CHAPTER 61

Reproductive Health Programs for Dairy Herds: Analysis of Records for Assessment of Reproductive Performance

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RECORDS AND MONITORING

The effective use of records is a cornerstone of modern dairy production medicine. Records provide access to the performance results of a dairy's management and serve as a major source of diagnostic information when problems arise. As veterinary service to dairy farms has matured, practitioners have become more involved in herd-level analysis, management consulting, and problem solving. Monitoring is an essential component of any system that must respond to external influences (Fig. 61-1).[1–3] A parameter of the system is measured and compared with standards, goals, or past performance. If the parameter does not meet the goal, then plans are made and actions are taken (usually including collection of more diagnostic information). Because of both the action taken and the external influences on the system, a result is achieved. The result becomes the new status and the cycle begins again. Even though this activity is routine in most veterinary reproductive programs, in many cases it is not as fully developed or deliberately documented as might be most useful to the client.

Although the general scheme described is consistent across all types of monitoring, it is useful to distinguish between the following four general classes of monitoring.

1. **Surveillance.** Surveillance is a monitoring system designed to generate action at the first detection of a parameter. *Brucella* testing for reproductive disease control and public health is an example. The monitoring system (milk ring test or herd serology) is set such that a predetermined course of action will be taken if any indication of brucellosis is detected. These sort of monitoring systems typically play a minor role in day-to-day dairy farm management.
2. **Status monitoring.** This form of monitoring involves the measurement of a parameter and the comparison of its absolute value to a goal figure. Services per conception might be set at 3.0, with the intent that performance worse than that number will initiate further diagnostic effort or management changes. In outbreak investigation, this is the typical starting point for the veterinarian. Status monitoring simply asks, "Are things as they should be?"

   Although attempts have been made to arrive at a single "index" that will assess the performance of a dairy's reproductive program, none are adequate alone.[2] Evaluating reproduction involves a complex set of issues that are to some degree unique to the particular dairy. Attempts have been made to develop expert computerized systems to evaluate reproduction,[4] but none are in widespread use at the current time.
3. **Trend monitoring.** Typically more robust than status monitoring, tracking the trend in a parameter over time provides an added dimension of understanding to the analysis. Services per conception of 3.0 may be a problem in a herd that had been at 2.5, whereas it may be cause for celebration in a hot climate herd whose historical average has been nearer to 3.5. Trends allow for graphic display of the data and improve both client understanding and motivation.
4. **Exception monitoring.** Here, the trend of the herd as a whole is not the emphasis; instead attention is focused on displaying the individuals whose performance is substandard. In a sense, this is status monitoring within the herd, applied to individuals. Generally, this sort of detailed monitoring can be accomplished conveniently only with computerized record systems. Exception monitoring results are generally in the form of counts, graphic distributions, or action lists.

Viewed from another perspective, monitoring can be applied to two classes of information:

1. **Outcomes:** Traditionally, monitoring focused on measuring and evaluating the results of some system in operation on the dairy. Most of the measures used to monitor reproduction on dairies still fall into this class (e.g., days open, conceptions, pregnancies). These outcomes can be seen as the "objectives" of the system in operation, that is, its output. If the system is inadequate (in design or in operation or because

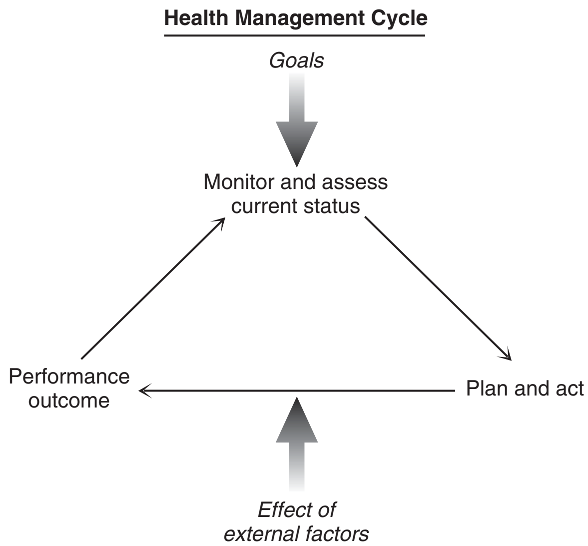


Fig. 61-1 Role of monitoring in farm management feedback cycle. (Adapted from Radostits O, Leslie K, Fetrow J: *Herd health: food animal production medicine,* 2nd ed. Philadelphia: WB Saunders, 1994.)

of unanticipated external influences), the objectives are not reached.

2. **Processes:** Monitoring can also be applied to systems in operation to discover whether the prescribed activities of the system are being done and being done properly. To be effective, this presupposes that a specific operating system is defined and the person(s) responsible are aware and properly trained. For example, in a dairy reproduction program based on estrus detection, are personnel actually taking the time to observe the breeding population of cows? Do they know what to watch for? Do they report observations to the right person in a timely manner? Are they accurate in their observations? Are enough cows bred within a specified period? The distinction between these two classes of monitoring sometimes is indistinct (e.g., are enough cows bred?), but the conceptual difference is valuable. Real beneficial changes on the dairy happen at the process level, and problems can often be most quickly detected as undesirable changes in processes. Economic impact largely happens at the outcome level. Process monitoring (oversight) is a major part of a manager's responsibilities and is key to assuring that the right things are done in the right way. Veterinary involvement in reproductive programs may include such process monitoring, either as a trouble-shooting activity or as part of the dairy's operating management. To be effective in the latter role, the veterinarian must be on the dairy on a consistent basis and sufficient time has to be committed to the task. Typically, such process monitoring by the veterinarian includes a training component.

As dairies become more rationalized and as science and process development advances, the connection between processes and outcomes becomes tighter and more predictable. As that development continues, more and more time and attention will be committed to process monitoring, with less focus on outcomes because they will follow more reliably (but not necessarily perfectly) from proper processes.

PITFALLS OF MONITORING PARAMETERS

The practitioner should be aware of several pitfalls in status and trend monitoring that can lead to inappropriate inaction (real problems escape notice) or inappropriate action (situations are misdiagnosed as problems and the wrong action is taken). Of the two, inappropriate inaction is probably the more common in reproductive production medicine and the more costly. The major pitfalls are as follows.

1. **Variation in methods of calculation:** There are many sources of reproductive indices and each has arrived at its own (often undocumented) approaches to calculating reproductive indices.[2] Recommendations regarding calculation have been put forth, but remain inconsistently implemented.[5] Furthermore, new approaches have become more appropriate since the last time a committee met to consider standardization. Care is necessary in interpreting numbers as presented, particularly when comparing results between various recording and summarizing programs.[2,5,6]
2. **The dangers of averages.** Reproductive herd records, and therefore reproductive herd monitoring, are rife with averages (means). Average days open, average services per conception, average annual culling rate as a percent of the herd (which is neither an average nor a rate)—these and others are used daily by veterinarians as they try to track the reproductive performance of their client herds. Averages measure one type of central tendency of a distribution of individual observations. Alone, they do not describe the spread of the distribution, nor do they call attention to failures of opportunities. Average days open, for example, can be the same in different herds, but with very different distributions. One herd can have a well-managed, tightly clustered distribution around the mean, while in another herd some cows might become pregnant very early while others are extremely delayed. Both herds might have the same average number of days open.

   Herd size can have a dramatic effect on the variation and computation of averages. In a 50-cow herd with 25 confirmed pregnant animals, a single cow with 350 days open increases the average days open of the currently pregnant cows by 10 days. If this cow is then sold, the average of the remaining 24 will drop by 10 days (example assumes average days open of 100 days). If the dairy farmer is unaware of this, false credit for a positive result may be given to an irrelevant intervention. Conversely, two animals conceiving at 37 days would drop the average of the 27 pregnant animals by 5 days. At the other extreme of herd size, in very large herds with many cows contributing to the parameter, the average in any time period will tend to regress toward the long-term mean, obscuring problem cows that as individuals can be quite costly. Herd size effects cannot be avoided when averages are calculated; the practitioner must be aware of the possible pitfalls and use judgment when analyzing reproductive records.

