A fresh look at inter-service intervals in UK dairy herds

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Abstract

Good heat detection is essential for good reproductive performance in the modern dairy herd using artificial insemination. Veterinary surgeons and farmers use a variety of tools to monitor heat detection including the analysis of inter-service intervals (ISIs). The aim of this study was to explore the distribution of inter-service intervals in a large sample of UK dairy herds and establish targets for use by practitioners when interpreting ISIs. In this study service records from 167 dairy herds from across the UK were used to generate ISI profiles for each calendar year of each herd. Intervals between serves were categorised as short irregular (2-17 days), short regular (18-24 days), long irregular (25-35 days), long regular (36-48 days) or extended (>48 days). Herd-years were ranked by oestrus detection efficiency, the mean of the top quartile of herd-years had 6%, 40%, 16%, 19% and 19% of intervals in each interval category respectively. There was no correlation between the percentage of serves falling in the short regular and short irregular category for a given herd-year (Spearman rho magnitude <0.01, p=0.84), suggesting little direct correlation between the sensitivity and specificity of a herd's heat detection. The results show a substantial difference to accepted targets and will be of use when interpreting herd data and target setting for UK dairy herds.

Introduction

Efficient reproductive performance is a prerequisite for good profitability in almost all dairy herds. In recent years, as numbers of dairy cattle in the UK have declined and milk yields have increased, concerns have been raised about a concurrent decline in reproductive performance (Dobson and others 2007), this has also been noted internationally (McDougall 2006). However, recent studies suggest that this trend may be reversing in the UK (Hudson and others 2010), predominantly due to improvements in heat detection.

Reproductive performance in dairy herds is dependent on both the rate at which cows are detected in oestrus and inseminated (submission rate) and the rate at which inseminated cows become pregnant (conception or pregnancy rate) (Breen and others 2009), and monitoring reproductive performance on dairy farms is a key role of veterinary surgeons. Various parameters can be used to monitor reproductive performance including multiple approaches for measuring oestrus detection (Gordon 2011). It is important to monitor both the ability to detect a cow's first oestrus after calving, and the ability to detect subsequent oestruses in cows previously served but not pregnant. In both instances it is important to consider both the accuracy of detection (specificity) and the efficiency (sensitivity) of detection (Heersche and Nebel 1994; Meadows 2005).

A commonly proposed method of using farm data to monitor heat detection in cows returning to oestrus after a previous service is to calculate the frequency distribution of intervals between subsequent inseminations during a cow's lactation (inter-service intervals, ISIs). The use of ISI profiles to monitor heat detection at a herd level involves comparing the distribution of ISIs across set categories (Meadows 2005). These categories are determined based on the assumption that a normal, cyclic, non-pregnant cow will ovulate on average every 21 days, with a normal range of 18 to 24 days (Hartigan 2004). These categories are defined in

Table 1.

Various target and intervention levels are suggested when examining ISI profiles. For example,Roelofs and others (2010) propose that intervals less than 18 days should account for less than 10-15% of re-serves, normal intervals of 18-24 days should account for greater than 60-70% of re-serves. Heersche and Nebel (1994) suggest the ratio of 18-24 day (1st heat) serves compared to 36-48 (2nd heat) should be 6:1, with an intervention level of 4:1.

Whilst this method is commonly described in the literature (Hanks 2008; Heersche and Nebel 1994; Meadows 2005) little work exists to assess the distribution of intervals on a large population of dairy cows and quantify the normal between-herd variation; especially in modern UK herds. One such study of 71 Wisconsin dairy herds (Gaines and others 1992) found that most herds failed to achieve the commonly accepted target ISI distributions described above and that there was a poor correlation between abnormal ISIs and other reproductive parameters.

The aim of this study was to explore the distribution of inter-service intervals in a large sample of UK dairy herds and establish targets for use by practitioners when interpreting ISIs.

Materials and Methods

A set of management data from 468 English and Welsh dairy herds contributed by a group of 20 bovine practitioners as part of a larger project (Hudson and others 2012; Hudson and others 2010) was used for this study. The data was amalgamated and standardised from various sources and contained health, fertility and production data for each farm. The anonymised herd datasets were individually analysed for indicators of good quality fertility data. These included identifying randomly missing events: for example by calculating the proportion of calvings for which a corresponding serve was recorded, and calculating the lactational incidence rate of various fertility events. Systematic errors were also identified by, for example, evaluating the apparent first serve pregnancy rate and the proportion of serves which were the second of a pair between milk recording test days. Data quality was evaluated at herd-year level, so that herds only contributed data for calendar years in which recording appeared acceptable. The data from one herd for one calendar year will be referred to as a “herd-year” throughout the manuscript. Only data from lactations beginning in the years 2000-2008 was used.

