

Adjusting production targets and interference levels: How to help your clients avoid being tricked

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Summary— *The veterinary profession continues to make greater use of production databases in serving the swine industry. These increasingly sophisticated database management systems, which combine financial and biological data, allow producers and practitioners to consider the biological, statistical, and economic implications of possible management interventions. Frequency distributions and simple descriptive statistics can be very helpful in understanding the patterns that underlie commonly used measures of swine herd productivity. Statistics can be used to set feasible production targets and confidence intervals to accommodate the variability inherent in biology. Confidence intervals and interference levels can be adjusted to lessen the chances of Type I and Type II errors being made when sample sizes are small (e.g., in smaller herds or when one wishes to analyze performance over short time periods). These simple statistical techniques can help us avoid confusing normal variation with real changes in productivity.*

The computer software programs used in the swine industry to monitor productivity today are so sophisticated that users can be overwhelmed by the numerous options and reports. Increasingly, producers are turning to their veterinarians to help them interpret the production information generated by their **database** programs. Properly applied, this information can be enormously valuable in identifying and diagnosing management problems. As in any biological system, however, there will be some normal variability in the production parameters for a pig herd. The challenge facing the practitioner is to differentiate between production values that represent normal biological variation and those that truly warrant interference.

For example, the weights of 30 individual market hogs killed this week will not be identical, but will range predictably around an average value. The individual animal weights will differ from those of a similar group sold during the previous week from the same farm. Ultimately, interpreting this variability is a game of assessing how well a subpopulation (e.g., a group of pigs going to market during a given week, or a group of sows that farrow within a week or month) represents the productivity of the entire herd.

Statistics help us interpret production values in meaningful ways. By understanding and using simple statistics, one can determine:

- how confident one can be that the data for a subpopulation is not different from the long-range goals for the productivity of the entire herd (i.e., the **confidence interval**); and
- at what point productivity falls outside of this confidence interval, meaning that productivity is truly off-target and interference is warranted (i.e., the **interference level**).

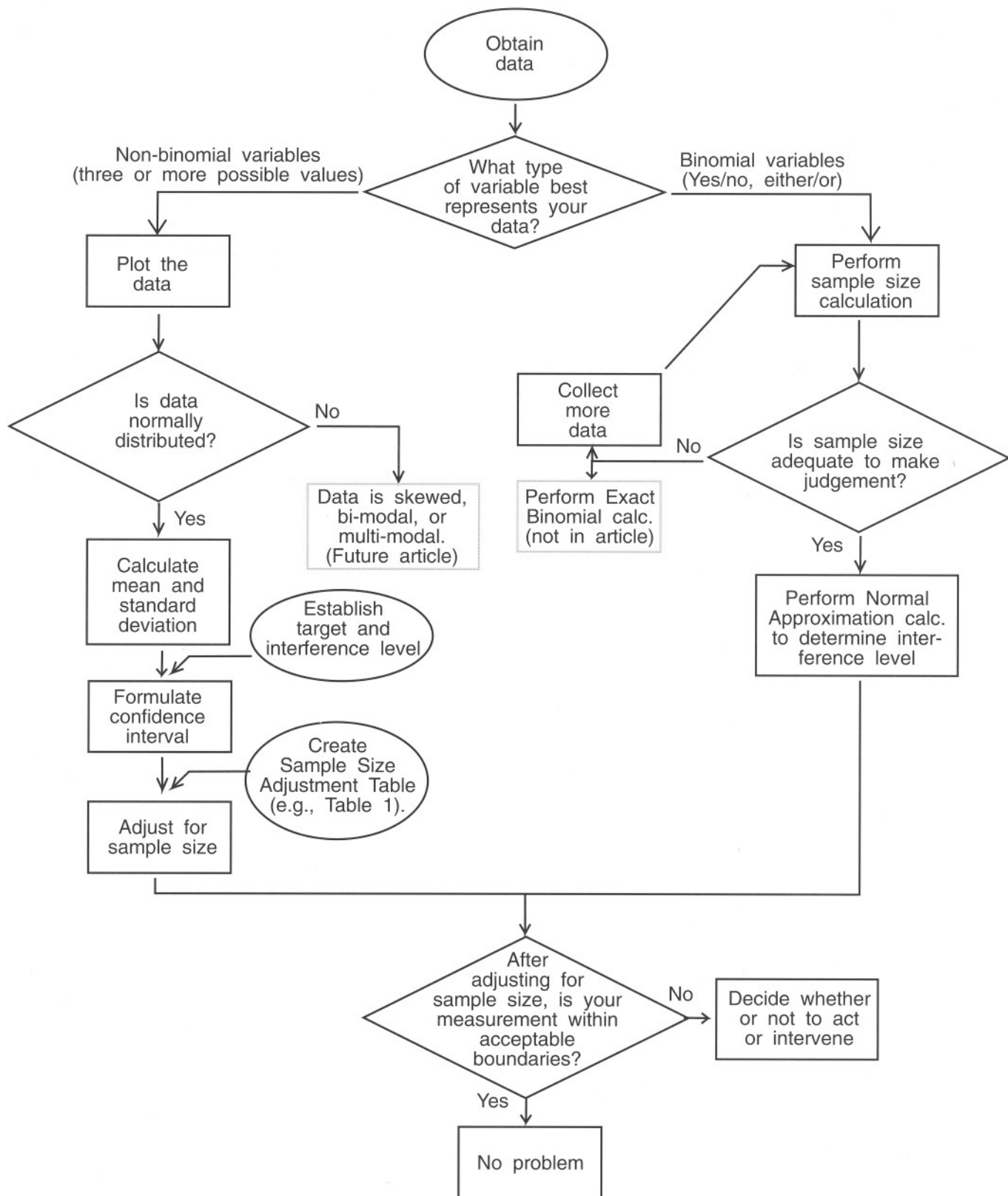
Database: large collection of data in a computer, organized so that it can be expanded, updated and retrieved rapidly for various uses.¹