3. **Percentages.** Percentages, like averages, can be misleading. In small herds or with small subsets of large herds (e.g., first-lactation animals bred by Joe Smith in June), one must be very careful not to overinterpret deviations from proportions used as standards. As an example, the 95% confidence interval (i.e., the true mean likely falls within this range) for services per conception when 13 pregnancies result from 40 breedings (a 33% conception rate) extends from 17% to 48%. One end of that range is a conception rate disaster, the other would be considered outstanding on modern commercial dairies. For many smaller Midwestern dairies, 40 breedings would take 6 months to accumulate, making tracking conception rates a problematic process. The practitioner must use judgment about when to intervene. Dairy managers are rarely willing to wait until something is statistically proved before they intervene. The burden of "proof" necessary to motivate management action can be quite different than the proof needed to establish scientific "truth." Not doing something when it is needed can be just as costly (or more so) than doing something unnecessary.
4. **Momentum.** Momentum in a parameter occurs whenever the events from the distant past are included in the current calculation of a parameter. For the parameter to change appreciably, given the weight added by events that are long past, then either the current status must change radically or significant time must pass. Either way, momentum tends to dampen change in a parameter, obscuring the actual status and recent trend. Both average days open and calving interval include a great deal of momentum.
5. **Lag.** Lag or delay occurs when the outcome of an event or intervention cannot be measured for some extended period of time. Lag is inherent, for example, in the calculation of conception rates, because conception (pregnancy) cannot be confirmed until at least several weeks after breeding. Lag becomes more severe when an inappropriate parameter is chosen to monitor a management program's results. An example might be the use of age at first calving to monitor the results of a prostaglandin synchronization program in heifers. The lag period is nearly a year before the effect of the program can be measured. A parameter such as the number (and identification) of heifers older than 13 months and not bred would have far less lag and thus would be more valuable as a monitoring tool for this prostaglandin program.
6. **Bias.** Bias can be introduced in many ways into the calculation of parameters that monitor status and trends on dairy farms. Bias exists when a systematic error is made in the selection of animals used in the calculation, the information used is incomplete or inaccurate, or the assumptions made about the biology are wrong. Bias distorts the parameter's true representation of reality. Some of the causes of such bias in reproductive parameters are as follows.
   - **Effect of culls and "do not breed" cows.** In many record systems, animals that have left the herd are not included in the calculation of some reproductive parameters. For example, the average days in milk at first breeding for the past 6 months should logically include any animal that was inseminated for the first time in the past 6 months, whether she is currently in the herd or is no longer present. Similarly, cows designated as "do not breed" cows may also be excluded. These animals are commonly those with the worst reproductive performance. Their exclusion from the data set would make the reported parameter better than reality in the herd.
   - **Presumption of reproductive outcome.** Reproductive calculations often may make optimistic assumptions about the outcome or status of some animals. These compromise-approaches to calculating parameters are legitimately necessary in some cases, but the practitioner needs to understand that the parameter may represent the best-case scenario. As an example, some record systems may assume that all cows that are bred and not checked for pregnancy are pregnant for the purpose of calculating average days open.
   - **Exclusion of subpopulations.** Some measures report on the performance of individuals with a positive (or otherwise known outcome), but ignore (or do not reflect) the current numbers of animals either pending status confirmation or past a management cutoff with no action. As an example, average days open in pregnant cows excludes cows from the calculation that are not yet confirmed pregnant. These may be the most important cows from a reproductive program perspective.
   - **Synchronization programs.** The routine use of prostaglandin or other hormone interventions for estrus induction, although often cost-effective management strategies, wreaks havoc with the calculation of many reproductive parameters. Apparent estrus detection rates are often calculated based on the assumption of 21-day estrous cycles. Inducing estrous cycles obviously makes this assumption false. Similarly, calculation of the interestrous interval and the expected pattern of estrous cyclicity are

severely confounded in herds in which estrus synchronization is used.
- **Use of bulls.** The calculated reproductive parameters can be severely distorted by the use of bull breeding, especially in herds in which the use of bulls is poorly recorded. For example, pregnancy to the bull may be calculated as resulting from an artificial insemination (AI) breeding, influencing the apparent services per conception rates.

Although the preceding list of pitfalls may seem long, it should not deter practitioners from working with records to analyze a herd's reproductive performance. Instead, knowing these pitfalls should lead to a healthy skepticism about the number presented, a determination to increase accuracy and completeness of the underlying data, and a fuller understanding of the conditions under which parameters may not truly represent herd status.

Inadequacies of the Calving Interval

The classic parameter for monitoring the status of a reproductive program has been calving interval. Although a short calving interval might be the *goal* of a reproductive program, it is totally inadequate as a *monitoring parameter.* Calving interval has severe momentum. It requires two consecutive calving dates, so on a herd calculation basis, events from as much as 2 years before still enter into the current calculation. Similarly, it suffers from severe lag, because the outcome from reproductive management efforts must wait through at least one entire gestation before the results can be calculated. Calving interval introduces bias by excluding populations (culled cows, first-lactation animals, animals pregnant but not yet calved, "do not breed" cows). Last, by being an average, calving interval has all of the computational pitfalls described for averages. Veterinarians, as a profession, must stop using calving interval as a monitoring parameter.

Terminology Issues

There are many terms used in describing reproductive programs, terms that have survived and become part of the everyday lexicon of dairying. Unfortunately, some of these terms are not consistent with standard meanings of words. Although it is likely that many terms will go on being used even though improper, it would serve the industry and profession if everyone could be a bit more precise in how words are used. Specifically, rate is a term often misapplied to reproductive parameters. A rate is formally a measure of an event or statistic *per time period.* Thus, miles per hour or deaths per 1000 cows per year are rates. Unfortunately, many parameters associated with reproduction are discussed as rates but in fact are not rates. For example, conception rate is not a rate (no dimension of time). Conception rate (pregnancies per insemination) is a risk (proportion of a population with some particular characteristic[7]). Older terms with widely accepted meanings are probably best left as is. New terms should be more carefully chosen.

GENERAL GOALS OF A REPRODUCTIVE PROGRAM

It has long been known that there is an important economic advantage to be gained by efficient reproduction in dairy herds.[8–12] The economic effects of a sound reproductive program include increased milk by returning cows sooner to the earlier, more profitable phase of their lactation, increased numbers of replacement heifers and bull calves born, reduced costs of reproductive disease and reduced costs from culling, reduced nonproductive days due to extended dry periods, and increased rate of genetic gain.

On a biologic basis, the goal of a reproductive health program on a commercial dairy can be summarized as follows: Throughout her herd life, a cow should calve without difficulty and deliver a live calf, experience little or no postpartum reproductive disease, begin to cycle soon after calving, be inseminated soon after the voluntary waiting period, conceive to a high genetics bull within an optimal time period (or conceive at the right age as a heifer), and carry each fetus to term. This is not to imply that the goal is elimination of all pathologic events; to do so would be biologically impossible and economically inefficient. Rather, the goal is to have a minimum of pathologic events and a maximum of productivity within the constraints of practical biologic and economic reality. This general goal can be subdivided into sections, as follows.

1. **Prompt rebreeding** (appropriate voluntary wait period). After calving, uterine involution should occur promptly and cows should be reproductively sound by 45 days in milk (DIM). Once past the farm's voluntary wait period (VWP; usually 45–60 days), cows should be seen or induced in estrus, be inseminated, and conceive in an efficient manner. If both estrus detection and conception rates are adequate, then only a small percentage of cows should have extended days open.
2. **Genetic return.** Genetic return on the investment in semen or bulls should be optimized. Some computer packages can calculate optimal bull profiles for selection for artificial insemination, given the farmer's goals for genetic gain and variability.[13] It is worth noting that the genetic return on the investment in semen occurs only if the insemination results in a live *female* calf that subsequently conceives, calves, and has a productive lactation. Genetic improvement on a dairy farm is a long-term and somewhat risky investment. Assuming a 40% conception rate, 44% of females not born co-twin to a bull, a 10% abortion rate after pregnancy diagnosis, and a 20% loss of replacements from parturition until the end of a productive first lactation (includes stillbirths), only 13% of inseminations actually return any appreciable value in genetic gain to the producer. This means it takes at least 7 straws of semen just to produce a first lactation animal. On many farms, they need to purchase

well over 10 straws to produce a complete first lactation.

3. **Pregnancy wastage.** Pregnancy wastage should be at a practical, economic minimum (early embryonic death, abortion, stillbirths). Recent adoption of pregnancy diagnostic tests that can detect conception at an earlier stage is changing how pregnancy wastage is defined and the proportion of lost "conceptions" that are expected.
4. **Disease.** Peripartum disease morbidity should be minimized, enhancing animal welfare, avoiding impacts on later reproductive performance, lessening loss of cows either by death or culling, and minimizing therapy and labor costs.

