Reproductive Record Analysis
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Nationally, over 25,000 herds with more than 4 million cows participate in a Dairy Herd Improvement Association (DHIA) testing plan in conjunction with a Dairy Record Processing Center (DRPC) [1]. Countless other herds use on-farm record keeping systems to maintain information. Technological advances continue to enhance the ease and speed at which information can be recorded, transmitted, and processed, and have made records very accessible for analysis beyond interpretation of mailed test-day reports. A systematic approach to the analysis of reproductive records can yield quality information to enhance herd visits in promoting health and productivity of herds serviced by veterinarians. This article describes methods for interpreting DHIA reproductive performance data generated by off-farm DRPCs in the United States. Procedures described here have been used with data generated by two of five DRPCs listed by the Animal Improvement Programs Laboratory of the United States Department of Agriculture. The methods should be applicable using data generated by other DRPCs—although there are subtle differences among DRPCs in calculating some of the reproductive measures described, they are largely uniform because procedures and calculations are approved by DHIA [2].

Using records and presenting information

Before discussing any methodology, it is important to emphasize that analysis and interpretation of dairy records is a supplement to, but will never replace, the herd visit in the provision of services to clients. With reproductive record analysis, problems noted during a herd visit can be characterized with respect to the extent and severity of inefficiencies. Records are also useful in establishing baseline performance levels, setting
goals for improvement, and for monitoring changes over time. Thorough review of records can also be used to detect and initiate investigation of potential problems in herd health or management; however, any issues raised by records analysis need to be confirmed with observations made during a herd visit. Thus, interpretation of dairy records and the herd visit complement each other—problems detected on-farm can be described with the help of records review, and records review can highlight areas to inspect during a herd visit.

When sifting through herd data, it is beneficial to use techniques that simplify the process of reviewing records and make communication of findings with the client easy. Graphical summaries of reproductive indices over a history of test days are a useful way to organize information for review and presentation. Graphical exploration of the data offers opportunities to identify and illustrate relationships among measures used in analysis, as well as to describe the time course of any problems and to determine if situations are improving or worsening. Graphical analysis of herd data is usually straightforward, because herd data are typically available in electronic format, and DRPCs offer specialized software packages that can generate graphical reports. Herd data in electronic format can also be exported to productivity software packages, such as spreadsheet or database programs, for analysis.

Framework for analysis

An organized approach to records analysis assists in the extraction of useful information from the data. Fig. 1 presents a layout of a systematic approach to reproductive record analysis. It identifies key indices that are relatively easy to comprehend as they relate to each other and to herd health and management. The approach discussed here starts with an overall summary measure of reproductive performance, and then systematically examines measurable components related to it in two different periods of breeding. Each measurable component is then evaluated individually, and health and management factors impacting these components are considered for their potential to affect reproductive performance. For any measure used in analysis, it is important to be aware of benchmark values (which are often very difficult to achieve) and to be able to gauge the herd’s potential for improvement.

Selecting an overall summary of reproductive performance

Average calving interval (CI) or the closely related measure average days open (DO) have been used extensively to summarize the reproductive performance of dairy herds. Cows in herds with fewer DO or shorter CI produce more milk per day of herd life [3] and yield more replacement animals [4], so lower values of DO and CI are usually preferable in terms of
Fig. 1. Flow chart outlining a systematic approach to evaluation of reproductive performance using information in records. (Adapted from Hardin DK. Fertility and infertility assessment by review of records. Female bovine infertility. Vet Clin North Am Food Anim Pract 1993;9(2):393; with permission.)
herd profitability [5,6]. Although longer calving intervals may be acceptable in some circumstances for high-producing (primiparous cows averaging 11,232 kg and multiparous cows averaging 12,767 kg 305-day mature equivalent milk) cows [7], it is generally agreed that a 13-month calving interval is the economically optimal target [6,8]. Using a 280-day gestation for Holstein cows, the 13-month CI corresponds to approximately 115 DO.