Confidence Interval: the range within which one is reasonably confident that the true mean of a distribution occurs (i.e., that reflects the actual performance of the population).

Interference levels (also known as confidence limits): the acceptable boundaries for performance. If performance falls outside of these boundaries, the problem is probably real and the manager should intervene. In many cases (e.g., litter size), the concern is one-sided, as we are primarily interested in maintaining productivity above an acceptable base level. Over-shooting the set target is considered a bonus, not a signal for intervention. For other measures, such as average entry-to-first-service interval, production efficiency may be reduced by either mating gilts too early or too late after entry to the breeding herd. In this case, both upper and lower confidence limits are of interest.

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Of course, deciding where to set an interference level can never be based purely on statistics. Since management changes usually involve an expenditure of time or money, one must always assess the financial significance and riskiness of continuing to operate at or below the chosen



Errors

Type I Error: mistaking normal variability for a real change in productivity

Type II Error: failing to recognize a real change in productivity

Some Variable Types

Continuous variables: variables that can take on an infinite number of values. (e.g., body weights of pigs)— usually measured on some type of scale, often to one or more decimal places.

Discrete variables: variables that may only be assigned whole number values over a limited range, (e.g., total litter sizes)— usually counted.

Binomial variables: relates to discrete data for which there are only two possible outcomes, usually noted as 0 or 1 on each occasion (i.e., pregnant or not pregnant, diseased or not diseased). In the case of farrowing rate for an individual sow:

- 0: does NOT farrow approximately 115 days after mating; or
- 1: does farrow approximately 115 days after mating.

interference level. Because the productivity information on which we base management decisions is never complete and certain, we always run the risk of “diagnosing” a management problem that doesn’t really exist (a **Type I error**), or failing to detect an emerging management problem that truly does exist (a **Type II error**). These errors are particularly likely when management decisions must be based on data from a small sample size or short time period, because the fewer the number of observations, the more difficult it is to distinguish between real differences and normal biological variation. However, using statistics to compensate can greatly reduce the likelihood of such errors.

Consider this case: a 250-sow, continuous farrowing herd uses a 3-week weaning system, and farrows an average of 40 litters every month, with a farrowing rate of 80%. The herd manager has set the target for mean liveborn litter size across all parities at 10.6 pigs per litter, with a long-run (>100 litter) interference level of 10.2 pigs per litter. A PigCHAMP® Performance Monitor Report shows that the mean liveborn litter size for the previous month fell to 10.0 (40 farrowings), even though the distribution of parity numbers among sows that farrowed did not change between periods. This value (10.0) is below

the long run interference level of 10.2. Does your client have a problem with litter size? Is it severe enough to warrant interference? Is 10.6 pigs per litter a realistic target to set for this herd? Where (given the size of this herd and the time period you are analyzing) should you set the interference level for litter size?