Herds were assessed for any apparent seasonality in the number of serves per month. Two datasets were created, one using all herd-years with good quality data (ALL), and the subset of these herds which showed no apparent seasonal pattern of serves (all year round calving, AYR). This subset was created as it was considered possible that some analyses would be affected by seasonality (e.g. “falsely” extended service intervals in cows not becoming pregnant in a seasonal breeding block which were retained in the herd to be bred in the next season). After removing herds failing to meet the inclusion criteria for at least one year, a sample of 167 ALL herds and 103 AYR herds remained (descriptive statistics of all the herds included in the final analysis are given in

Table 2).

The data was structured so that each service event represented a line of data. The ALL group consisted of 449 471 serves in 181 159 lactations from 67 926 cows. The AYR consisted of 255 722 serves in 101 123 lactations from 40 409 cows. For each service record the date, lactation number and service number were recorded, along with calving date. Intervals between a service event and the cow’s previous serve in the same lactation were calculated, resulting in a total of 268 312 inter-service intervals (ISIs) in the ALL group and 154 599 in the AYR group. ISIs of less than two days were assumed to be related to the same oestrus event and so were excluded from the analysis (1870 of 268 312 intervals and 1088 of 154 599 intervals in the ALL and AYR groups respectively). As highly extended ISIs were considered likely to be related to abortion or anomalies in the records, a sensitivity analysis was carried out by repeating the analysis described below on subsets of the data excluding ISIs over 150, 200, 250 and 300 days. Results for analyses of these subsets were extremely similar, so results from the subset excluding intervals over 200 days (11 181 of 268 312 intervals and 1 525 of 154 599 intervals in the ALL and AYR groups respectively) are reported. Herd-years containing less than 100 ISIs were removed from the dataset to eliminate outliers caused by very small numbers of ISIs occurring in a herd-year (512 of 1396 herd years were excluded in the ALL group and 210 out of 741 herd years in the AYR group).

The proportion of ISIs that fell into each of the categories described in

Table 1 was calculated for each herd-year in both the ALL and AYR datasets. The distributions of these proportions across the herd-years were visualised using violin plots (Hintze and Nelson 1998). The proportion of ISIs within the short irregular category (intervals <18 days) was plotted against the proportion within the short regular category (18-24 days) for each herd-year. The correlation between these was evaluated using Spearman's rank correlation coefficient. This was done to identify whether herds with more 'sensitive' heat detection (i.e. those detecting more oestrus events at the short regular interval) tended to be less specific (i.e. inseminating more cows in the short irregular interval).

To enable achievable targets to be set for the interpretation of ISI profiles, the herd-years were ranked by an overall measure of heat detection. An accepted way of generating a single measure of heat detection based on ISI profiles is to calculate oestrus detection efficiency (ODE) using the Warren equation (Gordon 2011). ODE was calculated for each herd-year by dividing the number of ISIs falling in the short and long regular interval categories by the total number of intervals, with long regular and extended intervals weighted in the denominator by a factor of two, as shown in Equation (1).

Herd-years were ranked by ODE, with those having the highest ODE considered the best performing. Herd-years were then split into subsets representing the top 10%, top 25% and top 50% of the dataset by ODE. For each of these subsets, the mean percentage of ISIs falling into each of the categories was calculated, in order to represent "typical" ISI profiles for herds achieving top 10, 25 and 50% heat detection performance.

Average calving interval for each herd-year was calculated as a measure of overall fertility performance. Spearman's rank correlation coefficient was used to evaluate the relationship between herd-year ODE and calving index to confirm whether ODE was a valid method or ranking the herd-years. Spearman's rank correlation coefficient was also used to evaluate relationships between ODE and herd-year average 305 day milk yield, average herd size and year. In all statistical tests $p<0.05$ was considered significant.

The data was restructured and amalgamated using Microsoft Excel 2010 (Microsoft Corporation, Redmond, Washington) and analysis carried out in R 2.15.0 (R Core Team 2013). The vioplot package (Adler 2005) was used to produce the violin plots in R.

Results

Table 3 shows the mean, median, upper and lower quartile herd-year in the ALL group for each category of the ISI profile, the ODE and the short regular to long regular ratio. For example, when comparing herd-years in the ALL group, 25% of herd-years had more than 39% (upper quartile) of intervals in the short regular (18-24 days) category, half the herd-years had >33% (median) and 75% of herd-years had >27% (lower quartile) in this category. Both the ALL and AYR datasets showed a wider between-herd variation in the percentage of ISIs in the 18-24 day and the 49+ category compared to the remaining categories. The findings were broadly similar across the two groups and for the remaining seasonal herds (median ODE was 0.36 for all groups), and so all subsequent analysis was carried out using the ALL group.