MONITORING STATUS AND HERD REPRODUCTIVE TRENDS

Many parameters are used to monitor reproductive status and trends on the dairy farm. Some of these goals are shown in Table 61-1. For the most part, these are the traditional monitoring parameters for dairy reproduction. These herd goal levels must be applied with caution and may not be the appropriate alerting levels for management intervention on an individual cow basis. Several reviews of these parameters and their application have been written, so what follows is only a brief outline of the major parameters.[5,14–20]

Overall Reproductive Efficiency

Herd Distribution of Cows by Reproductive Status

Perhaps the best starting place for evaluating a dairy's reproductive status is simply a breakdown of cows by reproductive status and lactation (see Table 61-1[21]). Cows are split into the following groups:

1. *"Do not breed" cows:* cows for which management has decided to stop inseminations
2. *Fresh cows:* typically cows less than the voluntary wait period; on some dairies those cows not yet confirmed to have completed their normal involution post partum
3. *Cows OK to breed and known to be open:* includes cows previously bred but determined to be open
4. Cows bred and awaiting pregnancy diagnosis
5. Pregnant cows still milking
6. Dry (nonlactating), pregnant cows
7. Animals that have exited the dairy in the time frame of interest (whether sold or died)

Note that the principal focus of a dairy's reproductive program should be on cows in preceding groups 2 and 3, that is, those that can either be seen in estrus or synchronized to come into estrus and be inseminated and those transition cows that need careful attention, with lesser focus on early postpartum cows for uterine pathology (part of group 2) and bred cows that need a pregnancy diagnosis (part of group 4). This breakdown of cows in the herd may help focus management attention on those cows that can be usefully affected by management action.

Pregnancy Risk (Pregnancy Rate)

Pregnancy risk is probably the single most telling parameter to evaluate the reproductive performance of a dairy (although pregnancy risk alone is not sufficient, as noted earlier). Pregnancy risk is the proportion of open cows that become pregnant during a specified period of time. It is the proportion of cows that make the transition from open to pregnant (as a percentage of eligible cows) over a 21-day period. Thus, it estimates the "risk" that an eligible open cow will become pregnant on the dairy in the next 21 days. The definition of pregnancy risk is the total number of cows that become pregnant during a period of time (typically 21 days) out of the total number of cows eligible to become pregnant during the same period.

To be eligible, each cow should meet the following criteria:

- The cow should be past the voluntary wait period at the beginning of the period.
- The cow is known to be open at the start of the period.

TABLE **61-1**

Breakdown of Cows in a Dairy Herd by Reproductive Status (RPRO)

COMMAND: SUM BY RPRO LCTGP FOR LACT>0 RC>0\B

RPRO	%COW	#COW	LCTGP=1	LCTGP=2	LCTGP=3
NO BRED	0	3	0	1	2
OK/OPEN	17	158	54	46	58
BRED	19	182	81	48	53
PREG	27	256	24	78	54
DRY	6	64	25	17	22
SLD/DIE	27	252	49	63	140
Total	96	915	233	253	329

NO BRED, do not breed cows; fresh, cows not ready to breed; OK/OPEN, cows available to breed; BRED, cows bred, not checked for pregnancy; PREG, pregnant, milking cows; DRY, pregnant, dry cows; SLD/DIE, sold or dead cows. LCTGP, lactation groups are first, second, and third or later lactations.

- The cow is not flagged as a "do not breed" cow in the period.
- The outcome of any insemination during the period is known—pregnant or open.
- Additionally, if both AI and bull pens are used on the dairy, the AI pregnancy risk should not include any animal that was not inseminated in the AI pen but was moved into the bull pen during the period.
- **Note:** for computational purposes, cows that meet these criteria for at least half of the 21-day interval are eligible.

Pregnancy risk has been estimated by multiplying estrus detection rate (or insemination risk) times the conception rate in a herd, but this estimate is fraught with potential errors. Estrus detection rate may not include cows not yet bred, estrus events may be detected but the cow not inseminated,, and estrus may be recorded more than once in a 21-day period. This may bias the estimate of estrus detection in terms of a cow's single chance of getting pregnant in a 21-day period. Conception rate calculations may only include pregnant cows, and again, cows can be bred more than once in a 21-day period. Finally, the time periods over which estrus and conception rates are calculated are often not the same. It is far better that pregnancy risk be calculated directly from cow level data, not computed from estrus and conception rate parameters.

Pregnancy risks may be calculated for a single cycle, but one must be careful not to extrapolate too freely from single cycle results to overall herd performance. Particularly for programs that synchronize estrus, the first cycle of a program may achieve relatively high pregnancy risks (essentially equal to conception rate as all cows are inseminated), but the following cycle may experience much lower pregnancy risks, as cows awaiting pregnancy examination are not detected as they return to estrus. In synchronization programs in which cows have different risks of pregnancy in alternating cycles, any calculation of pregnancy risk across an odd number of cycles will distort the herd's real reproductive performance. Similarly, one should be careful of only calculating pregnancy risk for a set number of days of lactation which may only include an odd number of cycles.

Pregnancy risks have the advantage that the only lag in their calculation is the period until pregnancy status can be determined after breeding. Because all eligible cows are included, bias is not introduced in the parameter. If the risk is calculated for each successive 21-day period, there is little momentum in each number and trends in the parameter can be observed (Table 61-2). Pregnancy risks vary widely across dairies, with typical average pregnancy risks of about 12% to 14% (Fig. 61-2[21]). If a dairy could reliably and accurately submit 60% of eligible cows for insemination at least once in a 21-day period and achieve 40% conception for animals submitted for insemination in this 21-day period, the pregnancy risk would be 24%. Clearly, there is a great deal of opportunity to improve overall reproductive performance on most dairies.

The data that were used in generating Figure 61-2 were mostly based on pregnancy confirmation by rectal palpation, typically at day 35 after breeding or later. These

TABLE **61-2**

Example of Pregnancy Risk Determination for a Dairy Herd

COMMAND: BREDSUM\E

Date	Ht	Elig	Heat	Pct Pg	Elig	Preg Pct	Aborts
2/27/03	175	102	58	172	36	21	6
3/20/03	165	81	49	164	26	16	1
4/10/03	182	94	52	177	33	19	2
5/01/03	171	111	65	167	50	30	8
5/22/03	138	58	42	136	22	16	4
6/12/03	122	75	61	121	25	21	0
7/03/03	113	53	47	112	15	13	2
7/24/03	138	75	54	138	18	13	5
8/14/03	152	87	57	151	21	14	7
9/04/03	148	82	55	146	23	16	1
9/25/03	174	100	57	172	35	20	6
10/16/03	171	91	53	170	29	17	3
11/06/03	184	115	62	183	34	19	3
11/27/03	168	72	43	166	19	11	2
12/18/03	182	88	48	176	25	14	4
1/08/04	192	113	59	188	43	23	2
1/29/04	179	89	50	0	0	0	0 no preg status
2/19/04	152	105	69	0	0	0	0 no preg status
Total	2575	1397	54	2539	454	18	56

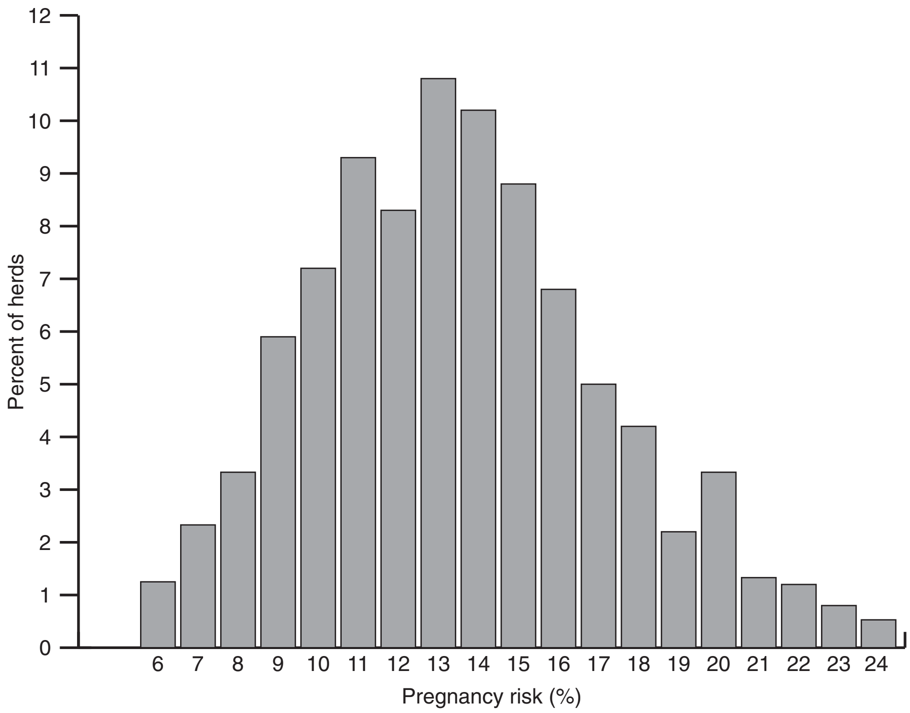


Fig. 61-2 Pregnancy risks: Minnesota dairies: risk that a pregnancy eligible cow will become pregnant in a 21-day period. (Data provided by Dr. Steve Stewart based on 1532 Minnesota DHIA herds, 2003.)

are the numbers routinely used by dairy veterinarians and for which the profession has a sense for what is acceptable and what is not. The advent of earlier pregnancy diagnosis (e.g., ultrasound and possibly immunologic tests) will tend to shift expectations. Ultrasound at day 26 will detect pregnancies that may no longer be there at day 42 after insemination. If these earlier "pregnancies" are considered real, the computational result will be higher pregnancy risks, but also higher abortion risks, as some of those early embryos are lost. There is not a consensus within the industry yet about how to handle this issue. Perhaps agreement could be reached that would continue to refer to pregnancy losses after pregnancy confirmation at 45 days (or 60) of gestation as abortions, and losses earlier as embryonic deaths. However, most dairies cannot reliably identify when a cow actually aborted.