Binomial versus nonbinomial data

The first important step in addressing these questions is to decide what type of data you are working with (Fig 1). Litter size data represents **discrete variables** that can take whole number values over a limited range. If we were instead assessing whether or not the herd had a problem with farrowing rate, we would be working with **binomial variables**, that on an individual sow basis can take only one of two values: either the sow farrowed, or she did not, consequent to a particular mating event.

Other examples of binomial variables are preweaning mortality (a piglet lives or dies) and morbidity (the animal is diseased or healthy). We will discuss the procedure you should use with binomial variables later in this paper.

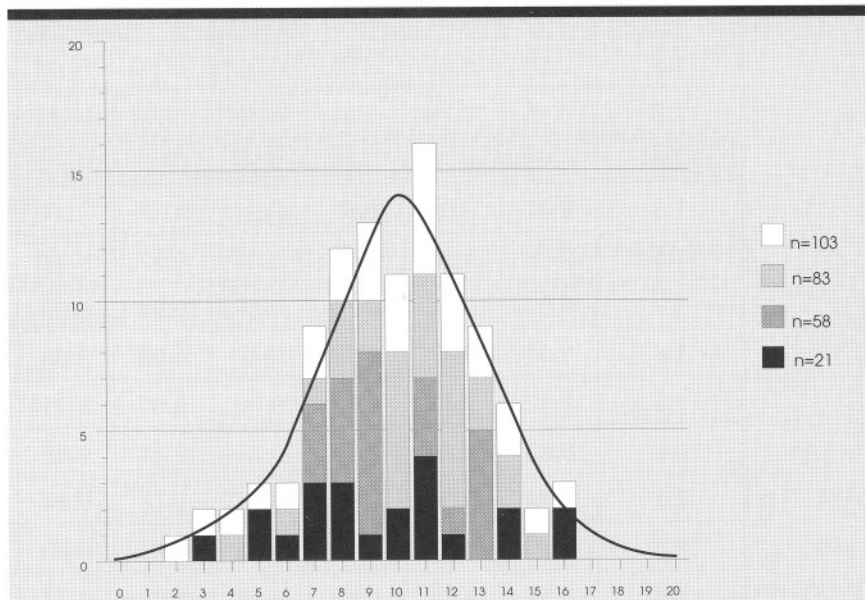


Fig 2.— Liveborn litter size distributions for the same herd using a small number of observations ($n=21$) and enlarging the period of interest until the number of observations is adequate to be able to “see” whether the distribution approximates normal ($n=103$). A normal curve is superimposed on the graph, which illustrates the importance of an adequate sample size.

Table 1.— Interference levels at various sample sizes, assuming a target of 10.6 pigs born live per litter and a standard deviation of 2.8

Standard Deviations*	Number of observations									
	10	20	30	40	50	60	70	80	90	100
0.0	10.60	10.60	10.60	10.60	10.60	10.60	10.60	10.60	10.60	10.60
0.1	10.51	10.54	10.55	10.56	10.56	10.57	10.57	10.57	10.57	10.57
0.2	10.42	10.47	10.50	10.51	10.52	10.53	10.53	10.54	10.54	10.54
0.3	10.33	10.41	10.45	10.47	10.48	10.49	10.50	10.51	10.51	10.52
0.4	10.25	10.35	10.40	10.42	10.44	10.46	10.47	10.47	10.48	10.49
0.5	10.16	10.29	10.34	10.38	10.40	10.42	10.43	10.44	10.45	10.46
0.6	10.07	10.22	10.29	10.33	10.36	10.38	10.40	10.41	10.42	10.43
0.7	9.98	10.16	10.24	10.29	10.32	10.35	10.37	10.38	10.39	10.40
0.8	9.89	10.10	10.19	10.25	10.28	10.31	10.33	10.35	10.36	10.38
0.9	9.80	10.04	10.14	10.20	10.24	10.27	10.30	10.32	10.33	10.35
1.0	9.71	9.97	10.09	10.16	10.20	10.24	10.27	10.29	10.30	10.32
1.1	9.63	9.91	10.04	10.11	10.16	10.20	10.23	10.26	10.28	10.29
1.2	9.54	9.85	9.99	10.07	10.12	10.17	10.20	10.22	10.25	10.26
1.3	9.45	9.79	9.94	10.02	10.09	10.13	10.16	10.19	10.22	10.24
1.4	9.36	9.72	9.88	9.98	10.05	10.09	10.13	10.16	10.19	10.21
1.5	9.27	9.66	9.83	9.94	10.01	10.06	10.10	10.13	10.16	10.18
1.6	9.18	9.60	9.78	9.89	9.97	10.02	10.06	10.10	10.13	10.15
1.7	9.09	9.54	9.73	9.85	9.93	9.99	10.03	10.07	10.10	10.12
1.8	9.01	9.47	9.68	9.8	9.89	9.95	10.00	10.04	10.07	10.10
1.9	8.92	9.41	9.63	9.76	9.85	9.91	9.96	10.01	10.04	10.07
2.0	8.83	9.35	9.58	9.71	9.81	9.88	9.93	9.97	10.01	10.04
2.1	8.74	9.29	9.53	9.67	9.77	9.84	9.90	9.94	9.98	10.01
2.2	8.65	9.22	9.48	9.63	9.73	9.80	9.86	9.91	9.95	9.98
2.3	8.56	9.16	9.42	9.58	9.69	9.77	9.83	9.88	9.92	9.96
2.4	8.47	9.10	9.37	9.54	9.65	9.73	9.80	9.85	9.89	9.93