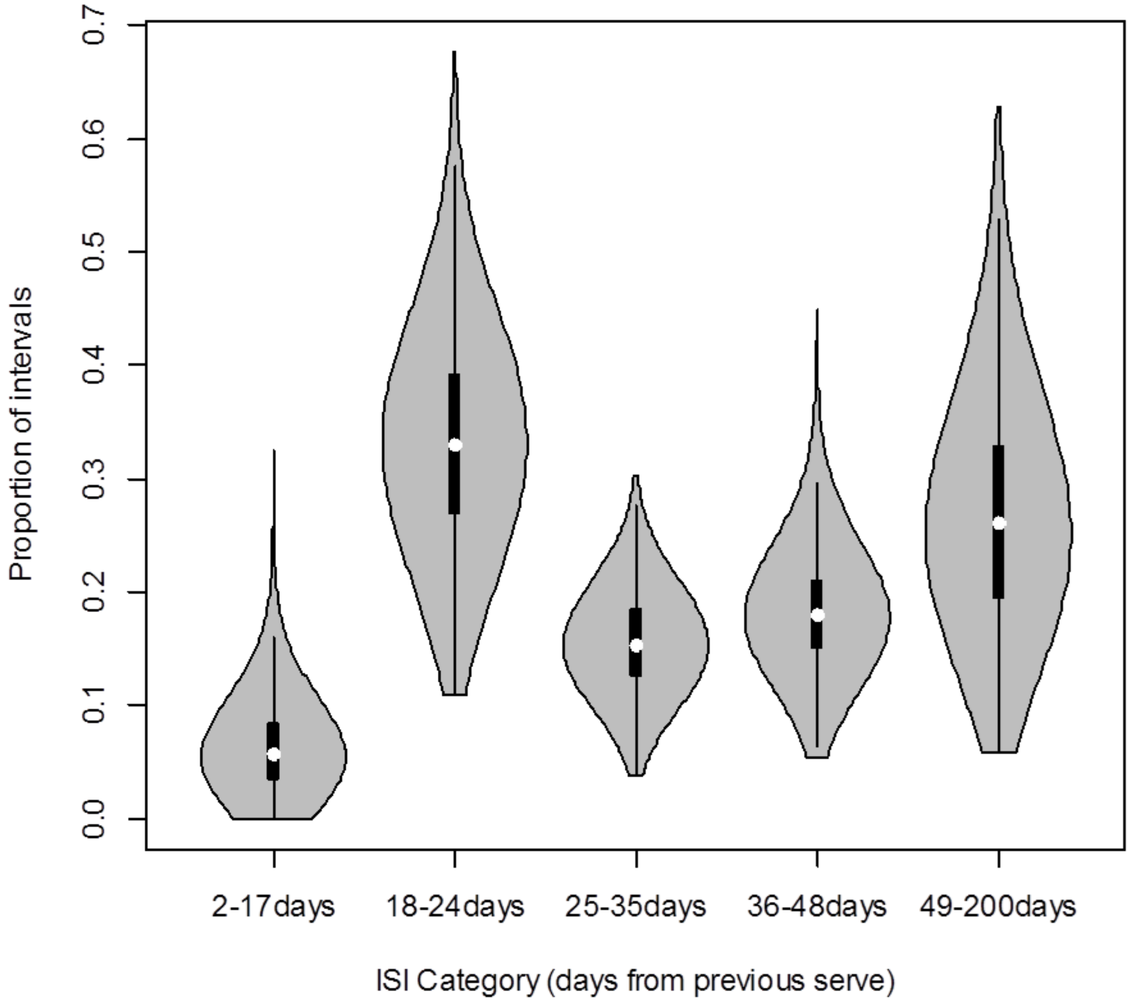

Figure 1 shows the distribution of herd-years within each category. The vertical range of the violin plot for each category shows the range of herd-years and the width of the violin plot represents a fitted kernel density (showing the frequency distribution). The white dot represents the median herd-year and the thick black line represents the inter-quartile range. For example the herd-years range from having 11% to 68% of serves within the herd-year falling in to the short regular (18-24 day) category, whereas the range for the late irregular (25-35 day) category is much narrower with herd-years performance ranging from 4% to 30%. The distribution of herd-years also varies between categories. For example in the short irregular (2-17 day) category the median herd-year (shown by the white dot) had 6% of serves in this category with an inter-quartile range from 3 to 8% with half the herd-years clustered in this range, however there are a small number of herd-years with a much higher percentage of serves falling in this category (up to 33%) of serves falling in to this category, this is shown by the upward tail of the violin plot, whereas in the late irregular (25-35 day) category the herd-years are much more symmetrically distributed around the median of 15%.