Number of Pregnancies per Time Period

A pragmatic, but not particularly diagnostic approach to monitoring reproductive function on a dairy is to simply monitor the number of confirmed pregnancies per period of time. The logic is approximately as follows: If a dairy intends to calve 120 animals per year (as an example), then on average it must achieve somewhat more than 10 pregnancies per month in cows and heifers (more than 10 to allow for some abortions and cow culling) in order to have enough calvings 9 months hence. Given the average conception rate, one can also use this approach to monitor the number of breedings needed each month as well. This approach may be crudely useful for a quick managerial scan of reproduction (very little lag, no momentum), but it cannot detect the sector of the reproductive program in which a breakdown may have occurred.

Days Open

Better described as the calving-to-conception interval, in the past this was the most widely used parameter to assess "overall" reproductive performance in a herd.[22] As calculated by many DHIA record programs, it tends to estimate the minimum projected days open, and in some cases is named just that. Calculated on an annual basis, days open has significant momentum and lag and is distorted by exclusions, culling, "do not breed" cows, and assumed outcomes. Different record systems deal with these issues in different ways.[22] Nonetheless, it is a readily available and understandable parameter and so remains in widespread use. In addition to the difficulties inherent in calculating average days open, depending too much on this single number may mask serious reproductive inefficiency from a wide distribution of individual cow performance. Suffice it to say, although some veterinarians will continue to use average days open as a historical assessment of reproductive efficiency, prudent practitioners will do so with care.

Calving Interval

Although maintaining a short calving interval is the conceptual goal of reproductive management, the parameter itself is fraught with problems. As noted earlier, calculating an actual calving interval requires that a cow has calved twice. The parameter has severe momentum and excludes first-lactation animals and culled cows. It is the weakest monitor of a herd's reproductive performance, and should not be used.

Survival Curves

Survival curves are the graphic presentation of the change in a population from one "state" to another over time, for example, from being open to being pregnant or being not yet bred to bred for the first time. Ideally these curves could provide some information about the trajectory of transition, about what proportion of the population is pregnant or bred by a given time, and about what portion ultimately does not become pregnant or get bred. The slope of the survival curve is *not* the rate of conversion (the "risk") because the denominator population changes at the same time as the numerator changes. There are significant and troubling problems in the construction of these curves in all but deliberate prospective studies (e.g., in defining what the population at "risk" is for a survival curve, what to do with a cow bred 34 days ago but not declared pregnant, what to do with a cow that was pregnant, lost the fetus and is pregnant again). Survival curves are perhaps most useful when two different beginning populations are compared on the same curve. Differences in the experiences of the two populations are often rapidly apparent but may be confounded by differing time periods for the two populations, culling rates in early lactation, etc. (Fig. 61-3[21]). Although survival analysis is a valuable research evaluation tool, it is a problematic herd monitoring tool.

Breaking Days Open into Components

In a pivotal 1975 paper, Barr[23] laid out a conceptual framework for allocating the total days open to several components. That conceptual framework remains a cornerstone of the production medicine approach to addressing reproductive efficiency on dairy farms. As stated by Ferguson and Galligan, "most variations in herd performance result from pathology of management and not pathophysiology."[24,25] Barr's conceptual framework allows the practitioner to dissect the influences of management to localize the subsystem that is responsible for poor reproductive performance. Figure 61-4 provides a schema for this framework, as well as identifying typical problems by subsystem.

Barr's concept is that days open (in normal, fertile cows) comes from four sources:

1. Farm policy for the voluntary wait period (VWP).
2. One half of an estrous cycle past the VWP for the first estrus to occur. Some cows may be in estrus the day after the VWP and others 20 days after the VWP, but on average, it will take one half of a cycle. This is physiologically dictated, in the absence of synchronization programs.
3. Failure to detect estrus. Again, each missed estrus requires another 21 days of waiting (in the absence of synchronization programs).
4. Failure to conceive when bred. Each failure to conceive adds another 21-day estrous cycle to the tally of days open.

The effects of estrus detection and conception rate are not independent. For example, if it takes two services per conception and if every other estrus goes undetected,

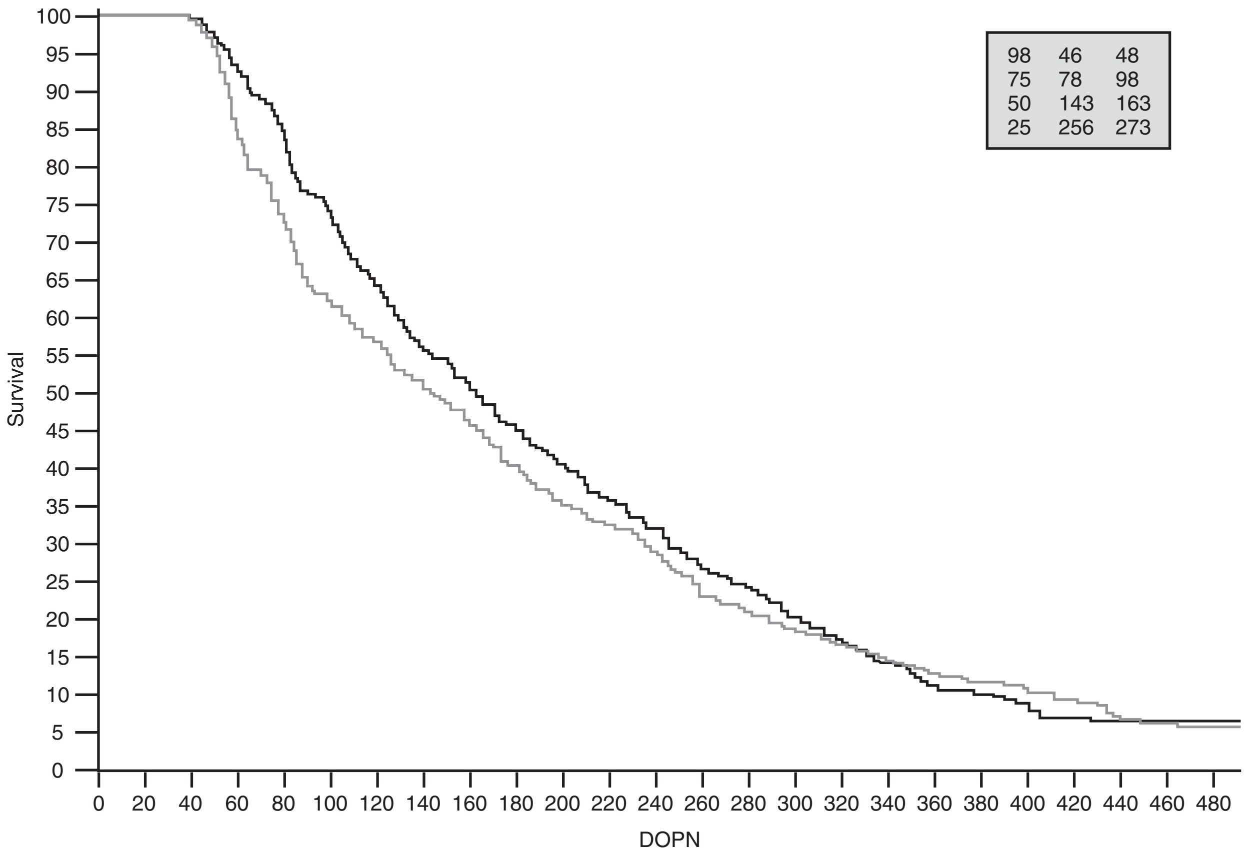


Fig. 61-3 Survival curve for days open for first lactation with second and older lactation.