*The standard deviation of 2.8 was derived by running the PigCHAMP® STATISTICS report type under Database Applications (which will report the mean and the standard deviation).

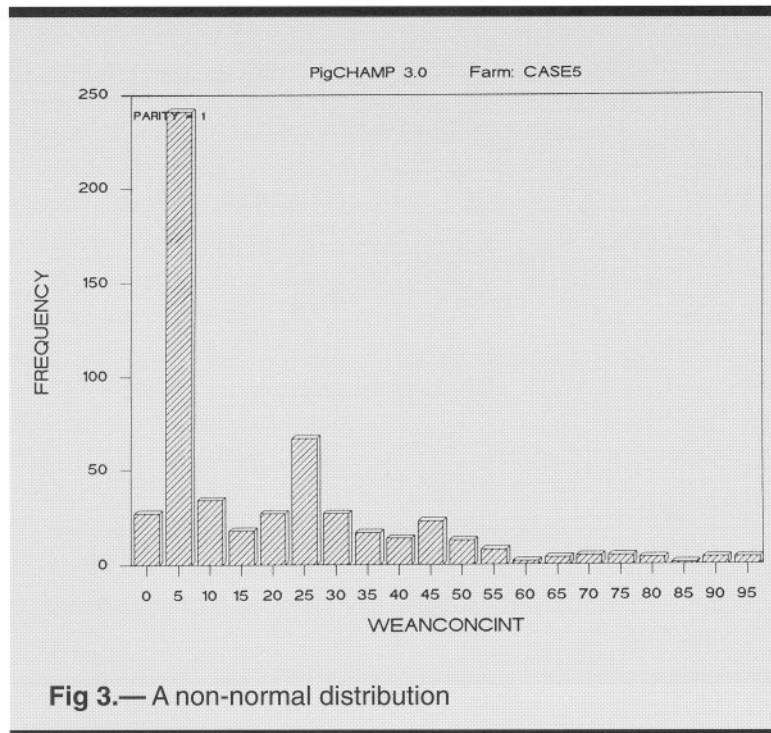


Fig 3.— A non-normal distribution

Our immediate task is to determine whether there is a problem with litter size, which is nonbinomial data. The next step, then, is to plot a **frequency distribution** of the data for the last (say) 100 litters to give a pictorial representation of the underlying litter size distribution. We recommend that you plot data for at least 100 farrowings because only when you have an adequate number of observations will you realistically be able to assess whether the distribution it follows is normal (Fig 2). Frequency distributions are obtained by plotting the range of possible values (in this case, individual litter sizes) along the horizontal (X) axis against the number or proportion of the population that falls within each interval on the vertical (Y) axis (in this case, percentage of the last 103 litters farrowed).

Remember that your challenge is to differentiate real dips in productivity from inherent biological variability. Your second step in interpreting this client's production data, then, is to verify whether the data for the previous month is normally distributed (i.e., approximates a normal, bell-shaped curve, Fig 2). From the plot, we can see that the liveborn litter sizes from the most recent 103 farrowings are reasonably close to being normally distributed. The **mean** is 9.9, the **median** is 10, and the **mode** is 11. The minimum value is 2, the maximum is 16, so the **range** is 14.

(Note: distributions that are skewed [resulting in one "tail" of the distribution curve being longer than the other], bi-modal or multi-modal give us valuable insight into the situation in a herd [Fig 3]. These types of distributions require special interpretation, which is beyond the scope of the present article. A future article will specifically treat the topic of skewed and multi-modal data.)

