THE USE OF RETURN INTERVAL PATTERN TO INDICATE DAIRY HERD INFERTILITY PROBLEMS

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SUMMARY

In this paper the causes of variation in the non-return rates of herds using Artificial Breeding in New Zealand are examined. The herds have been divided into four non-return rate groups according to their deviation from the average of all herds in the same A.B. technician group, and the percentage of short, normal, and long return intervals in the four groups has been used to estimate the incidence of such factors as failure to conceive and embryonic mortality. Some assumptions have had to be made, but the estimates provide background information for field studies on these aspects. They enable an assessment to be made of the relative importance of factors causing variation in herd non-return rates, failure to conceive and embryonic mortality appearing to be equally important. The problem of locating "true" problem herds for survey work has been examined and it has been found that the field can be narrowed by taking the return interval pattern as well as the non-return rate into account.

It is a quarter of a century since the Dairy Board carried out its first survey of dairy herd fertility and for many years, until the early 1950's in fact, service details from a number of naturally mated herds were collected annually. The information was used to assess the variation in bull, cow and herd fertility, to study some of the factors associated with this variation, and initially to explode such theories as the one that high-producing cows are more difficult to get in calf than low-producing cows. But in later years the information was a valuable guide to trends, or rather to the lack of trends, in dairy herd fertility. Over the years there have been fairly regular outbreaks of concern because infertility appeared to be increasing. This was particularly noticeable when the Dairy Board's 1949–50 wastage surveys showed that there was an increase in the percentage of cows culled for sterility and late calving. The statement that this increase was due to penicillin treatment having reduced the number of cows culled for mastitis, enabling farmers to cull more heavily for infertility, might not have carried much weight had it not been backed by information from the fertility surveys, which showed that the percentage of cows in calf to first service and the percentage of cows not in calf at the end of the mating season had remained about the 62% and 7% mark, respectively, for 10 years at least.

It will be appreciated that the collection of service details from naturally mated herds was not the most popular of the projects undertaken by the Board's officers, and there was probably just as much energy expended in surveying 200 of these herds as there is expended at present in analysing artificial breeding records for four or five thousand herds. As artificial breeding increased, therefore, the collection of information from naturally mated herds was reduced to occasional field surveys carried out mainly to provide a basis for comparing A.B. and natural mating results.

Artificial breeding records have two very real advantages over natural mating records for studying variation in herd fertility. First, bull and herd effects are not confounded and, secondly, reliable records are readily available for a much larger sample of herds over a period of years. Insemination details are recorded daily on insemination certificates and the information is transferred to punched cards to be used in the first place for working out routine statistics of interest to the bull centres and herd improvement associations, then for more detailed study of certain aspects of A.B. operations and, finally, for research into factors associated with variation in herd non-return rates.

Thus information on herd fertility is now just a by-product of routine A.B. operations, and like many by-products it has tended to be pushed aside in favour of the problem of improving the main product. Until a year or two ago, A.B. records were used mainly to provide material for operational research aimed at improving the quality of the semen issued from the Centres, and rightly so, too, for nationally this is likely to be the most profitable line of approach to the problem of increasing conception rates in A.B.

In his paper on dairy herd fertility, Shannon (1962) dealt with the variation in herd non-return rates in any one year, partitioning the variance into that due to technician differences, sampling variation, and "true" herd differences. Because he had found that a considerable portion of the variation in herd non-return rates in A.B. herds was due to sampling variation or "chance" as he called it, he concluded that a study of herd records would be unlikely to give rapid improvement.

While this is true in general, it does not mean that herds that would benefit considerably from a detailed examination of their problems just do not exist. It means that there are not enough of them for the solution of their problems to make much difference to the national average. However, although expensive research into this aspect is probably not justified, it is possible that, by examining, on paper, the reasons for variation in herd non-return rates, some profitable lines for research into herd fertility problems, either through experimental work or field studies, may be discovered. One further aspect that will be dealt with in this paper is the question of how to distinguish "true" problem herds from those experiencing a temporary run of bad luck, the only reason for which is likely to be statistical. It is this aspect, incidentally, which is mainly responsible for the view that research into herd fertility records is likely to be unrewarding.