There was no correlation between the percentage of ISIs in a herd-year falling in the short irregular (2-17 days) and short regular (18-24 days) category (magnitude of Spearman rho (r_s) <0.01, p=0.84) (Figure 2). ODE over the herd-years ranged from 0.16 to 0.63 with a median of 0.35, an upper quartile of 0.41 and a top decile of 0.47. The mean percentage of ISIs in each category for the top 10%, 25% and 50% of herd-years by ODE are shown in

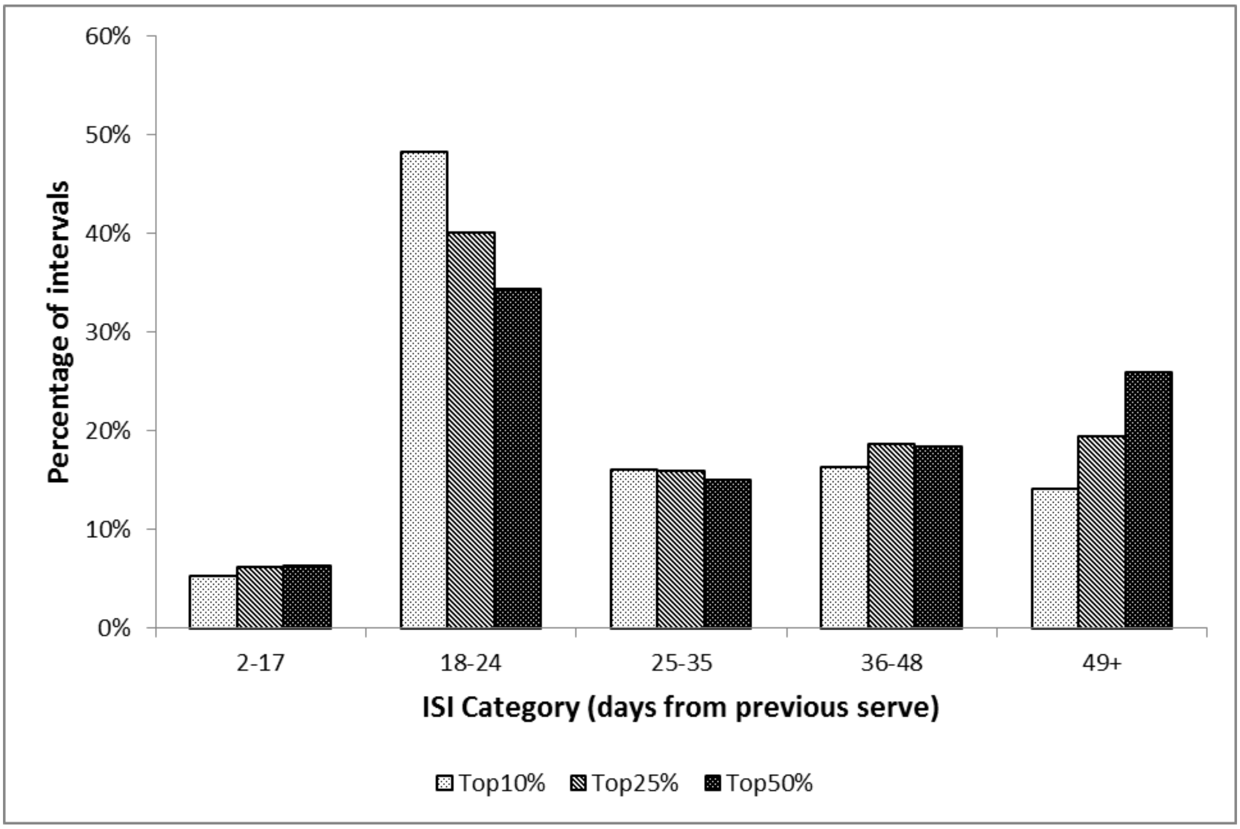

Figure 3. The top 10% of herd-years averaged 48% short regular intervals and 5% short irregular intervals.

Herd-year ODE negatively correlated with herd-year mean calving interval (r_s=-0.4, p<0.01). The ratio between short regular and long regular serves correlated less strongly with mean calving interval (r_s=-0.24, p<0.01), with both the percentage of serves in the short regular and extended interval categories having a stronger correlation with mean calving interval (r_s=-0.36, p<0.01 and r_s=0.39, p<0.01 respectively). There was no significant correlation between herd-year ODE and average herd size, 305day milk yield or year.

Discussion

The analysis of ISI category distribution between herd-years in this study shows that most UK herds in this sample achieve the proposed target of less than 10-15% of intervals occurring at less than 18 days (Roelofs and others 2010), but that very few achieve a target of 60-70% of re-serves occurring at 18-24 days and only 25 out of 879 herd-years exceed the accepted intervention level of a 4:1 ratio for serves in the 18-24 category compared to the 36-48 category. The average herd-year in the top quartile (by ODE) in this study achieves short irregular intervals of 6%, short regular intervals of 40%, long irregular intervals of 16%, long regular intervals of 19% and extended intervals of 19%. These could be considered more appropriate targets when interpreting inter-service intervals than the suggested targets previously described. It should be remembered that any performance targets should be adapted to the herd being assessed: clearly there are already some herds exceeding this level of performance. However, having an appreciation of wider performance is a good context for such target setting.