If our distribution is approximately normal, our next step is to determine the degree of variance in our data (how the individual values are dispersed about the mean). The classic way to measure variance is to calculate the **standard deviation** (Fig 4). The larger the variance or standard deviation, the more scattered the individual data points. Mathematically, in a normal distribution:

- 68% of the observations will fall within ± 1 standard deviation of the mean;
- 95% of the observations will fall within ± 2 standard deviations of the mean; and
- 99% of the observations will fall within ± 3 standard deviations of the mean.

Determining the standard deviation allows us, in turn, to calculate the **confidence interval**— i.e., how confident we can be that our small subpopulation (the litter sizes of females that farrowed in the previous month) accurately represents the entire herd. Essentially, the confidence interval is a mathematical expression of the relationship between the mean, the standard deviation and the sample size.

Does this herd have a problem with liveborn litter size? The answer must be based on the confidence interval for the herd, which takes into account the sample size of the subpopulation, e.g., litter sizes of females that farrowed in the previous month (Table 1). The values in Table 1 were com-

Frequency distribution: a plot of the data so that the range of possible values is along the horizontal (X) axis and the number or proportion of the population that falls within each interval is along the vertical (Y) axis. In a normal distribution, the plot forms a bell-shaped curve.

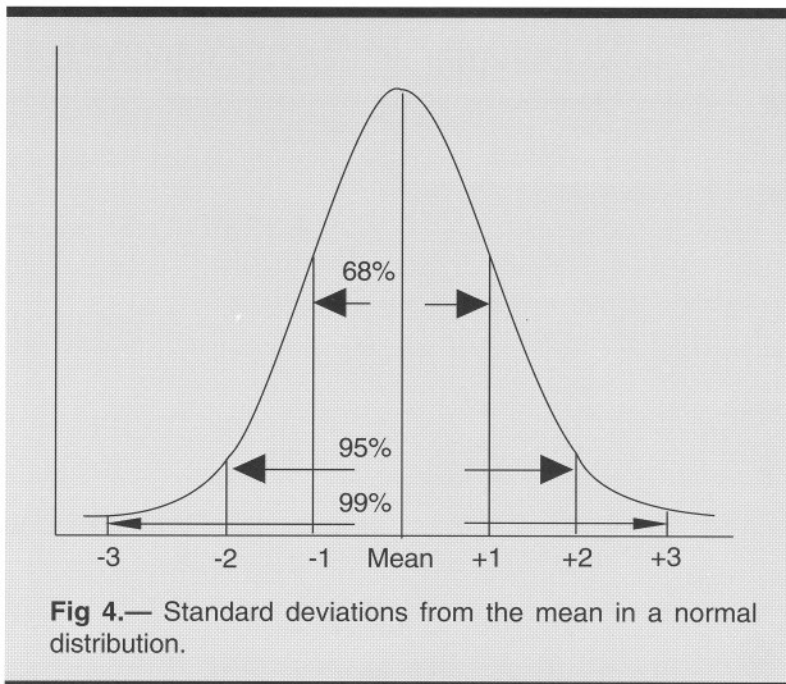
Normal Distribution: a mathematical model that describes the distribution of repeated measurements of the same physical property by the same instrument such that the dispersion of the measurements represents random variation alone⁵ The normal distribution is characterized by a symmetric, bell-shaped curve with tails extending to infinity. Since the frequency distribution for many continuous, random variables in biology *approximate* a normal distribution, it provides a useful theoretical model for calculating central tendency (mean) and dispersion (standard deviation) of biological data.

puted for the target litter size of 10.6 that was set for the herd using the formula to generate confidence intervals. The standard deviation (2.8) used in the Table was derived by running the PigCHAMP® STATISTICS report type under Database Applications (which will report the mean and the standard deviation). If you do not have access to PigChamp®, you may use the following approximation to calculate the standard deviation:

$$\text{Standard deviation} \approx \frac{\text{Highest value} - \text{Lowest value}}{6}$$

To use the table:

- read down the column headed "100" to the number closest to the long-run interference level the herd manager has set. In this case, a litter size of 10.21 corresponds to 1.4 standard deviations below the mean (extreme left-hand column).
- read across the 1.4 standard deviations row to the column headed with the number closest to the sample size for the period of interest (40 in this case).