DESCRIPTION OF THE DATA

The study is based on 1,930 herds in the Auckland Herd Improvement Association in which at least 50 cows were inseminated with chilled semen in 1960 and which were in the A.B. scheme again in 1961. The non-return rate for this sample, which includes two-thirds of all the cows inseminated by the Auckland Association in 1960, is 62. This is the same as the figure for the whole Association.

The official non-return rates for A.B. in New Zealand are based on first inseminations only and on a non-return period of 49 days. Thus, the non-return rate is the number of cows out of every hundred inseminated for the first time that do not return within 49 days. For example, if the non-return rate is 62, this means that of every 100 cows inseminated 38 are either inseminated a second time or naturally mated within 49 days of the date of their first insemination.

For herds of 50 cows or more, the total variance in herd non-return rates is 88, approximately 20% of this variance being due to differences between technician groups. The remaining 80%, that due to differences between herds serviced by the same technician, is the portion that this paper deals with.

Because it is the variation within technician groups that is being studied the herds in the sample have been classified according to their deviation from the technician group non-return rate and allotted to the four groups shown in Table 1.

TABLE 1: DISTRIBUTION OF HERDS IN SAMPLE ACCORDING TO THEIR DEVIATION FROM THE AVERAGE NON-RETURN RATE OF ALL HERDS IN THE SAME TECHICIAN GROUP

Description of Non-return Rate Group	*No. of Herds*	*% of Herds*	*Average Non-return Rate*
Group 1 — Herds 5 or more *above* technician group average	577	30	70.0
Group 2 — Herds within ±4 of technician group average	855	44	61.9
Group 3 — Herds 5 to 9 *below* technician group average	296	15	54.1
Group 4 — Herds 10 or more *below* technician group average	202	11	48.0
All herds in sample	1,930	100	61.7

These four groups form the basis of this study and when referring to them collectively the term "non-return rate group" will be used to distinguish them from technician groups. Individually they will be referred to by their numbers. Group 1 with an average non-return rate of 70 consists of 577 herds with non-return rates 5 or more above the technician group average in 1960. Group 2 are the "average" herds, their average non-return rate of 62 being the same as the Association figure.

As the main interest is in the herds below average, these have been sub-divided into Group 3 with 296 herds which were 5 to 9 below the technician group average and Group 4 with 202 herds with a non-return rate of 10 or more below the group. The 11% of herds in Group 4 are the ones which have had really disappointing results — the majority of them would have more than half their cows returning to their first service and by the end of the A.B. period probably only about 70% of the cows inseminated would be in calf.

PATTERN OF RETURN INTERVALS

The other information used is the pattern of return intervals in the four groups and this may be regarded as the probe used to examine the reasons for variation in herd non-return rates. What are the main reasons for cows returning to service and how are they likely to affect the return interval pattern?

First, the cow may not have ovulated either because, owing to faulty observation on the part of the farmer, she was not on heat when she was inseminated, or because she was suffering from some condition such as cystic ovaries.

In either case these cows are likely to return to service after a short interval.

Secondly, the cow may have been cycling normally, and have ovulated but not conceived. Most of the cows in this category will return to service after a normal interval although, largely owing to faulty observation of heat or silent heats, a few will be recorded as having returned after short or long intervals.

Thirdly, the cow may have conceived and the embryo have died. Early embryonic mortality will not affect the return interval but late embryonic mortality will mean a delayed return.

It is safe to assume that some or all of these factors causing a low non-return rate will be operating to a greater extent in Groups 3 and 4 than in Groups 1 and 2, and as they all influence the return interval pattern it should be possible by studying the pattern in the four different groups to get some indication of the relative importance of these factors in causing variation in herd non-return rates.