It is important to understand how DO and CI are calculated and reported. Typically, DRPCs report two versions of CI: (1) historical CI (HCI), which is the average time between successive calvings for the same cow; and (2) projected CI (PCI), which is based on a calculated measure known as projected DO (PDO). There are considerable limitations in using HCI to monitor herd reproductive performance. In order for a cow to have HCI measured, she must have calved at least twice, which means that the HCI only summarizes reproductive performance of multiparous cows. Also, the HCI measurement has a lot of lag, meaning that a herd with problems getting cows pregnant today will not show increased HCI until these cows finally settle and then recalve at least 9 months in the future. Likewise, if a herd makes positive changes in its reproductive program today and achieves earlier pregnancies, a shorter HCI will not be noticed for at least 9 months.

The PDO and PCI are better alternatives for monitoring overall herd reproductive efficiency, because they overcome limitations described for HCI. Projected CI is a standard gestation (usually 280 days) added to PDO, which is the weighted average of PDO for three populations of cows defined by the American Association of Bovine Practitioners (AABP) [9]:

1. For cows diagnosed pregnant, PDO is the days from calving to conception.
2. For bred cows without a pregnancy diagnosis, it is assumed that they are pregnant, and PDO is the days from calving to most recent breeding.
3. For cows beyond the voluntary waiting period (VWP) and not yet bred, and for previously bred cows that are known to be open, it is assumed that they will be inseminated and become pregnant in 10 days.

Each of the two DRPCs used by this author follow slightly different definitions for the third population of cows—one uses the greater of current days in milk (DIM) plus 10 or average days to first service for the entire herd [10]; the other uses current DIM, but only for cows more than 30 days beyond VWP [11]. The differences in PDO between the AABP methodology and that of the DRPCs are small; however, it should be noted that because the calculations for PDO assume that all bred cows of unknown status (population 2) are pregnant and that all open cows eligible to be bred (population 3) will become pregnant in a short period of time, these methods of calculation represent a minimum estimate of DO. Therefore PCI is a best-case minimum estimate of the CI that will be realized in the future [9,12].

Although PDO and PCI represent a best-case estimate of reproductive efficiency, they are still very useful measures because they are calculated
using current information from as many herd members as possible [9]. Coupled with their relationship to milk and calf yield and overall herd profitability, PDO and PCI are good summary measures to begin evaluation of dairy reproductive records. Because PCI is based on PDO, the remainder of this article focuses on PDO as the overall summary measure from which to begin records analysis.

The effect of culling on projected days open

Before discussion of measurable components of efficiency in dairy records, reproductive culling needs attention. It is known to distort PDO, because open cows with extended DO are often removed from the herd and may be omitted from DRPC calculations. Reproductive failure is the most common reason for removal from the herd, with an average of 20% and a range of 0% to 45% of culling attributable to reproductive failure [13]. High reproductive culling rates will cause the PDO and PCI measures to be low [12,14]. Fig. 2 shows the relationship between PDO and reproductive culling rate for herds with different levels of reproductive efficiency. In Fig. 2, it can be seen that an inefficient herd (represented by lower heat detection rate) with high reproductive culling rate may have PDO similar to a more efficient herd (represented by higher heat detection rate) with low reproductive culling rate. This presents a challenge in record interpretation—changes in culling rate may mask some changes in PDO. It is important to be aware of this effect, particularly when herds are monitored

Fig. 2. Graph illustrating the relationship between predicted days open (PDO) and annual reproductive culling rate (RCR) for herds with different levels of reproductive efficiency, assuming a 50-day voluntary waiting period. Levels of reproductive efficiency are: (◇) 40% HDR, 50% CR; (∥) 60% HDR, 50% CR; (△) 80% HDR, 50% CR. (Data from Esslemont RJ. Relationship between herd calving to conception interval and culling rate for failure to conceive. Vet Rec 1993;133:163–4.)
over time—PDO may change little in the face of improving or worsening reproduction because of changes in culling. Processing centers do report on the herd’s annual culling rate and reasons for removal. The utility of reproductive indices, particularly PDO, is questionable in herds that exhibit high annual reproductive culling (over 15%) or high overall annual culling (over 45%). Also, analysts should be cautious in comparing data from different points in time if culling changes more than 10% between the points in time.