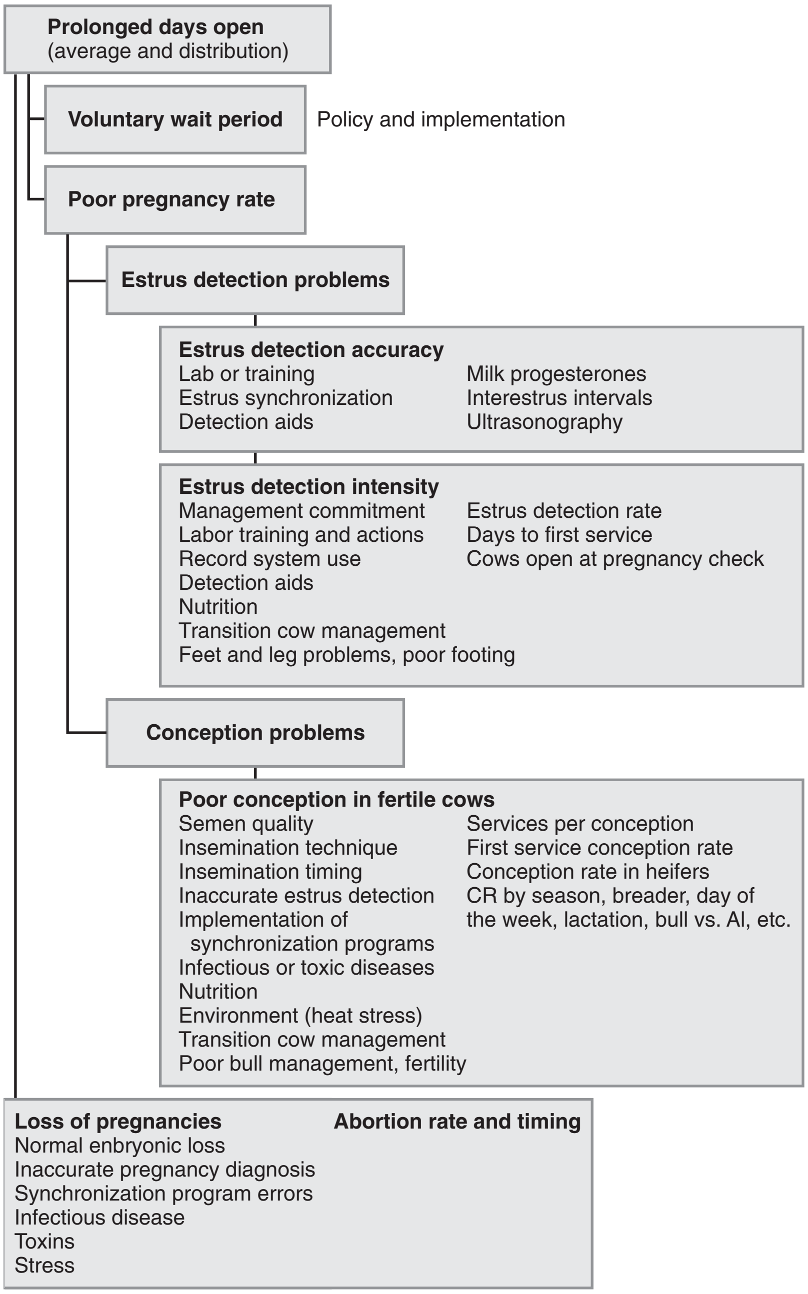


Fig. 61-4 Conceptual framework for evaluating dairy herd reproduction. (Adapted from Radostits D, Leslie K, Fetrow J, eds: *Herd Health: Food Animal Production Medicine*, ed 2, Philadelphia, WB Saunders, 1994.)

then it will take four estrous cycles to detect the two estruses that are needed to achieve two breedings and one pregnancy.

Consider the example of a herd with the following reproductive performance: 50-day VWP, 33% conception, 50% of estruses detected. (DIM = days in milk, or days since calving):

50 DIM: voluntary wait period
60 DIM: average cow has her first estrus in the breeding cycle, which goes undetected
81 DIM: second estrus, detected, inseminated, does not conceive
102 DIM: third estrus, not detected
123 DIM: fourth estrus, detected, inseminated, does not conceive
144 DIM: fifth estrus, not detected
165 DIM: sixth estrus, detected, inseminated, conceives

With no disease, no abortion, and normal management, the average cow has 165 days open. A tally of the 165 days by cause shows:

50 days: VWP
10 days: one half of an estrous cycle
42 days: failure to conceive on the two unsuccessful breedings
63 days: failure to detect three estruses
______
165 days total

This estimate of 165 days is based on performance in conception and estrus detection that is better than the average U.S. herd (note: this example would have a pregnancy risk of 17%), but it also assumes that all cows in the herd are fertile and are bred until they finally conceive. In reality, dairy managers give up at some point trying to get the final few percentages of cows pregnant and those cows are culled. As a practical example, given the aforementioned assumptions and accepting that no cow will be bred past 300 days in milk, the result would be approximately 134 days open for the average pregnant cow in the herd and roughly 11% of cows culled as not pregnant (Table 61-3[26]). These numbers do not account for the effects of abortion. This means that more than half of all herds are doing more poorly than 135 days open (accepting a 10% culling proportion for open cows), many substantially so. For most herds, achieving the oft extolled average days open number of 115 days (a 13-month calving interval) is an unreasonable starting goal under traditional management. It should be remembered, too, that in this example herd case, 11% of cows remain open after 300 DIM, in the absence of any reproductive disease.

A critique of Barr's concept lies in the assumption of no reproductive disease. The issues of infertile cows, chronic infections, and scarring of the reproductive tract should be taken into account. Although certainly operative on an individual cow basis, the effect of disease (absent herd level nutritional, toxic, venereal or contagious reproductive pathogens) seems to be small in most herds. In particular, there seems to be little reproductive "memory" from one lactation to the next, at least for cows that remain in the herd for a subsequent lactation. Current herd average days open seems to be the best predictor for an individual cow's days open, if that prediction must be made near the time she calves. When studied across a large population, a cow's reproductive history in the previous lactation had little or no effect on her reproductive performance in the current lactation.

Given the conceptual breakdown of the source of days open in a herd, the question is how one can monitor each of these critical controllable components.

Voluntary Wait Period

The obvious first step to determining the dairy's policy regarding voluntary wait period (VWP) is to ask. Unfortunately, stated policy and actual behavior are often not the same. The minimum wait period can be determined by finding the unusual cow with the fewest DIM at first breeding, but this is seldom a reasonable description of true management behavior of the herd. An estimate of actual VWP can be better derived from the DIM, where first breedings begin to cluster. Scatter plot distributions of days in milk at first breeding will give an impression of what is actually happening (Fig. 61-5[21]).

These types of graphic displays have the advantage of little or no lag or momentum. They are sensitive to the herd's status and help identify individuals with unacceptable performance. They seldom fail to illustrate real problems, although they may flag problems in individuals that are not indicative of a general herd mismanagement problem. They also allow action to proceed

TABLE **61-3**

Example of a Spreadsheet Calculation of the Number of Cows Still Open and the Average Days Open by Estrous Cycle in Dairy Cows*

Cycle	Days in Milk	Cows Open	Number of New Pregnancies	Number Still Open†	Herd Average Days Open in Pregnant Cows
1	60	100	17	84	60
2	81	84	14	70	70
3	102	71	12	58	78
4	123	58	10	49	87
5	144	49	8	41	95
6	165	41	7	34	102
7	186	34	6	28	108
8	207	28	5	24	114
9	228	24	4	20	120
10	249	20	3	16	125
11	270	16	3	14	129
12	291	14	2	11	134
13	312	11	2	10	137
14	333	10	2	8	141
15	354	8	1	7	144
16	375	7	1	6	146
17	396	6	1	5	149

From John Fetrow, VMD.

*This dairy reproduction model assumes that only one estrus and one insemination per cycle. It does not account for abortions, and it assumes all cows are fertile.

†Reproductive culls if breeding stops at this point.