The distribution of return intervals following the first insemination in the four non-return rate groups is given in Table 2. An interval of less than 18 days is regarded as short, of 18 to 24 days as normal, and of 25 to 49 days as long.

TABLE 2: DISTRIBUTION OF RETURN INTERVALS IN THE FOUR NON-RETURN RATE GROUPS

Non-return Rate Group	*% of Return Intervals that were*		
	Less than 18 days	*18 to 24 days*	*25 to 49 days*
Group 1	9.9	65.9	24.2
Group 2	10.5	64.8	24.7
Group 3	12.2	64.3	23.5
Group 4	14.7	60.9	24.4

The distribution in Group 2 gives the average picture — 10% of the return intervals are less than 18 days, 65% are 18 to 24 days in length, and 25% are 25 to 49 days in length. This must not be regarded as typical of the distribution of oestrous cycle lengths following natural mating in New Zealand, particularly so far as the short intervals are concerned, as some cows are inseminated when not actually on heat.

The pattern varies at the different non-return rate levels, the percentage of intervals that are normal decreasing as the non-return rate decreases. The corresponding increase takes place in the short intervals while the proportion of long intervals remains fairly constant. This, incidentally, is different from the trend shown in naturally mated herds where the proportion of short intervals remains the same at all levels and the proportion of long intervals increases as the herd non-return rate decreases.

ESTIMATE OF FACTORS CAUSING DIFFERENCES IN HERD NON-RETURN RATE

As mentioned earlier, the proportion of cows returning to service is determined largely by:

(1) The percentage of cows with false heats or which were inseminated in mid-cycle.
(2) The percentage of embryos that die.
(3) The percentage of ova not fertilized.

But these three factors, together with the percentage of long cycles or multiple cycles due to missed or silent heats, largely determine the return interval pattern also. It is therefore possible to obtain expressions for the percentage of short, normal and long intervals in terms of the four factors which influence the return interval pattern and, by equating these to the actual percentages in each non-return rate group, values for the different factors can be obtained (see Appendix).

TABLE 3: ESTIMATED INCIDENCE OF FACTORS INFLUENCING NON-RETURN RATES IN THE FOUR GROUPS

Non-return Rate Group	*% of Cows not Ovulating*	*% Ova not Fertilized (or Early Embryonic Deaths)**	*% of Late Embryonic Deaths*
Group 1	3	23	7
Group 2	4	29	10
Group 3	6	35	12
Group 4	8	38	16

* Assuming that only one ovum is shed by each of the cows that ovulate.

PERCENTAGE OF COWS WITH FALSE HEATS OR WHICH WERE INSEMINATED IN MID-CYCLE

By making the assumption that all the cows in the short interval group are in this category the following estimates of the incidence in the four groups are obtained. Group 1 — 3% ; Group 2 — 4% ; Group 3 — 6% ; Group 4 — 8%. These are shown in the first column of Table 3.

PERCENTAGE OF EMBRYOS THAT DIE

Oddly enough it is necessary to estimate the embryonic mortality before dealing with the percentage of ova not fertilized. The only estimate that can be made at this stage is of late embryonic mortality because the death of the embryo in the very early stages would not affect the cycle length. Here it is necessary to make not so much an assumption as an educated guess at the percentage of long or multiple cycles because this will also affect the proportion of long return intervals. Approaching the problem in two different ways, it appears that it will be between 5% and 10%. Fortunately, whether a value of 5% or 10% is used makes very little difference to the estimate of late embryonic mortality (see Appendix). The estimates of late embryonic mortality based on the assumption that the percentage of long or multiple cycles is 10%, for the four groups are as follows: Group 1 — 7%; Group 2 — 10%; Group 3 — 12%; Group 4 — 16%. These are given in the third column of Table 3.