**Estrus detection and conception and projected days open**

Fig. 1 indicates that PDO is only a starting point for analyzing reproductive records—an understanding of measurable components of reproductive performance that are related to PDO is important. Estrus or heat detection rate (HDR) and conception rate (CR) have been identified as the two most important determinants of PDO [15], and it follows that HDR and CR should be monitored with respect to PDO.

Estrus detection and conception can be monitored in DHIA reproductive records during distinct periods of dairy cow breeding. Bailey et al [16] described record analysis during the preservice period, representing the time from calving to first insemination; and the postservice period, the time from first insemination until pregnancy diagnosis. A similar approach is used here to monitor estrus detection and conception in two distinct periods: period one is the time from calving until the outcome of the first insemination is known, whereas period two monitors cows requiring more than one service. Partitioning records analysis into periods helps to identify and characterize strengths and weaknesses of reproductive performance in relation to early (period one) or later (period two) lactation. Graphical exploration of relationships between PDO and measures of estrus detection and conception in each period are emphasized. When focusing on a single reproductive measure, it is important to be aware that changes in other measures may act to modify the effect.

**Monitoring efficiency in period one**

As mentioned previously, period one covers the time from calving to the outcome of the first breeding. Efficiency in this period can be monitored in DHIA records using the herd’s average days to first service (DFS), and the first service conception rate (FSCR). The DFS for the herd is the average DIM when cows are inseminated for the first time, and FSCR is the proportion of cows that settle to first service [10,11]. Herds should try to have low DFS and high FSCR; however, herds must find a balance between DFS and FSCR, because there is evidence that earlier DFS is associated with a lower FSCR [17–19].
Monitoring days to first service

Herds with lower DFS have shorter HCI [20], and a recent study [15] observed that a 1-day decrease in DIM at first estrus (which was highly correlated with DFS) was associated with a 0.6-day decrease in PDO. To achieve a goal of 115 PDO, a reasonable target for DFS is VWP + 18 days [21]. A 60-day VWP is typically assumed in DRPC calculations and is appropriate for most farms [10], so a target value for DFS is between 75 and 80 days. A graphical analysis is an easy way to explore relationships between DFS and PDO.

Fig. 3 presents DHIA data from a dairy herd that demonstrates the association between DFS and PDO—generally, during periods of earlier DFS, this herd’s PDO tends to decrease. Fig. 3 emphasizes the strengths of graphical exploration of records—although not perfect, a relationship between DFS and PDO has clearly presented itself and would be easy to communicate to the producer. The next step is to work with the producer to try to determine why DFS has changed over time and what can be done to ensure that cows are consistently inseminated in a timely fashion in order to reduce DFS and capture benefits of reduced PDO.

Days to first service is affected by the herd’s VWP and heat detection (see Fig. 1). A shorter VWP is associated with earlier DFS [22], and herds with higher HDR have lower DFS [23]. It is worthy to mention also that calculation of PDO is affected by the herd’s reported VWP, in that changing the VWP setting in DRPC calculations will change the PDO (by changing population 3 in the AABP calculation listed earlier). Producers looking to reduce DFS should consider their breeding policy with respect to VWP, but make sure that values reported to DRPCs match actual practice in the herd.

Fig. 3. Graph illustrating a relationship over time between predicted days open (◊) and days to first service (□) for a dairy herd.
Also, changing VWP from a management perspective only means that cows will be considered eligible for breeding earlier in lactation. Execution of this still requires that cows be detected in estrus and inseminated; thus estrus detection is a critical determinant of DFS, and it requires that cows are cycling, express estrus, and are observed by management. Failure to detect estrus in early lactation cows can be related to any of these factors (cycling cows, expression of estrus, detection of estrus), reflecting overlapping concerns of cow health and herd management (see Fig. 1).