- The number in this table at this point is 9.98. A litter size of 9.98 pigs for a sample size of 40 is equally likely to be found as a litter size of 10.21 pigs for a sample size of 100 farrowings, as they both represent a deviation of 1.4 standard deviations from the mean, adjusted for sample size.

Descriptive statistics

Mean: the average. To calculate the mean, add all the values and divide this sum by the number of values.

Median: the middle value of a distribution. To calculate the median, sort data in numeric order, then count to the middle so that there are an equal number of observations above and below this middle value. The median is less influenced by extreme values than is the mean. For example, if one millionaire moves into a city of 7000 people, it would significantly increase the mean income of the population. The change in median income, however, would be negligible. When there are extreme values, the median is the more robust statistic. If, for example, the weaning-to-conception interval is too long, one way to reduce the mean is to simply stop mating sows that return to service after a certain number of days postweaning. If in our example 250-sow herd, the manager was to cull rather than mate sows that return to estrus after 50 days postweaning, the mean interval would be reduced from 13.4 days to 11.1 days, but the median would remain at 6 days. Similarly, by culling the eight oldest sows (parities 9-12), the mean parity of the herd would be reduced by 0.16 from 3.02 to 2.86 while the median parity remains at 3. The means would look better on paper, but the herd would probably not be more productive.

Mode: the most common value within a given range, found by looking for the value with the most observations.

Range: the difference between the minimum and maximum values for a given set of data. The simplest measure of dispersion.

The table also shows that in a period with only 10 farrowings, a mean liveborn litter size as low as 9.36 should be considered to be in the acceptable range, while in a period of 50 farrowings, the interference level adjusts to 10.05. This relationship is shown graphically in Fig 5, and illustrates how the width of the confidence interval tends to narrow with increasing numbers of observations. Our conclusion in this example is that an average of 10.0 liveborn pigs per litter among a sample of 40 litters is not inconsistent with a target of 10.6 among 100 litters, we cannot be sure that anything is really wrong, and no intervention is warranted. Note also that in this example, an average live born litter size of 11.2 pigs is equally likely to occur as 10.0, and that both possibilities are in line with the long-run target of 10.6.

Interpreting binomial variables

We would apply the same statistical principles if our task were to investigate a problem with farrowing rate (i.e. a binomial variable). Unlike the normal distribution, the binomial distribution is not usually described by a mean and standard deviation. Rather, it is based on a mathematical expression that considers the probability of a number of successes (farrowings) occurring out of a number of trials (services).

Consider this case: Let's look at the same herd and determine whether it has a problem with farrowing rate (based on 40 litters per month). To calculate the farrowing rate, we must look back 115 days and see how many females were mated during a corresponding 1-month period. Most managers breed more than they expect to farrow because the farrowing rate is never 100%. For example, if 50 females were bred during the corresponding 1-month period, and 40 farrowings resulted from those matings, the farrowing rate is calculated as:

$$40 \div 50 = 0.8, \text{ or } 80\%$$

How do we calculate confidence intervals for productivity parameters that follow a binomial distribution? First, we must determine whether we have an adequate number of observations to draw safe conclusions (Fig 1). We do so by performing the following "sample size" calculation:

$$\text{Target Rate} \times (1 - \text{Target Rate}) \times \text{sample size must be } \geq 5.$$

In the case of an 80% Target Farrowing Rate (TFR):