The estimate of 10% for Group 2, the average group, is only slightly less than the estimate given by Robinson (1957). His estimates of early and late embryonic mortality are of interest at this stage. They are based on experiments carried out by several different workers all on very small numbers of cows. In these experiments, of every 100 ova shed 90 were fertilized, 10 of these died so early that they did not affect the cycle length and 10 more died prior to implantation but late enough to affect the cycle length. On this basis his estimate of early embryonic mortality would be 10/90 or 11% and of late embryonic mortality as calculated in this study 10/80 or 12.5%. Opinions vary as to when implantation is completed but the most commonly accepted figure seems to be 40 to 45 days. If this is so, it is probable that the majority of the delayed returns resulting from late embryonic mortality would be included in the 49-day period being dealt with. Thus the estimate of 10% as compared with Robinson's 12.5% is reasonable.

Percentage of Ova not Fertilized

If it is assumed that all the cows that have not returned to service within 49 days are still carrying live embryos, then using the estimates of late embryonic mortality and the non-return rates in the four groups, an estimate can be made of the percentage of the ova shed that were not fertilized or that were fertilized with the resulting embryo not surviving the early stage. These figures, because early embryonic mortality is included as well, will over-estimate the true percentage of ova not fertilized. They are given in the second column of Table 3 and are as follows: Group 1 — 23%; Group 2 — 29%; Group 3 — 35%; Group 4 — 38%.

These estimates, which give the trend in incidence of the three factors in the different groups, can now be used to indicate the amount of improvement in non-return rate that can be achieved through attention to any one of them.

For example, in Group 4, which probably contains most of the problem herds, 8% of cows inseminated do not ovulate, either because of a higher incidence of cystic ovaries or because of faulty observation of heat. If this incidence could be reduced to the figure for the "average" group, Group 2, four more cows in every hundred inseminated in Group 4 would ovulate. However, if the incidence of the other factors remained at the Group 4 level, only three of the additional ova would be fertilized and survive, so that the non-return rate in this group of herds would be 51 instead of 48.

In a similar manner can be estimated the amount of improvement in the non-return rate in Group 4, achieved by bringing the other factors to Group 2 level. If the embryonic mortality in Group 4 were reduced from 16% to 10% and the incidence of the others factors remained the same, the non-return rate would be 51 instead of 48. If the percentage of ova not fertilized were reduced from 38 to 29 while the incidence of the others factors remained the same, the non-return rate in Group 4 would be 55 instead of 48.

Thus there is scope for an improvement of 7 in the non-return rate of Group 4 by reducing the percentage of ova not fertilized, of 3 by reducing the embryonic mortality, and of 3 by reducing the proportion of cows inseminated in mid-cycle or with false heats.

The estimates refer to the scope for improvement in problem herds and not to the amount of improvement that could be made in the general level of non-return rates in New Zealand which would be very small. They have been made to indicate the relative importance of the three factors in causing variation in herd non-return rates generally, and it appears that failure to conceive is the most important cause. However, it should be remembered that the effect of early embryonic mortality has also been included in this estimate. Late embryonic mortality increases as the non-return rate decreases and, as it seems likely that early embryonic mortality will vary similarly, these figures probably underestimate the influence of this factor on non-return rates. If the assumption is made that early and late embryonic mortality vary similarly, then embryonic mortality and failure to conceive become equally important causes of variation in herd non-return rates.

Here then, with reservations, is the situation as it appears on paper. To speculate on the reasons for these two factors is beyond the scope of this study but the observation can be made here that one of the important reasons for failure of fertilization is likely to be bad timing — that is, the cows are inseminated too early in heat, or else left so long that they have already ovulated by the time they are inseminated. With the technician calling only once a day some of this sort of thing is unavoidable, but no doubt some farmers observe more carefully and show better judgement than others when deciding when a cow should be inseminated, and these are the ones, incidentally, who are less likely to put cows up for insemination in mid-cycle. This point is made merely to indicate that field studies on this management aspect should prove rewarding.