Intensity of estrus detection is strictly management-related—devoting more time and effort or using multiple estrus detection aids should increase heat detection [24], and thus reduce DFS. The importance of educating herd personnel about the signs of estrus, of watching cows for estrus, and of maintaining a reliable system for recording which cows are standing cannot be overemphasized during the herd visit. Herd managers who wish to reduce DFS should consider increasing the frequency or time spent watching cows, the use of estrus detection aids, or even ovulation synchronization (OvSynch) protocols coupled with timed artificial insemination (TAI).

The effect of high milk production on overall reproductive performance has been examined numerous times, often focusing on conception in high-yielding cows. A recent study [25] used a radiotelemetry system to record frequency and duration of standing estrus behavior, and found that higher milk yield was associated with decreased duration and intensity of estrus, possibly due to increased hepatic blood flow and increased metabolic clearance of circulating estradiol. Herds with high milk yield in early lactation may present challenges in detecting estrus, and thus have delayed DFS. Again, OvSynch protocols and TAI may be of use in herds with delayed DFS associated with high milk production in early lactation.

It has been suggested that nutritional factors, such as excessive loss of body condition due to energy demands of lactation exceeding nutritional supply, can affect ovarian physiology and delay the time from calving to resumption of ovarian cyclicity [26]. High-producing cows are at risk of being in negative energy balance, but so too are average and even low producers that do not get adequate nutrition. During the herd visit, body condition of pre-fresh cows should be compared with cows in early lactation near the end of the VWP. Evidence of excessive condition loss may be a reason for delayed DFS, and producers in this situation should consider if their nutritional program can improve their reproductive performance.

Environmental conditions such as summer heat can impair ovarian function and cyclicity [27], and thus affect estrus expression and delay DFS. Producers are limited in their ability to control the weather, but efforts can be made in barn design and layout to ameliorate summer heat stress. Other environmental conditions, such as poor footing, can limit mounting activity and impair estrus expression and delay DFS. The herd visit should include an assessment of ventilation and floor surfaces of the barn if extended DFS is a problem in the herd.
Diseases in transition cows, such as milk fever, retained fetal membranes, metritis, ketosis, and displaced abomasum, have been shown to be associated with delays in time to pregnancy [28]. A possible mechanism may be that cows “start slowly,” have poor feed intake, and lose body condition, which can affect heat detection and DFS. Assessment of the incidence of these diseases as well as of management actions that may increase risk of occurrence is an important aspect of the herd visit. Cow health during the time around calving can have impacts on reproductive efficiency months later.

A final important cow health factor affecting estrus expression and DFS is feet and leg health—lameness can delay DFS [29]. The herd visit should assess locomotive abilities of cows as a potential cause for delayed DFS due to impaired estrus expression; however, identification of lameness represents only a sign of an underlying problem. Potential causes of lameness are numerous, and may include management, diet, environmental conditions, or infectious disease. Again, the herd visit is very important to assess the presence, potential impact, and possible causes of lameness in relation to DFS and reproductive performance.

Monitoring first service conception rate

The second important component of PDO measured during the period one is the FSCR. In DHIA records, DRPCs report overall and service-specific CR (including FSCR) as the proportion of bred cows that are diagnosed pregnant [10,11]. It has been suggested that a normal FSCR is 45%, but that 60% FSCR is attainable [30]. Although there is an association with reduced FSCR at earlier DFS, herds should be able to achieve FSCR of 50% by 75 to 80 DFS [31].

Fig. 4 shows data from a herd that displays an association between FSCR and PDO. During the 2-year period shown, FSCR declined and PDO increased; however, the records analysis only illustrates a relationship between two measures—the critical role of the veterinarian is to consider factors that can cause a decline in FSCR and a resultant increase in PDO. The herd visit would allow exploration of potential reasons for the drop in FSCR, and allow the management team to try to correct the problem.