There is no perfect measure of overall fertility performance. Herd-year mean calving interval was used in this study to give an idea of herd performance because it was available in the data, however it will not account for fertility culling rates. The correlation between ODE and calving interval indicates that this was an appropriate method of ranking herd-years in this study. As would be expected due to the multifactorial nature of herd fertility, ODE does not fully predict calving interval. ISI profiles can only ever provide information on re-serves and will not incorporate return to cyclicity, heat detection for first serve or pregnancy/conception rate.

The apparently good/low number of short irregular intervals in herds in this study and the apparently disappointing number of short regular intervals suggests that specificity of detection is often acceptable in UK herds, but that sensitivity of detection is very often sub-optimal. This indicates that sensitivity is very often more limiting than specificity and this should be kept in mind when trying to improve heat detection on a unit. This may be because the signs of oestrus have been well documented (Roelofs and others 2010) and that farmers are confident in identifying those that are definitely in oestrus. It could also be because this method looks at the sensitivity of detecting oestrus in those cows that have already been served, farmers may be less willing to inseminate cows that may potentially be pregnant compared to those that have not yet been served. It may just be that good sensitivity with heat detection is more challenging than achieving good specificity.

With many tests sensitivity and specificity are often negatively correlated, this would lead to the assumption that herds which detect a high proportion of returns to oestrus may also have high numbers of heats incorrectly diagnosed and vice versa. This would lead to a correlation between the number of incorrectly identified heats (short irregular) and the number of correctly identified heats (short regular). The lack of correlation between short irregular and short regular serves (Figure 2) suggests that these two are relatively independent, and that herds are capable of increasing sensitivity without compromising specificity.

Care should be taken when extrapolating the results of any study to other UK herds. The herds used in this study may not be representative of all UK herds, the fertility data quality controls could plausibly select larger, better managed herds. This possibility is supported by the summary statistics described in

Table 2, with median herd size being slightly above the median herd size in a sample of 500 randomly selected milk recording herds (Hanks and Kossaibati 2012), although median, upper and lower quartile 305day yield and calving index figures are very similar to those in the larger sample. However despite this potential bias the median percentage of re-serves occurring at 18-24 days in our study (33%) is extremely similar to the 31% median found by Hanks and Kossaibati (2012) in their larger sample of herds: this analysis is clearly only possible in herds with accurate records. It is also possible that these patterns will have changed since the data was gathered in 2009. However this data still provides a more current reference than the commonly accepted targets described previously, and the similarity with the findings of Hanks and Kossaibati (2012) suggest that there has been no dramatic change in performance between 2008 and 2012.

In conclusion, ISI profiles appear to be a valid method to consider as part of a package of methods to monitor heat detection as a component of dairy herd fertility. Currently accepted targets seem optimistic and the results of this study will be of use for practitioners when interpreting ISI profiles.

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Conflict of interest declaration

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References

Adler, D. (2005) vioplot: Violin Plot. R package version 0.2

Breen, J. E., Hudson, C. D., Bradley, A. J., Green, M. J. (2009) Monitoring dairy herd fertility performance in the modern production animal practice **17**, 196-201

Dobson, H., Smith, R. F., Royal, M. D., Knight, C. H., Sheldon, I. M. (2007) The high-producing dairy cow and its reproductive performance. Reproduction in Domestic Animals **42**, 17-23

Gaines, J. D., Thomas, C. B., Eicker, S., Rhoda, D., Goedtel, M., Larson, P. L., Lindner, E. R., Lindborg, M. (1992) Interestrous interval profiles of 71 Wisconsin dairy herds and relationship to days to pregnancy. Preventive Veterinary Medicine **12**, 47-58

Gordon, P. (2011) Oestrus detection in dairy cattle. In Practice **33**, 542-546

Hanks, J. (2008) Using milk recording data to investigate herd fertility. UK Vet: Livestock **13**, 37-40

Hanks, J., Kossaibati, M. (2012) Key Performance Indicators for the UK national dairy herd. Ed V. E. E. R. U. (VEERU). University of Reading

Hartigan, P. J. (2004) Reproductive Physiology in Cattle. In Bovine Medicine: Diseases and Husbandry of Cattle. 2nd edn. Eds A. H. Andrews, R. W. Blowey, H. Boyd, R. G. Eddy. Oxford, England, Blackwell Science Ltd. pp 471-505

Heersche, G., Jr., Nebel, R. L. (1994) Measuring efficiency and accuracy of detection of estrus. Journal of Dairy Science **77**, 2754-2761

Hintze, J. L., Nelson, R. D. (1998) Violin Plots: A Box Plot-Density Trace Synergism. The American Statistician **52**, 181-184

