animals which only calve once, or animals intended to be bred that never calve at all. This is a serious disadvantage of the parameter as an estimate of reproductive efficiency. An annual live calf rate, related to all animals either entering or in the herd and intended for breeding, would be a more appropriate index of breeding efficiency.

2. The average interval from calving to first service and from first service to conception was 84 and 11 days respectively in this investigation. This indicates delayed breeding and a 365 day calving interval is therefore not possible. If the calving to first service interval could be reduced by the simple management procedure of breeding each cow between 46-66 days post partum, a 365 day calving interval would be achieved (Table XVI). Such an approach depends on all animals intended for breeding showing overt heat during this time, a practical proposition provided management practices geared to effective feeding and efficient heat detection are applied.

An alternative to breeding earlier in the post partum period would be to increase 'conception rate' - apart from improving detection efficiency, however, practical procedures for achieving any substantial lift over a large population of animals do not at the present time seem to be available.

3. A high incidence of short (11.6%) and long (49.5%) return intervals to first service, together with a mean inter-service interval of 44 days, demonstrate that missed heats and detection

errors were important contributing factors to the prolonged calving intervals and high number of services per cow calving recorded in these Town Supply Herds. Improved detection procedures as outlined in the Literature Review, together with routine pregnancy testing of cows six to eight weeks after they are bred, would help reduce such deficiencies.

4. Because the spring period clearly resulted in the best reproductive performance, compared with the other seasons of the year, as high a proportion of the herd as possible should be bred at this time. The extent to which this could be done depends on milk quota requirements, especially during the difficult winter period. It is inevitable that a proportion of cows must be bred to calve during the autumn in order that they will be producing at their most efficient per unit of feed consumed when costs are at their highest.

5. The reproductive performance of the younger age groups of cattle, particularly the two year old cows, was poor. Since they constitute a relatively high proportion of the animals in a herd, any improvement in reproductive efficiency achieved with this group could have considerable influence on herd performance.

High levels of anoestrus (Fielden et al., 1976) and a slow return to cyclical activity after calving (Moller, 1970b) have already been established as characteristics of younger cows in Seasonal Supply Herds in New Zealand; more attention to the nutritional needs of the group has been suggested as the way to solve the problem. A similar situation is likely to apply in the Town Supply industry.

6. More research is needed if reasons for the considerable differences in reproductive efficiency observed between herds are to be further defined. It seems likely, however, as illustrated by the variation between herds in return interval analyses, that the general breeding policies and managerial skills of the owner play a major role in determining the level of reproductive efficiency achieved. Never-the-less the multiplicity of factors concerned with the reproductive process under field conditions, together with the experience gained during this study, suggest that even the most

sophisticated investigation is unlikely to explain more than a small proportion of the total variation in reproductive performance that is observed.

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APPENDICES

TOWN MILK HERD REPRODUCTIVE EFFICIENCY INVESTIGATION

<p>Herd</p> <table border="1" style="width: 100%; height: 30px; border-collapse: collapse;"> <tr> <td style="width: 50%;"></td> <td style="width: 50%;"></td> </tr> </table> <p>1 2</p>			<p>Cow</p> <table border="1" style="width: 100%; height: 30px; border-collapse: collapse;"> <tr> <td style="width: 33%;"></td> <td style="width: 33%;"></td> <td style="width: 33%;"></td> </tr> </table> <p>3 4 5</p>				<p>Age</p> <table border="1" style="width: 100%; height: 30px; border-collapse: collapse;"> <tr> <td style="width: 100%;"></td> </tr> </table> <p>6</p>		<p>Breed</p> <table border="1" style="width: 100%; height: 30px; border-collapse: collapse;"> <tr> <td style="width: 100%;"></td> </tr> </table> <p>7</p>		<p>Fate</p> <table border="1" style="width: 100%; height: 30px; border-collapse: collapse;"> <tr> <td style="width: 100%;"></td> </tr> </table> <p>8</p>			
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<p>4th Calving</p> <table border="1" style="width: 100%; height: 30px; border-collapse: collapse;"> <tr> <td style="width: 25%;"></td> <td style="width: 25%;"></td> <td style="width: 25%;"></td> <td style="width: 25%;"></td> </tr> </table> <p>69 70 71 72</p>					<p>5th Calving</p> <table border="1" style="width: 100%; height: 30px; border-collapse: collapse;"> <tr> <td style="width: 25%;"></td> <td style="width: 25%;"></td> <td style="width: 25%;"></td> <td style="width: 25%;"></td> </tr> </table> <p>73 74 75 76</p>									