Because pregnancy diagnosis occurs about 5 to 6 weeks after breeding, FSCR (and overall CR) reported in records is a function of successful fertilization of the oocyte as well as implantation and maintenance of the conceptus to pregnancy diagnosis. In healthy cows, it has been suggested that successful fertilization occurs in as many as 90% of inseminations [32], but that 20% of embryos fail to survive beyond 18 days of gestation, around the time of maternal recognition of pregnancy [33]. Furthermore, pregnancy rates at day 32 of gestation can be as high as 60%, with a further loss of 15% between day 32 and day 74 [34]. Therefore, if records analysis identifies unacceptable FSCR, the herd should consider factors in period one that
affect success of fertilization, as well as factors that affect pregnancy wastage. Successful fertilization can be affected by multiple factors, including the insemination program, accuracy of heat detection, nutrition, environment, metabolic disease, and infectious disease. Factors that affect pregnancy wastage are similar, and it is often difficult to differentiate problems with fertilization from problems with pregnancy maintenance.

Producers with herds that experience problems with FSCR should consider their insemination program, including semen storage, handling, thawing, and placement in the cow. Although not common, problems in the insemination program can severely affect herd reproductive performance by limiting fertilization success [16]. It is important that all personnel performing insemination are aware of and follow proper techniques to maximize the chance of fertilization when cows are submitted for insemination.

Accuracy of heat detection refers to the status of cows that are submitted for insemination, and can affect FSCR—if cows that are not in estrus are submitted for insemination, herd CR will decline [35]. In a multiherd study [19], it was found that 5% of cows submitted for insemination had high (≥1 ng/mL) milk progesterone concentration; but for individual herds, inaccuracy ranged from 0% to 60%. Increased reliance on secondary signs of estrus (such as roughened tail head, rubbed-off paint or chalk, triggered heat-mount detectors, mucus on vulva) can increase estrus detection (and reduce DFS), but may reduce CR (and FSCR) [19,36]. Kinsel and Etherington [15] observed that herds with increased HDR had shorter DFS but lower CR, perhaps due to increased reliance on secondary signs of estrus. This presents a dilemma to the producer—weighing the benefits of
increased HDR (and lower DFS) against potential reductions in CR (and FSCR). Usually, it is better to favor insemination of cows (higher HDR). Barring major inaccuracies in estrus detection, it has been found that improvements in estrus detection lead to economic benefits [37]. Additional information (interestrus intervals) in the records can be used to help shed light on accuracy of estrus detection, and are discussed later.

In addition to playing a role with respect to estrus expression, nutritional factors can impact FSCR. Relating to energy balance, recent studies have suggested that loss of body condition was associated with decreased FSCR [38]. With respect to dietary protein, high milk urea nitrogen concentration, a marker of protein-to-energy balance in the diet, has been associated with decreased CR [39]. Thus, managers of herds with depressed FSCR should consider the potential for the nutritional program to impact the reproductive program.

The environment can also affect FSCR in dairy herds. Heat stress with high ambient temperature is a notable cause of depressed fertility in dairy cattle [40]. When reviewing reproductive records, one may anticipate declines in FSCR during periods of high heat. During the herd visit, facilities should be evaluated for their potential to exacerbate heat stress.

Diseases such as milk fever, retained fetal membranes, metritis, cystic ovarian disease, and even mastitis and lameness have been associated with reduced risk for pregnancy at first insemination [28]. It is difficult to differentiate an impact on fertilization from pregnancy maintenance, but a complete work-up for herds with reduced FSCR should consider high incidence of any disease condition that can delay normal uterine involution or affect reproductive tract health, as well as disease conditions that affect overall health, as potential contributors to reduced conception efficiency.