$$(0.8 \times (1 - 0.8)) \times \text{minimum sample size} = 5$$

$$(0.8 \times 0.2) \times \text{minimum sample size} = 5$$

$$\text{Minimum sample size} = 5 / 0.16$$

$$\text{Minimum sample size} = 31.25$$

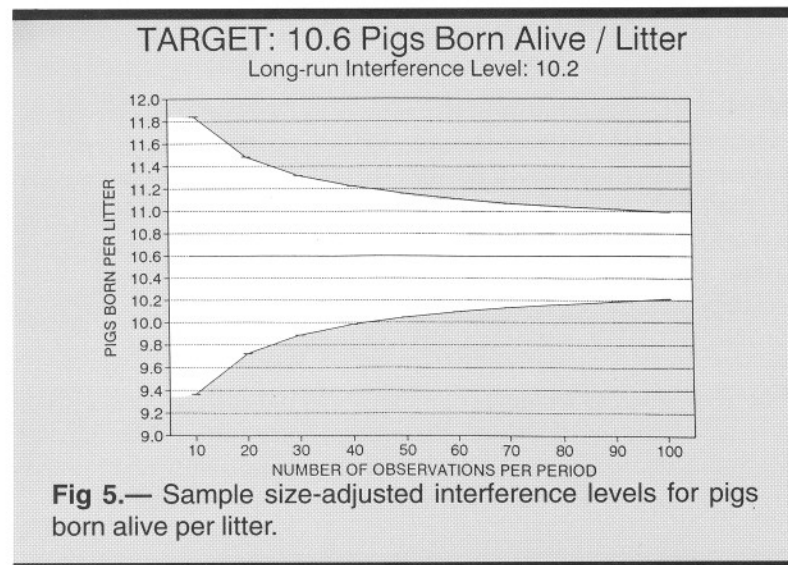


Fig 5.— Sample size-adjusted interference levels for pigs born alive per litter.

Measures of variation

Average Deviation: the sum of differences between each data point and the mean, divided by the number of data points. The usefulness of this measure is limited. Because there are as many negative differences as positive differences, the average deviation always turns out to be zero. Therefore, we use the:

Variance: the average squared deviation from the mean. The same computation for the average deviation, except that all values are squared to guarantee positive numbers. However, as variances are no longer in the same units as the mean, we must calculate the:

Standard Deviation: the square root of the variance. How much (on average) individual values differ from the mean.

$$\text{variance} = \frac{\text{Sum of (individual value - mean)}^2}{\text{Number of values}}$$

$$\text{standard deviation} = \sqrt{\text{variance}}$$

The smaller the standard deviation, the more tightly the individual values are packed around the mean. The wider the spread of individual values, the larger the standard deviation becomes.

An adequate sample size would require a minimum of 32 sows mated per period. An 85% TFR requires a minimum of 40 sows mated—the sample size must increase as the TFR increases. Because of the characteristics of the binomial distribution, the smallest sample size occurs when the target value is 50%. Thus, targets that are very low, e.g., 2% nursery mortality rate, will require larger populations if the Normal Approximation is to be used (255 pigs).

(This same sample size calculation can be used to determine the adequacy of a sample size for any binomial variable we might be working with [e.g., mortality rate or morbidity rate]).

Once we have an adequate number of observations, we can perform a simple calculation called the Normal Approximation to compute our confidence interval. Using the Normal Approximation, the approximate 80% confidence interval is determined by:

$$\text{TFR} \pm 1.28 \times \sqrt{(\text{TFR} \times (1 - \text{TFR}) \div \text{sample size})}$$

(TFR is target farrowing rate.)

Example: to calculate the 80% confidence interval for an 85% farrowing rate with a sample size of 50 farrowings:

$$0.85 \pm 1.28 \times \sqrt{(0.85) \times (1 - 0.85) \div 50}$$

$$0.85 \pm 0.065$$

80% confidence interval: (0.785 < 0.85 < 0.915)

...indicating that the interference level is 78.5%.

Thus, if the long-run (≥ 100 females mated) targets and interference levels for farrowing rate were 85% and 81% respectively, then intervention would be warranted only if the farrowing rates fell below 79% in a sample of 40 matings (Fig 6).

If you do not have an adequate sample size, we recommend that you enlarge the time period of the report showing the farrowing rate statistic to ensure that the number reported is always based on a minimum of 40 matings in each period. If you do not have at least this many observations, you would need to calculate the confidence interval using a calculation called the "Exact Binomial," which is so complex it requires a computer to calculate it and thus is of limited practical value in a real-life situation.² For the sake of discussion, we have used the Exact Binomial formula to calculate that the interference level is at 77% in a sample of 20 sows mated during the period of interest, or 74% in a sample of 10 sows mated during the period of interest (Fig 6).

Setting appropriate productivity targets and interference levels

Setting productivity targets is a fairly straightforward process: consider historic performance and expectations of future productivity based on anticipated genetic improvement, and culling and replacement policy (and their effect on the parity distribution of the herd), to arrive at a desired target