LOCATING HERDS FOR FIELD STUDIES

There is one very awkward angle when it comes to field studies, namely, the fact that a lot of time and effort will be wasted unless it is possible to distinguish the "true" problem herds from those which are having a run of bad luck. One very obvious approach would be to wait until a herd has been in Group 4 for two or three years and then to classify it as a problem herd and worthy of investigation. There are a number of these herds in the Dairy Board records now which would provide a nucleus for field studies — but as a general method of approach to the problem of locating herds which need help, everyone, and farmers in particular, would agree that it leaves much to be desired!

Considering again the most important reasons for low herd non-return rates, namely, failure to conceive and embryonic mortality, it would be stretching the arm of coincidence a long way to expect that many herds in Group 4 would have the odds against them in both these factors. In most cases chance will have operated either to increase the percentage of ova not fertilized or to increase the embryonic mortality but not in both ways in the same herd. If it operated either at the fertilization stage or at the early embryonic stage the cows affected would be expected to return to service after a normal interval, so that the majority of the herds in Group 4 that have a high proportion of normal intervals are likely to be those which had the odds against them either at the fertilization stage or at the early embryonic stage. If there is anything in this theory, among herds with a low non-return rate, those with a high proportion of normal intervals should be the ones that will recover spontaneously and qualify for Groups 1 and 2 the next year, whereas those with fewer normal intervals will tend to remain in the below average bracket.

The 202 herds in Group 4 were therefore sorted into three groups according to the proportion of their return intervals that were normal in 1960 and their non-return rates in the next year, 1961, were examined. The data are given in Table 4.

TABLE 4: 1961 NON-RETURN RATE IN GROUP 4 HERDS ACCORDING TO THE PROPORTION OF NORMAL INTERVALS IN 1960
(Group 4 herds were 10 or more below the technician group non-return rate in 1960)

Proportion of Normal Intervals in 1960 Relative to Technician Group Average	*No. of Herds*	*Non-return Rate Group in 1961*					
		Group 1		*Group 2*		*Groups 3 and 4*	
		No.	*%*	*No.*	*%*	*No.*	*%*
More than 5% above average*	50	6	12	30	60	14	28
Within ±5% of average	71	12	17	21	30	38	54
More than 5% below average	81	8	10	25	31	48	59
Total — all herds in Group 4	202	26	13	76	38	100	50

* In each herd in this group, the percentage of return intervals that were normal was at least 6 percentage units higher than the average of all the herds in the same technician group.

The classification of the herds on their return interval pattern had to be done within technician groups as the percentage of normal return intervals for a whole group varies with the efficiency of the technician. The fertilization rate will be high in a group serviced by a good technician and consequently the proportion of normal intervals will be low.

Of the 50 herds with more normal intervals than average, 72% qualified for entry into Groups 1 or 2 in 1961, whereas of the herds with the same number or fewer normal intervals than average, over 50% were still in the low non-return rate groups in 1961. Thus it appears that a fruitful source of problem herds will be herds experiencing a low non-return rate in any one year and where relatively few of the cows return after a normal period.

Thus, it appears that in any one year approximately 10% of herds in A.B. have non-return rates that the owners could justifiably complain about, and that failure to conceive and embryonic mortality appear to be equally important causes of these poor results. If field studies on these aspects are to be carried out, the probability of locating "true" problem herds will be increased if attention is confined to herds which have a relatively high proportion of abnormal return intervals as well as a low non-return rate.

These studies are a very necessary preliminary to field work and while there is still more to be done in this direction, it is suggested that the next episode in this herd fertility serial might well be a report on field observations on some of these low non-return rate farms.

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APPENDIX

(1) *Method Used to Obtain Values in Table* 3

Let S be the proportion of cows inseminated that do not ovulate because of false heats or cystic ovaries. It is assumed that these cows will return in less than 18 days.

Let F be the proportion of ova fertilized and surviving the early embryonic stage.