Another very important factor that can impact FSCR and overall CR in dairy herds is the presence of infectious diseases. A variety of infectious diseases can affect conception rate, either by reducing fertilization success or increasing early embryonic death (EED). Infectious agents such as bovine viral diarrhea virus (BVD), *Leptospira borgpetersenii* serovar hardjo (type hardjo-bovis), *Neospora caninum*, and bovine herpes virus type 1 (infectious bovine rhinotracheitis, IBR) are capable of causing EED, fetal loss, and abortions in dairy cattle [31]. Managers of herds with problems in FSCR (or CR) should consider infectious disease as a potential cause for declines in DRPC reported measures. To this end, it is important to evaluate the herd’s current and historical biosecurity and vaccination programs. Furthermore, any apparent abortions should be worked up through a diagnostic lab service. It is critical to do this even in the face of inconclusive results. Laboratory work-ups of abortions do not always yield definitive etiological results; a study in California found that a definitive etiology was determined in just 43% of submissions to state diagnostic laboratories [41].
The effect of ovulation synchronization protocols in period one

In the 1990s, reliable programs for synchronization of ovulation using gonadotropin hormone-releasing hormone (GnRH) and prostaglandins were developed [42]. When used, these programs effectively eliminate the need for detection of estrus and allow cows to receive TAI. In DHIA records, use of these protocols and TAI increases estrus detection to 100% in cows enrolled in the protocol. These programs are quite effective in period one at reducing DFS to a consistent uniform value [43]. Synchronization protocols and TAI can also be used in period two to ensure that cows are being inseminated. Depending on the extent of use at the herd level, DHIA records will likely show decreased DFS and increased HDR as more cows are submitted for insemination.

An important consideration when using OvSynch protocols and TAI is that CR assessed by ultrasound at 5 weeks is about 40% [43,44], which means that 60% of cows will continue to cycle and should be watched for estrus. Therefore, estrus detection is still critical for more than half of all synchronized cows. Thus, it is important to evaluate estrus detection efficiency in light of any synchronization and TAI; the records may indicate low DFS and high HDR (because of many cows being submitted for insemination), but efficiency of detection in cows following TAI may be low. Evaluation of interestrus intervals, discussed below, may help to shed light on estrus detection efficiency in herds with a high proportion of cows under OvSynch and TAI.

Monitoring efficiency in period two

Period two concerns the reproductive performance of the herd for all cows requiring multiple services to become pregnant. This period can be monitored in DHIA records using the herd’s HDR, and either the services per conception (SPC) or CR. The herd HDR is the percentage of possible estruses detected (all recorded breedings are assumed to be estruses) in eligible cows during a test period [9]. The term SPC is calculated separately for all cows and pregnant cows, but this article focuses on all cows. SPC for all cows is the total number of services recorded for all cows (pregnant, open, and even cows designated as culls) divided by the number of pregnancies; CR is the inverse of SPC. Herds should strive to have high HDR and high CR (low SPC) although a balance must be struck between HDR and CR—Kinsel and Etherington [15] found a small but significant reduction in CR as HDR increased.

Monitoring heat detection rate in period two

Efficient and accurate estrus detection is the cornerstone of a successful dairy herd reproductive management program [35], and increased HDR is
associated with lower PDO [45]. Heat detection of 70% or greater is considered good, and HDR less than 60% may be considered suboptimal [16]. The calculation of HDR is complex and does vary between DRPCs [10,46], but it is important to realize that calculated HDR reflects the recorded number of cows submitted for insemination, and that it does not reflect the accuracy of effort. Heat detection rate in records can be low if all breedings are not recorded; also, as mentioned earlier, HDR will be higher in herds using synchronization protocols and TAI.

Fig. 5 illustrates a relationship between HDR and PDO for a dairy herd. During most of 2000, HDR was lower and PDO higher than in most of 1999. Of particular interest is the period in late 1999 when HDR dropped and PDO increased. The herd visit should investigate how management or health conditions may have changed, and triggered a change in HDR that affected PDO.