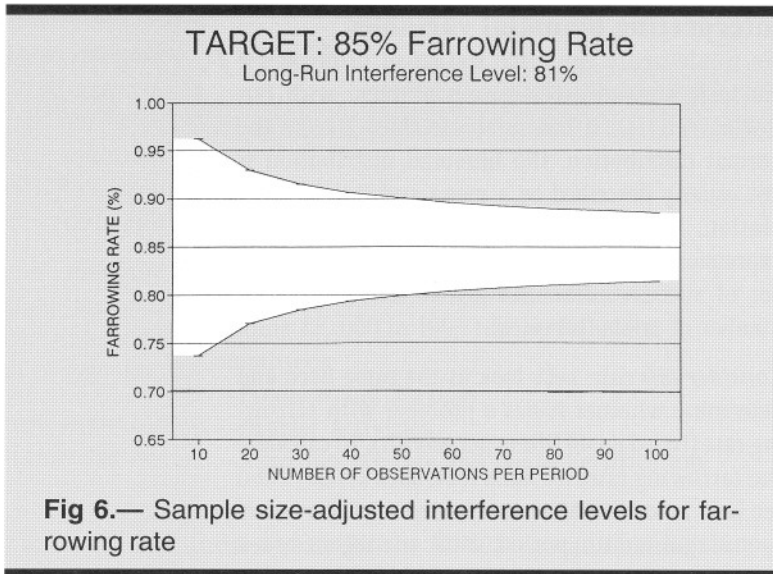


Fig 6.— Sample size-adjusted interference levels for farrowing rate

level. Setting the appropriate interference level, however, is a more personal and subjective process. Some producers tend to over-manage by immediately reacting to very subtle changes in productivity, while others with a more relaxed approach tend to be more willing to ride out fairly major productivity drops. Effectively, members of the latter group tend to tolerate wider confidence intervals (e.g. 95%) than over-managers, who may be inclined to interfere when productivity approaches the lower 80% confidence limit.

Ultimately, of course, determining when to interfere in the herd should take into account the economic importance of

Computing confidence intervals

To compute confidence intervals, we need four pieces of information:

- the mean (our target value)
- standard deviation
- the sample size
- a "constant"

"Constants": Statisticians have computed "constant" values from the shape of the normal distribution. These "constants" are the number of standard deviations from the mean within which specified proportions of the distribution are expected to occur. For example, to compute a 99% confidence interval, we use the constant 2.58, because 99% of the observations in a mathematically perfect normal distribution will fall within the range of -2.58 to +2.58 standard deviations.

The 99% confidence interval is calculated as:

$$\text{Mean} \pm \frac{(2.58 \times \text{standard deviation})}{\sqrt{\text{sample size}}}$$

For the total litter size data, we use:

$$10.2 \text{ pigs/litter} \pm \frac{(2.58 \times 2.8)}{\sqrt{30}} \\ = 10.2 \text{ pigs/litter} \pm 1.319$$

The result is expressed as:

$$(8.88 < 10.2 < 11.52)$$

i.e., our estimate of the mean is 10.2, and there is a 99% probability that the true population mean lies between 8.88 and 11.52. For a given sample size, other confidence intervals can be calculated simply by substituting the appropriate constant into the equation:

$$\begin{aligned} 95\% \text{ C.I. } & 10.2 + (1.96 \times 2.8 / 30) = (9.20 < 10.2 < 11.20) \\ 90\% \text{ C.I. } & 10.2 + (1.64 \times 2.8 / 30) = (9.36 < 10.2 < 11.04) \\ 80\% \text{ C.I. } & 10.2 + (1.28 \times 2.8 / 30) = (9.55 < 10.2 < 10.85) \end{aligned}$$

Thus, as we move from the 99% to the 80% confidence interval, the width of the interval narrows, reflecting the decreasing (but still relatively high) probability that the true population mean lies within the calculated range.

the problem. Even though experienced managers tend to ponder economic considerations when adjusting targets and interference levels, it is important to consider the financial repercussions of alternative interventions (or doing nothing), rather than interfere as a matter of course. In cases where the herd is already managed very efficiently, the cost and additional risk of interference may outweigh the potential expected benefits. Also, because many indicators of breeding herd productivity (e.g., litter size) are affected by seasonal influences and by shifting parity distributions, the solution to a productivity dip may be to over-breed at certain times of the year, or to maintain the optimal parity distribution for the herd genetics and production system. As a practitioner, you will need to understand not only how to exploit statistics to help your clients interpret their productivity data, but you will also need to tailor your recommendations to the season, the particular management practices in the herd, and the personality of the producer or herd manager.

The simple procedures we have outlined (from plotting data to show distributions, setting feasible production targets,

calculating confidence intervals, to adjusting interference levels to compensate for small sample sizes) can improve effective communication between the herd manager and consultant. Properly applied, these techniques can help us avoid becoming distracted by spurious production changes while improving our power to detect emerging problems before they cause severe economic loss.

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