Let E be the embryonic death rate (resulting in return intervals of 25 to 49 days).

Let M be the proportion of cows with long or multiple cycles due to missed or silent heats.

Then of the cows inseminated the proportion

that ovulate .... $= 1 - S$

in which the ovum is fertilized ...... $= F(1 - S)$

in which the embryo dies .... $= E \times F(1 - S)$

So that of cows inseminated the proportion that

do not return within 49 days ...... $= F(1 - S) - E \times F(1 - S)$

$= F(1 - S)(1 - E)$

return in less than 18 days .... $= S$

return in 18 to 24 days .... $= (1 - F)(1 - S)(1 - M)$

Example: Using the values for Group 1 in Tables 1 and 2, the percentage of intervals less than 18 days is 9.9 and the percentage of non-returns is 70 so that the proportion of cows inseminated that return in less than 18 days is $0.099 \times 0.30 = 0.03 = S$.

Similarly, the proportion of cows inseminated that return in 18 to 24 days is $0.659 \times 0.30 = 0.198 = (1 - F)(1 - S)(1 - M)$. Because $S = 0.03$ and it is assumed that $M = 0.10$, $1 - F$ or the proportion of ova not fertilized will be 0.23, and because $F(1 - S)(1 - E) = 0.70$, E will be 0.07.

(2) *Values of E for M equal to* 0.10 *and* 0.05 *in the four Non-return Rate Groups*

Non-return rate group	*Values of E where* $M=0.10$	$M=0.05$
1	0.07	0.08
2	0.10	0.12
3	0.12	0.14
4	0.16	0.19

DISCUSSION

J. W. STICHBURY: Field studies carried out in herds with poor conception rates have been able to find no cause of infertility in a large percentage of cases. This paper will greatly assist the field investigator in giving a lead on the type of problem likely to be encountered, and in indicating the type of herd in which a true infertility problem may be found.

Q: *Are the effects of time of insemination during a heat period relative to time of shedding of the egg of very great importance?*

P. SHANNON: I have recently carried out an experiment in conjunction with Mr Bishop of Ruakura on this aspect. Cows noticed on heat in the morning were either inseminated that morning or held over until the following morning when all the cows were palpated to determine the proportion in each group that had already ovulated. It was found that, in the group inseminated the morning they were first noticed on heat, a considerably higher proportion of cows had ovulated than in the group held over. Thus, because it appears that insemination hastens ovulation, timing of insemination within certain limits might not be a very important factor.

Q: *Has the return interval pattern in herds which have had infertility problems over several years been studied to determine if it is similar to the Group 4 pattern?*

MISS O. M. CASTLE: No, this has not been done yet, but we have found that herds in Group 4 that have a high proportion of abnormal intervals tend to remain in the low fertility group for three years at least.

Q: *Could any of the fertility problems in A.B. herds be due to inherited factors, similar to the extended gestation period found in Holsteins in the U.S.A.?*

MISS CASTLE: I do not think that inherited factors would play a big part in causing herd fertility problems, particularly in herds which have been in A.B. for some time as their breeding would be similar. Again, even in naturally mated herds there would have been automatic selection against inherited factors associated with poor fertility.

Q: *Would early embryonic death not be likely to affect the oestrus cycle length?*

MISS CASTLE: Most writers on the subject of embryonic mortality distinguish between those deaths occurring so early that they do not affect the cycle length and those occurring later which do affect the cycle length. As mentioned in the paper, according to Robinson's summary of work on this aspect, nearly half the embryonic deaths take place too soon to affect the cycle length.

Q: *The regular pattern in the estimates of Table 3 indicates a completely deterministic set of equations. How accurate are the estimates involved? Would it be possible to obtain some check on the estimates by considering also return intervals following the second service?*

MISS CASTLE: The information on return intervals following second inseminations is available, but I would doubt its value as the sample could be biased because of the limited period during which A.B. operates.