Managers of herds with suboptimal HDR should consider that multiple factors related to management and cow health may affect success in this area (see Fig. 1). Factors that affect HDR, such as intensity of detection, milk production, nutrition, environment, metabolic disease, and feet and leg health, have been discussed with respect to DFS, and apply to problems with HDR. In many situations, herds with suboptimal HDR will also have extended DFS.

Monitoring conception in period two

The herd’s CR is an important component of PDO [47], reported as the proportion of bred cows that are diagnosed pregnant [10,11]. The inverse of CR is SPC, so it is possible to calculate the SPC first and then the CR. If this
is done, it is important to use the SPC for all cows (which represents all breedings in the herd) rather than SPC for pregnant cows (which just uses breedings for pregnant cows). Using SPC for pregnant cows overestimates CR, because SPC for pregnant cows is less than SPC for all cows. Some have suggested a target CR of 50% [48], whereas others have suggested that SPC should be less than 2.25 (CR greater than 40%) [30].

Fig. 6 illustrates a relationship between CR and PDO for an example herd. In 2002, there was a higher CR and lower PDO, but in 2003 a drop in CR is associated with an increase in PDO. It is important to realize that the relationship does not mean that changes in CR are responsible for changes in PDO, only that the herd visit should investigate potential causes of reduced CR, and assess the potential of CR to affect PDO.

It was mentioned that when monitoring FSCR, conception is a function of successful fertilization of the oocyte as well as implantation and maintenance of the conceptus to pregnancy diagnosis. The same is true for CR, and the herd management should consider factors that affect success of fertilization as well as factors that affect pregnancy wastage, although it is difficult to differentiate failure of fertilization from pregnancy wastage. The same factors discussed when analyzing FSCR are applicable to evaluation of problems with low CR (or high SPC).

**Monitoring inter estrus intervals**

Earlier it was mentioned that accuracy of heat detection can affect conception rate and overall reproductive performance. For cows that are bred multiple times, DRPCs calculate the days between reported breedings as the inter estrus interval. The herd-level distribution of intervals into
specific categories can help offer insight regarding the efficiency and accuracy of heat detection as well as provide indicators of cow health issues. Interestrus intervals are best characterized as short irregular intervals (less than 18 days between breedings), short regular intervals (18–24 days between breedings), long irregular intervals (25–35 days between breedings), long regular intervals (36–48 days between breedings), and extended intervals (49 or more days between breedings).

Short irregular intervals are suggestive of inaccurate heat detection. Assuming an estrus cycle length of 18 to 24 days, intervals of less than 18 days suggest that either of the last two breedings was to a nontrue heat. It is recommended that fewer than 15% of intervals fall in this category [30].

The short regular interval represents an ideal interval for cows bred more than once. An 18 to 24-day interval suggests that the next to last breeding was to a true heat, but did not result in a pregnancy; however, the producer successfully identified the cow open returning to another true heat at the earliest possible time. The short regular intervals should be at least 60% of intervals [30], which is consistent with an overall herd HDR of 60%; the high values suggest efficient and accurate estrus detection.

The long irregular interval may suggest both inaccuracy and inefficiency of estrus detection, problems with ovarian physiology, or EED. The 25 to 35-day interval could result from one of the last two breedings being inaccurate, coupled with a missed true heat (inefficiency). It could also arise from factors affecting follicular development and luteinization (such as heat stress, high production, or nutrition), or because a pregnancy that was appropriately recognized by the dam was lost shortly thereafter. Herds should try to keep these intervals at less than 10% of all intervals [30].

Intervals of 36 to 48 days represent late regular intervals, and are the next best to short regular intervals. Intervals of this duration represent two accurately detected heats separated by a missed heat (inefficiency). Although these suggest accuracy, the missed estrus is not ideal; intervals of this duration should represent less than 10% of all intervals [30].