Hudson, C. D., Bradley, A. J., Breen, J. E., Green, M. J. (2012) Associations between udder health and reproductive performance in United Kingdom dairy cows. J Dairy Sci **95**, 3683-3697

Hudson, C. D., Breen, J. E., Bradley, A. J., Green, M. J. (2010) Fertility In UK Dairy Herds: Preliminary Findings Of A Large-Scale Study. Cattle Practice **18**, 89-94

Mcdougall, S. (2006) Reproduction performance and management of dairy cattle. Journal of Reproduction and Development **52**, 185-194

Meadows, C. (2005) Reproductive Record Analysis. Veterinary Clinics of North America: Food Animal Practice **21**, 305-323

R Core Team (2013) R: A language and environment for statistical computing. Vienna, Austria, R Foundation for Statistical Computing

Roelofs, J., Lopez-Gatius, F., Hunter, R. H. F., Eerdenburg, F. J. C. M. V., Hanzen, C. (2010) When is a cow in estrus? Clinical and practical aspects. Theriogenology **74**, 327-344

Table 1 Description and interpretation of inter-service interval categories

Interval Range	Description	Interpretation
2-17 days	Short irregular	Inaccurate heat detection (estimates inverse of specificity) and pathological*
18-24 days	Short regular	Accurate heat detection at first heat (estimates sensitivity)
25-35 days	Long irregular	Late embryonic death and inaccurate heat detection
36-48 days	Long regular	Accurate heat detection following one missed heat
49+	Extended interval	Multiple missed heats, foetal loss and abortion

*****Whilst pathology (such as cystic ovarian disease) may affect the inter-oestrus interval of an individual cow, this is much rarer and is unlikely to have a dramatic influence on the herd pattern analysed using this technique

Table 2 Summary production statistics for herd-years included in the final analysis

	Mean	Median	Lower Quartile	Upper Quartile
Average 305 day milk yield/litres	7599	7713	7051	8478
Average herd size*	235	201	164	256
Calving index	420	417	431	404

*Average herd size was calculated by dividing the number of cows calving by the average calving interval/365 for each herd-year.

Table 3 The mean, median, upper quartile (UpperQrt) and lower quartile (LowerQrt) herd-years for each ISI category, oestrus detection efficiency and the ratio of short regular to long regular reserve intervals

	UpperQrt	Median	Mean	LowerQrt
2 to 17	8%	6%	6%	3%
18 to 24	39%	33%	33%	27%
25 to 35	19%	15%	16%	13%
36 to 48	21%	18%	18%	15%
49 to 200	33%	26%	27%	20%
Oestrus detection efficiency	0.41	0.36	0.36	0.31
Short regular to long regular ratio	2.52	1.86	2.01	1.32

Equation 1 Calculating oestrus detection efficiency (ODE) from the proportion of inter service intervals falling within each category

$$\mathrm{ODE} = \frac{\text{short regular} + \text{long regular}}{[\text{short irreguar} + \text{short regular} + \text{long irregular} + 2(\text{long regular} + \text{extended})]} \tag{1}$$