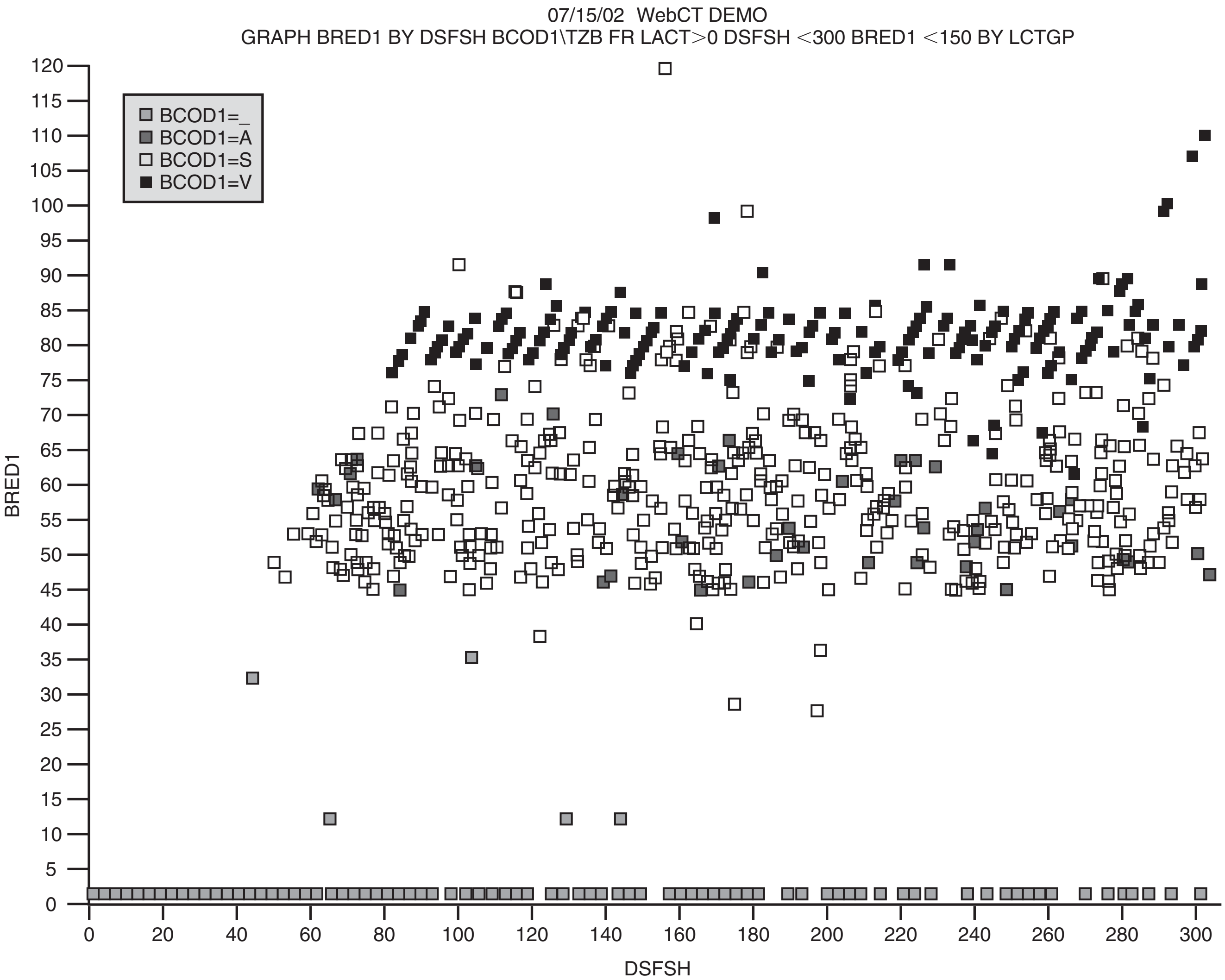


Fig. 61-5 Scatter graph of days at first breeding (BRED1) by current days in milk. This graph provides a reliable impression of the dairy's voluntary wait period before starting routine breeding (in this example about 50 days in milk). Note the use of routine synchronization in cows not bred by 75 days in milk.

without the need for precise quantification of overall herd parameters. Most important, they typically initiate a discussion.

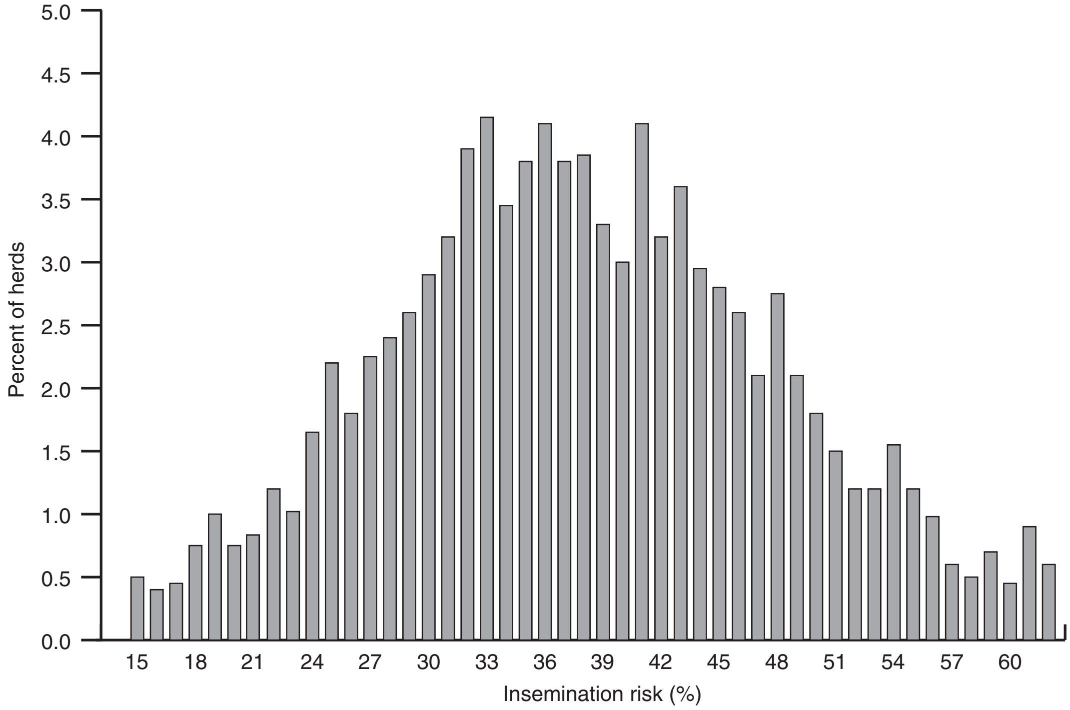
Estrus Detection

The two components of estrus detection are intensity (what proportion of cows are seen in estrus?) and accuracy (of those identified in estrus, what proportion really is in estrus?).

Estrus detection intensity. Percentage of estruses detected (estrus detection rate; actually a risk) is the usual parameter used to monitor estrus detection intensity. It is calculated based on the number of estruses detected over a period of time divided by the expected number of estruses in the breeding population (see Table 61-2[21]). Its calculation can have bias, depending on how cows are qualified as being eligible to come into estrus; it tells nothing about accuracy and is confounded by the use of synchronization programs.

Insemination risk is the chance that a cow will be inseminated at least once within a defined 21-day period. The difference between estrus detection rate and insemination risk lies in the point of view of the evaluation. Estrus detection rate measures how well the dairy identifies or induces cows to be in estrus, that is, the focus is on the cow and her behavior, heat detection aids, and labor on the dairy. Thus, a detected but noninseminated estrus counts in the calculation. In contrast, insemination risk focuses more on the herd dynamic: how effectively management is acting to get cows inseminated in a 21-day period. With insemination risk, cows bred twice in a 21-day period serve no better purpose than cows bred once, and cows detected in estrus but not inseminated do not count in the calculation. Insemination risk varies widely across herds, with the average rate centered at around 35% (Fig. 61-6).

Days to first estrus or days to first breeding is an indirect measure of prebreeding estrus detection intensity. If



Minnesota DHIA Data
1532 Herds Nov&Dec2003

	Ins_Risk	Preg_Risk	Conc_Risk
Mean	38.06%	13.92%	37.66%
Median	37.55%	13.56%	36.65%

Data provided by Dr. Steve Stewart based on 1,532 Minnesota DHIA herds, November and December 2003

Fig. 61-6 Insemination risk in Minnesota DHIA herds: risk that an insemination eligible cow will be inseminated at least once in a 21 day period. (Data provided by Dr. Steve Stewart based on 1,532 Minnesota DHIA herds, November and December 2003.)

the average is near to the VWP policy of the dairy (within 18 days or so in the absence of a synchronization program), then estrus detection intensity is probably acceptable. If the gap is longer, either estrus detection intensity is low, or the actual VWP is not the same as stated policy. Remember that this is a average, and calculation may suffer from lag, momentum, and bias. The scatter graph mentioned earlier will be far more useful.