Finally, intervals of 49 or more days, or extended intervals, are undesirable, and can arise due to inefficient estrus detection (two or more missed heats) or from fetal loss and abortion. These intervals should be less than 5% of all intervals [30]. In a herd considered to have efficient and accurate estrus detection, a high proportion of extended intervals may indicate unacceptable levels of fetal loss or abortion, and reasons for this, particularly infectious diseases, should be considered. Furthermore, any observed abortions should receive a full diagnostic work-up.

Interestrus intervals may also be useful in characterizing estrus detection in herds using OvSynch and TAI. In these herds, HDR may be high and DFS may be low, suggesting efficient detection of estrus (because of high numbers of cows submitted for insemination). If heat detection following TAI is inadequate, however, these herds may have low proportions of short regular interestrus intervals, and high proportions of late regular or even
extended intervals. Thus, the interestrus intervals are an important adjunct to monitoring estrus detection efficiency in OvSynch herds, and it is critical to remind producers that estrus detection is very important even in bred cows—at least half of these are expected to return to estrus.

**Other considerations in monitoring reproductive records**

*Age at first calving*

Another important piece of information to examine in dairy herds with respect to reproductive performance is the average age at first calving. Before first calving, heifers do not generate revenue for the producer. Also, earlier calving ensures that replacements are ready in a timely fashion. Thus, it is good to have heifers calve by 24 months of age, but it is important that heifers be of appropriate size—at least 544 kg (1200 lbs) after first calving [49]. If a herd has delayed age at first calving, the producer and veterinarian should evaluate the heifer rearing program with respect to nutrition, housing, and health status of growing heifers.

*“Slice-and-dice” analysis*

Bailey et al [16] point out that the distribution of herd reproductive performance is often as important as mean values in monitoring reproductive efficiency. Therefore, they suggest “slicing” records analysis by age (lactation number) and “dicing” by stage of lactation (DIM periods). The techniques described here dice records with respect to the two periods described, but more periods can be examined. Slice-and-dice analysis is useful to help zero in on specific ages, groups, or pens to investigate during the herd visit. Too much slice and dice, however, can yield unstable performance estimates by reducing the number of cows included in each group analyzed. The technique is limited in smaller herds—it can be performed, but veterinarians should note if cow numbers in any examined group are small (fewer than 10, and certainly no fewer than 5).

**Assimilating information**

When analyzing dairy records and investigating relationships between various measures, it is useful to consider that multiple interactions can be occurring simultaneously. For example, PDO may not change in response to increased HDR if CR simultaneously decreases. Likewise, in many cases an increase in DFS may occur with a reduction in HDR, or FSCR and CR may decline together. Being aware of the potential for these interactions to exist improves the quality of any records analysis. Still, any hypotheses generated from records analysis should be confirmed with impressions obtained during the herd visit.
Choosing intervention strategies

Although a number of ideal performance targets have been mentioned in this article, few herds achieve these performance levels. For example, an estimate of HDR for US herds is under 50% [50], far from an ideal of 70%. Furthermore, reproductive inefficiency is often caused by a number of shortcomings related to management and cow health. Therefore, producers and veterinarians need to prioritize targets for intervention; however, it is difficult to allocate finite labor and capital resources to programs that need attention. A good rule of thumb to follow is that measures that are further from targets often present greater opportunities for improvement. Each additional DO becomes more costly to herds as CI increases [5]. Also, benefits of marginal improvement in HDR are greater for herds when HDR is low as opposed to herds in which HDR is high [37].

Summary

Review of reproductive records for dairy herds can be useful in terms of detection of potential problems, confirmation and characterization of suspected problems, and suggestion of targets for intervention in the reproductive management of the herd. An organized strategy for analysis makes it easier to identify and communicate issues to the producer, as well as to offer factors that may be undermining reproductive performance. Records review may generate hypotheses with respect to the situation in the herd, but these must be corroborated by information obtained during the herd visit. Optimal targets are difficult to achieve, but it is important to realize that the greatest potential for economic gains lies in areas that are furthest from targets.

References