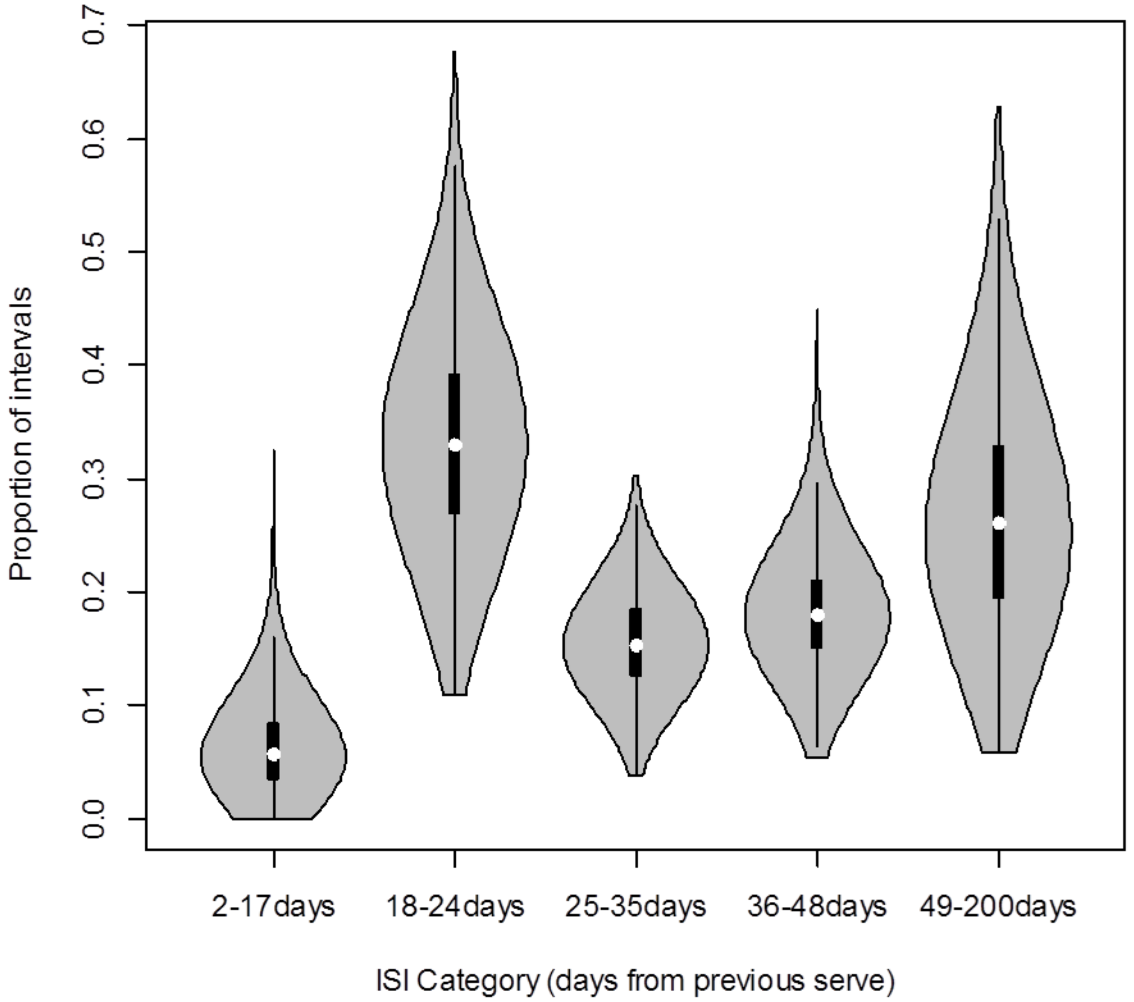

Figure 1 A violin plot showing the distribution of herd-years from the ALL group within each category. The white dot is the median value, the thick black line the interquartile range and the vertical length of the violin is the range. The width of the violin represents the distribution of herd-years within this range.