The number of cows pregnant at pregnancy examination is a more indirect measure of estrus detection intensity. The logic of expecting more than about 80% of cows to be pregnant when examined is that if estrus detection is intense, then most cows that did not conceive when bred will be detected in estrus before pregnancy examination, leaving mostly pregnant cows to be examined. However, the expected percentage varies, depending on how long after breeding cows are examined for pregnancy, and there are formulae to calculate an estimate of estrus detection rate.[27] This measure of estrus detection intensity is confounded by conception rate as well; high proportions of open cows found at the pregnancy check can result from very poor conception as well as from poor estrus detection.[27]

A form of Q Sum graph can also be used to assess estrus detection intensity (Table 61-4[21]). The computer calculates each expected estrus for each cow, typically assuming a first estrus at day 50 and a 21-day estrous cycle (and adjusting for prostaglandin use, if recorded). Given the expected estrus, the program then records the actual outcome and displays the result. In the graph in Table 61-4, O would mean bred and open, P would mean bred and known pregnant, B would mean bred and outcome unknown, and M would mean estrus missed. If an expected estrus is detected, the observation moves one character to the right. If missed, the observation moves one character to the left. For a 50% estrus detection rate, the line of observations would tend to fall vertically on the page. Although crude in some ways, this sort of graphic approach is a valuable monitoring, educational, and motivational tool. Because the data are sorted on a chronologic basis by day, Q Sum graphs are much less useful in large herds than in smaller herds.

Estrus detection accuracy

Milk progesterone. Cows truly in estrus should have low milk progesterone concentration. For reliable interpretation, 15 to 20 cows should be sampled, with milk taken at the same time as insemination or the first milking after insemination. Samples should be frozen until a cohort has been collected for testing. Care must be taken to conduct the tests properly. In practical application, fewer

TABLE **61-4**

Q-Sum Graph of Estrus Detection

COMMAND: BREDSUM\H
HEAT DETECTION:

Cow	Date	Lact	Dim	–––––––––––––––––––––––––0+++++++++++++++++++++++++
112	11/3	6	105	B
21	11/4	2	134	M
52	11/4	4	113	M
119	11/5	1	230	M
16	11/7	3	511	M
9	11/8	1	134	M
45	11/9	4	50	M
77	11/10	1	155	M
22	11/11	1	222	B
61	11/12	1	86	M
126	11/12	2	134	M
90	11/12	4	263	O
65	11/12	7	245	B
15	11/12	8	105	B
205	11/13	1	180	O
29	11/13	2	315	M
70	11/13	2	455	M
14	11/14	6	117	M
69	11/17	2	128	M
53	11/19	2	92	M
3	11/19	3	128	M
73	11/19	3	128	M
30	11/19	4	128	M
68	11/21	2	113	M
21	11/25	2	155	M
76	11/25	2	513	B
52	11/25	4	134	M
119	11/26	1	251	B
9	11/29	1	155	M
107	11/29	3	50	M
45	11/30	4	71	M
16	11/30	3	534	B
77	12/1	1	176	M
61	12/3	1	107	B
126	12/3	2	155	M
33	12/4	3	50	M

Estrus events are projected for each eligible cow. If an estrus is detected, the graph moves to the right (B means bred; O means bred but open). If the projected estrus is missed, the graph moves to the left (M means missed). In this example, estrus detection efficiency is less than 50% (a vertical progression downward is 50%).

than 10% of cows bred should have luteal levels of milk progesterone at the time of breeding.[28]

Interestrous intervals. With classic breeding programs, an argument can be made that estrus detection accuracy can be evaluated by monitoring the interval between breedings for cows (Table 61-5[21]). In theory, the intervals should be some integer multiple of 19 to 23 days; that is, they should follow a normal estrous cycle. The widespread use of synchronization programs on dairies often renders this approach unworkable.

Conception Rates

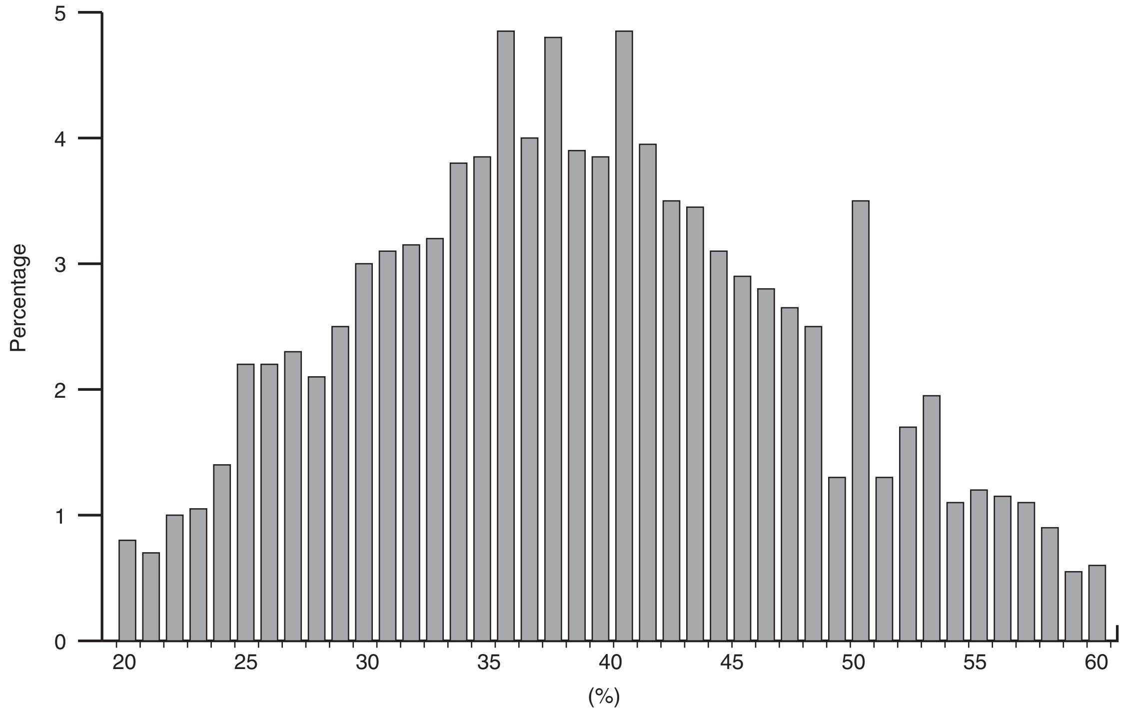
Various measures of conception efficiency are available: services per conception in pregnant cows (ignores repeat breeders), in all bred cows, stratified by lactation, by season, by artificial insemination technician, and so on. These analyses depend on accurate recording of the necessary information by the breeding staff of the dairy. Conception rates (again, really risks) on dairies range widely, with the median conception rate in a large sample of Minnesota dairies at 38% (Fig. 61-7). Table 61-6 shows one such stratification, in this case for conception by breeding type.[21] By their nature, conception parameters always have lag and momentum. Each parameter provides a window onto conception efficiency, and a combination of parameters can focus on the possible problem area if there is a serious conception problem in the herd. Q sum graphs can also be applied to conception in smaller herds, with the graph moving right when a breeding is successful and left when a breeding is unsuccessful.

TABLE **61-5**

Chart of Interestrous Intervals on a Dairy

COMMAND: BREDSUM \ID180 FOR LACT>0							
Heat Interval	**%Conc**	**#Preg**	**#Open**	**Other**	**Total**	**%Tot**	**SPC**
1–3 days	25	2	6	1	9	1	4.0
4–17 days	21	5	18	2	25	4	4.6
18–24 days	45	39	46	7	92	16	2.2
25–35 days	45	28	34	1	63	11	2.2
36–48 days	32	61	127	11	199	36	3.1
Over 48 days	35	54	100	8	162	29	2.9
Totals	36	189	331	30	550	100	2.8

Ideally, most inseminations should fall between days 19–23, or multiples thereof. This approach provides one measure of estrus detection accuracy. This is distinctly confounded by the use of synchronization programs that can return cows to estrus at other than 21-day intervals. Conc, conception rate; SPC, services per conception.



DC305 Conception *Rates: MN DHIA Jan–Mar 2004*
38.9 Mean (20–60 CR)
38.0 Median (20–60 CR)

Fig. 61-7 Conception rates in Minnesota DHIA herds 2004. (Data provided by Dr. Steve Stewart based on 2,193 Minnesota DHIA herds, 2004; only herds with conception rates of 20–60 percent are included.)

Bull Performance

There are many aspects involved in bull performance on dairies. Typically bulls are used as “clean up” breedings, with cows not pregnant to a series of AI inseminations turned into bull pens for breeding. Bulls are often poorly managed on dairies (poor feet, overused, not rested, etc.) and the result is that bull performance is commonly far below optimum. Dairymen may have a belief that the bull is naturally more efficient at getting cows pregnant than AI programs, but hard data often show this is not the case. If dairies reliably designate bull pens, record when cows are moved into those pens, and confirm pregnancy such that AI and bull pregnancies are distinguished, then pregnancy risks for bulls can be calculated in the same way as AI breedings (Table 61-7). It is not

TABLE **61-6**

Example Breakdown of Conception Rates for a Dairy

COMMAND: BREDSUM\O

Breeding	Code	%Conc	#Preg	#Open	Other	Total %	Tot SPC
Luteal heat	34	51	97	2	150	8	2.9
Ov-Synch heat	29	245	580	36	861	48	3.4
Standing heat	41	300	425	47	772	43	2.4
Totals	35	596	1102	85	1783	100	2.8

In this case the breakdown is by type of breeding, but many other breakdowns are possible and may be useful in characterizing conception problems (e.g., by day of week, by technician, by season, by insemination number). Conc, conception rate; SPC, services per conception.

TABLE **61-7**

Pregnancy Risk Performance by Clean-up Bulls on a Dairy

COMMAND: BREDSUM \U

Date	Ht Elig	Heat	Pct	Pg Elig	Preg	Pct	Aborts
2/07/02	13	2	15	13	1	8	0
2/28/02	14	1	7	14	1	7	0
3/21/02	11	3	27	11	2	18	0
4/11/02	18	4	22	18	4	22	1
5/02/02	12	1	8	12	1	8	0
5/23/02	11	1	9	11	1	9	0
6/13/02	17	2	12	17	0	0	0
7/04/02	33	0	0	33	0	0	0
7/25/02	36	7	19	35	4	11	0
8/15/02	28	1	4	28	1	4	0
9/05/02	29	4	14	29	3	10	0
9/26/02	28	4	14	28	2	7	0
10/17/02	29	5	17	29	3	10	0
11/07/02	26	10	38	25	4	16	0
11/28/02	26	3	12	26	0	0	0
12/19/02	27	3	11	26	1	4	0
Total	358	51	14	355	28	8	1

The bull pregnancy risk (8%) was substantially below the pregnancy risk for AI breedings in this herd.

uncommon for bull pregnancy risks to be poorer than AI rates in the same herd.

Reproductive Disease

Monitoring the incidence of reproductive disease can be useful as an indicator of underlying problems with management. It is important that the dairy settle on a consistent case definition so that everyone involved understands what and when to record as an event. Typically, retained placentas, metritis, dystocia, and stillbirths are monitored as indicators of dry cow and transition feeding program management (particularly mineral and energy balances), calving area hygiene, and calving supervision. Cystic ovarian disease incidence may be an indicator of early postpartum energy status, but care should be exercised to distinguish true high incidence from overzealous diagnosis. As a rough guide, no reproductive disease should have an incidence higher than 10% of cows per lactation, although this may be too stringent a standard for metritis, depending on the case definition used. The trend in incidence over time is a more useful indicator of problems than the specific level in any period.

Abortion

There are two scenarios in which abortion becomes a herd problem. The first is a herd in which there is an increased incidence of abortion over a long time frame (endemic abortion). The second is when a clustering of abortions occurs in a short time frame (an abortion outbreak). Determining when a herd has had an “abnormal” number of abortions is a difficult and controversial question and requires knowledge of what a “normal” abortion rate is and what level above the normal rate is acceptable to that particular dairy. Estimates of abortion are also confounded by the time of pregnancy diagnosis. Increased use of ultrasound for early pregnancy diagnosis will tend to elevate early pregnancy loss estimates compared to diagnosis based on rectal palpation 10 to 14 days later. The stages of pregnancy may be conveniently broken down into specific stages:

Gestation days 1 to 42: embryonic period (growth of embryo, no or limited placental attachment)
Gestation days 42 to 120: early fetal stage (placental attachment having taken place by about 45 days,[29] no or limited fetal immune function)
Gestation days 120 to 180: middle fetal stage (development of immune function)
Gestation days 180 to 260: late fetal stage (beginning of rapid increase of fetal weight)
Gestation days 260 to 280: premature birth stage (calf may be viable if born; stillbirth common if delivered prematurely)[30]

Estimates of the normal abortion rate for dairies range from 0.4% to about 10%.[31,32] Findings as low as 0.4% almost certainly reflect failure of diagnosis. One large study in 10 northwestern U.S. dairies found that 11% (range 7.6–13% by herd) of pregnancies diagnosed by rectal palpation after 31 days' gestation were lost between day 42 and day 260, during the fetal stage.[33] The range of reported abortion rates may be due to the definition of what constitutes an abortion (time in gestation), completeness of detection of lost pregnancies, the accuracy of the original diagnosis of pregnancy, and the population of cows that are used as the denominator in the calculation. Most loss of pregnancy does not lead to an observation of the aborted fetus or membranes; cows simply return to estrus or are found nonpregnant at a subsequent examination.[33] Taking these issues into account, normal abortion rates appear to be about 2% to 5% when only observed abortions are considered, approximately 8% to 10% or perhaps higher if one considers both unobserved and observed abortions based on pregnancy status determined by traditional rectal palpation programs.[34] As a rule of thumb, abortion rates in excess of 10% of pregnancies confirmed at 42 days of gestation or greater should be considered increased rates. More data are needed to clarify what constitutes "normal" loss of embryos prior to 42 days of gestation. Computer record programs must grapple with these definitions. Because the definition of an abortion is a pregnancy that is later determined to be open, then early pregnancy diagnosis will result in what appears to be a sharp increase in abortion rates in a herd where no biologic change has occurred. One approach is this issue is to accept a pregnancy as "confirmed" only if diagnosed after day 42. Earlier pregnancies, if lost by day 42, would fall back into the category of nonconception (or maybe as early embryonic death), rather than abortion. This compromise serves to reserve the term "abortion" for the fetal period of gestation, but combines two sources of reproductive failure (true conception failure and early embryonic death) together in one category. As diagnostic abilities increase, it seems very likely that what were once considered simple failures of conception are in large part really loss of early embryos.

Determining what constitutes a significant clustering of abortion remains problematic. In practice, waiting for statistical proof of an outbreak may not be prudent; practical importance may be established and action probably warranted well before statistical significance is reached. It is increasingly clear, however, that pregnancy diagnoses made in the first 2 months of gestation need to be reconfirmed so that lost pregnancies are identified in a timely manner and open cows are dealt with appropriately. Diagnosing the cause of abortion continues to be a challenge. There is a bias toward submitting fetuses aborted in later stages of gestation rather than younger ones, which may lead to inaccurate assessment of the major causes of fetal losses on dairies.[35] Fetal losses in earlier stages of gestation are far less likely to be observed, despite the fact that cows are more likely to lose their pregnancy in these early stages (particularly up to about day 60).[33] Serologic status of cows that abort may be similarly misleading, unless seroconversion can be demonstrated.[36]

Culling

As a reproductive monitoring tool, culling has very significant lag and momentum. By the time a cow is culled, the fundamental management problem that led to the cull (e.g., poor transition cow management, poor estrus detection) is probably distant history. Another difficulty lies in the definition of the reason an animal was culled.[37] If a low-producing cow with poor feet and legs and one blind quarter is open at 150 days post partum and the dairy manager decides to stop breeding her, is she a reproductive cull (open when culled at the end of lactation)? Thus "reproductive culling" is a very poor monitor of a herd's reproductive program. The tools described here remove all justification for ever attempting to use "reproductive culling rate" as a monitor of the reproductive program on a dairy.

MANAGING REPRODUCTION ON A DAY-TO-DAY BASIS

Monitoring for status and trends provides valuable insight into the herd's current and historical situation, but it often stops short of answering the question of what needs to be done on the dairy. As noted earlier, at any given time most cows on a dairy are not eligible for management intervention for reproduction. Record systems need to reach past the general herd status and target those cows for which action can be taken. What is often needed is not a measurement of the performance of those animals whose outcome (positive or negative) has already been resolved, but rather the identity and status of those animals for which positive management action is possible. Such cows might be past the VWP and not bred, bred but not confirmed pregnant, and so on. Given that estrus detection is the major opportunity area in the reproductive program on most dairy farms, much of the focus should be on cows that have not been detected in estrus and bred. Effective record systems allow these cows to be identified easily, often leading to efforts to induce a fertile estrus.

Data from dairy management software or downloaded DHIA records afford a significant opportunity for veterinarians to participate in this sort of "action list management" in their clients' reproductive programs. Care is necessary to be sure that lists correctly isolate those cows that are eligible for a particular intervention and that no cows are missed or incorrectly included. Many systems fail because of fundamental errors of management or implementation. It cannot be assumed on all dairies that cows have unique identification or that data are correctly entered. These basics are necessary before sophisticated programs can be implemented.

CONCLUSION

Reproduction has a central role in the management of a dairy farm. Veterinarians need to be fully involved in the reproductive management of their client herds. To do so most effectively, veterinarians must learn to routinely assess the herd's status and trends and identify both individual cows and general areas of management where intervention is possible and the client's welfare served.

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