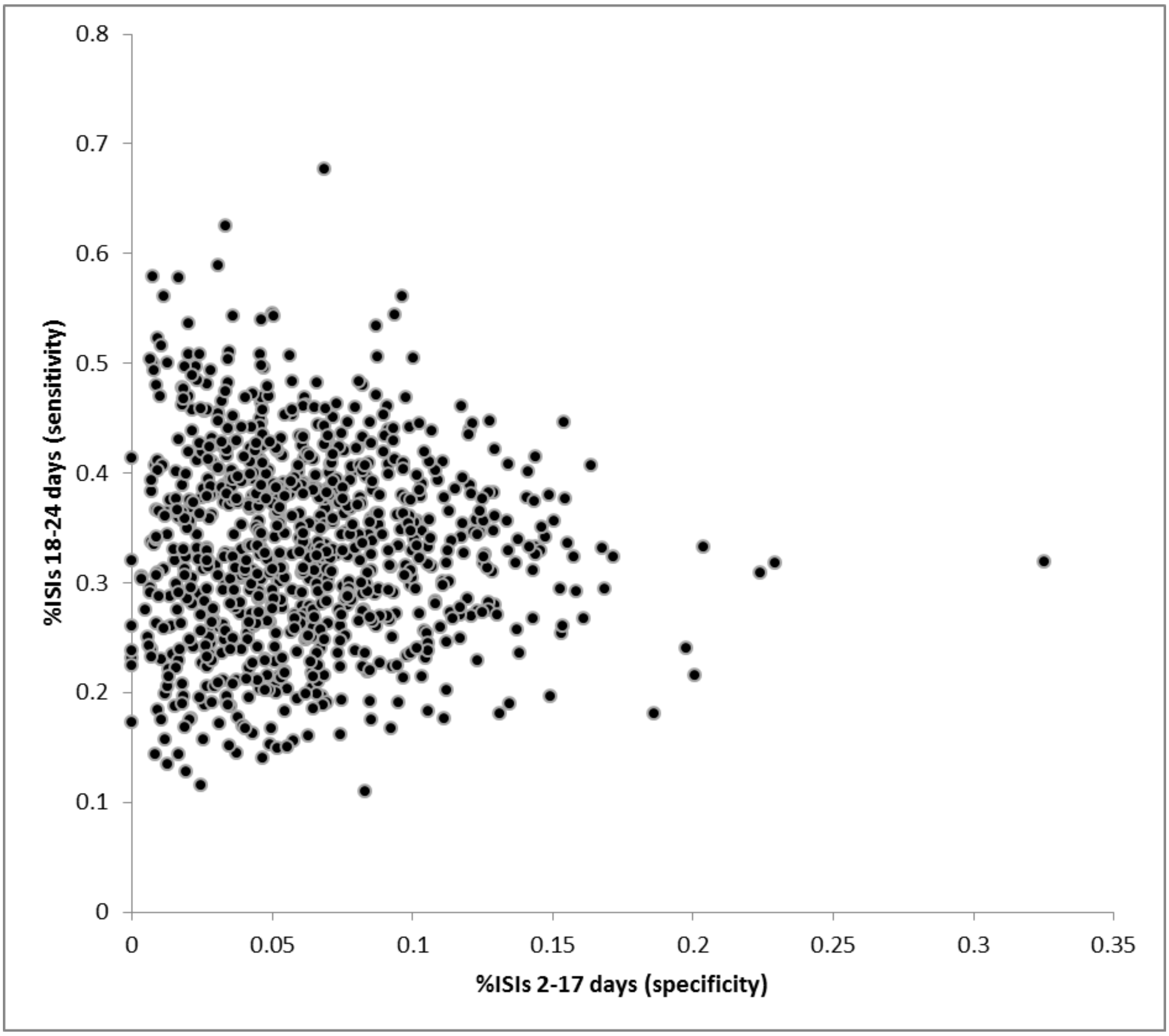

Figure 2 The relationship between herd-year short regular and short irregular interval categories (Spearman's Rho= -.0066)

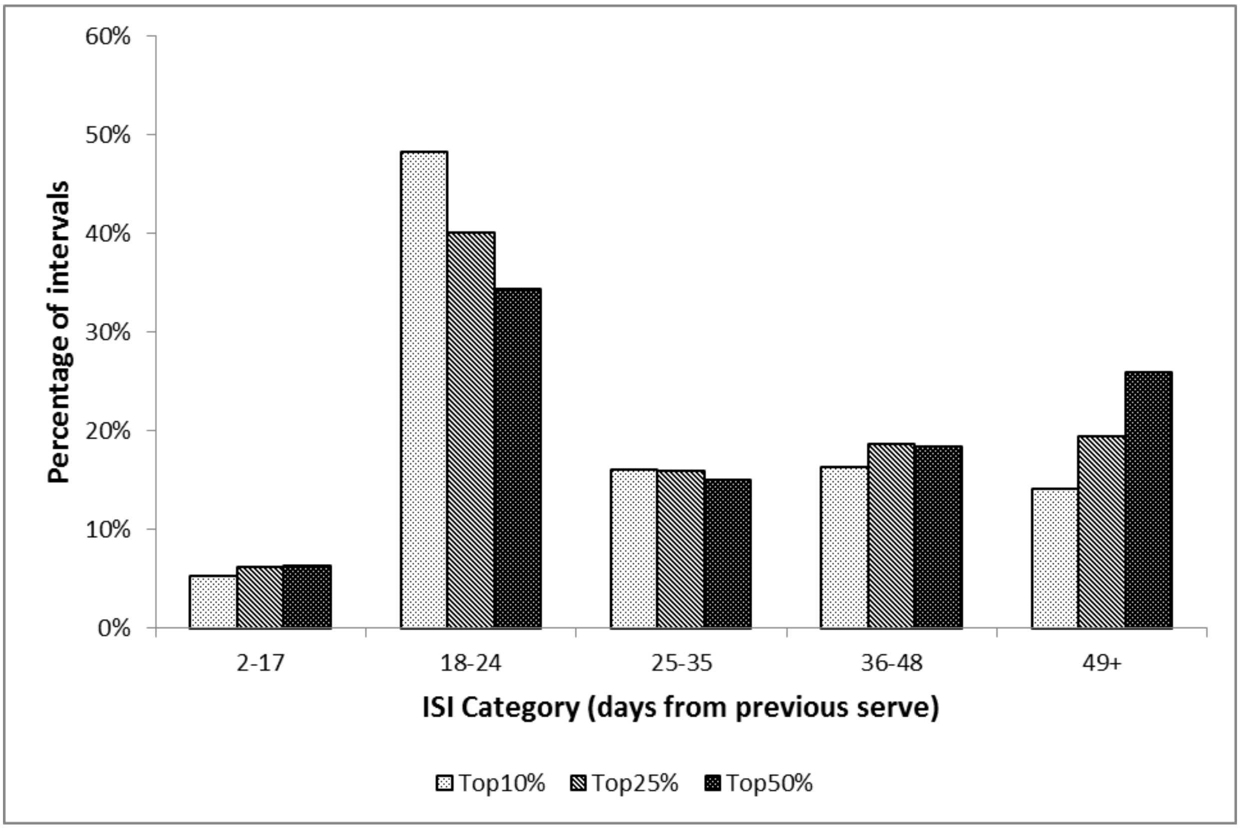

Figure 3 The mean percentage of intervals falling in each category for the top 10, 25 and 50 % of herd-years by oestrus detection efficiency