When trying to classify a herd of animals according to the presence or absence of an infective agent, investigators may sample a group of animals and apply various screening laboratory tests, i.e. they apply a herd-level testing scheme. The value of such scheme depends on several factors, most obviously, sensitivity and specificity of the screening tests but also herd size, prevalence within the herd, number of animals sampled, and the cut-off number of test-positive animals to classify herds as infected. These factors should be incorporated into the design of animal health surveys that depend on a herd-level testing scheme. Animal health authorities and researchers must consider the factors but also develop information regarding the number of herds in the population, the expected herd-level and animal-level prevalence.

Survey planning has relied on the assumption of perfect diagnostic tests as exemplified by the sample size estimates published by Canon and Roe. Recently, there has been recognition that the assumption of a perfect diagnostic test may not always be appropriate. Audigé and Beckett presented a stochastic model to quantitatively assess the validity of animal health surveys, but it was limited to relatively small surveys and to situations when a fixed number of animals was sampled per herd. The model has been adapted to accommodate other scenarios, thus allowing application to a wider range of survey designs.

This paper gives an overview of the most recent enhancement of this model, and illustrates the model’s use in the planning of surveys aimed at substantiating freedom from infection. The 1997 USDA:NAHMS survey of Mycobacterium paratuberculosis infection (Johne's disease) in US dairy herds, and two IBR surveys in Swiss cattle herds were used as examples.
Materials & Methods

The model is written on a spreadsheet in Microsoft Excel (Microsoft Corporation, Redmont, WA USA) and simulations are run using @Risk (Palisade Corporation Inc., Newfield, NY USA). The current procedure requires 3 modelling steps: (1) assessment of the sensitivity and specificity of the herd-level testing scheme, (2) calculation of the likelihood ratio of the survey result, and (3) determination of the post-survey probability of freedom of infection. This approach has been presented elsewhere\textsuperscript{2,5}, and its detailed presentation is beyond the scope of this paper.

The first simulation step can be used to assess the value of different herd testing schemes. An important enhancement is that the proportion (instead of the absolute number) of test-positive animals in each herd is modelled to allow variable sample sizes within herds. During the 1997 USDA:NAHMS Johne's disease survey, the herd-level testing scheme was based on the screening of 25-40 animals per herd (depending on herd size) using an ELISA. In this example, the dependency between within-herd prevalence of infection and herd size was also considered. The ROC curves of the herd-level testing scheme using an ELISA were compared considering the original testing scheme and a revised hypothetical scheme, i.e. whole herd testing up to 100 cows and only 100 cows for larger herds.

The model was used to assess the results of two large surveys to substantiate freedom from IBR in Switzerland. In 1998 and 1999, sera samples were taken from 5 cattle older than 2 years in 4672 herds and all cattle older than 2 years in 648 herds, respectively, and analysed by ELISA. Likelihood ratios for both survey results and resulting post-survey probabilities of freedom of IBR were compared.

Results

Herd-level testing for Johne's disease: using 2% of ELISA-positive samples as cut-off for the classification of herds as infected or not, herd-level sensitivity and specificity were 58% and 75.1%, respectively, for the NAHMS sampling scheme. With the alternative sampling scheme, using the same cut-off of 2%, the herd-level sensitivity and specificity were 66% and 74.7%, respectively. By increasing the cut-off to 4%, the herd-level specificity would be increased to 96.3%, but only 31.8% of infected herds would be correctly classified.

IBR surveys: The characteristics of both herd-level sampling schemes used were almost similar. Using a cut-off of 20% of ELISA-positive samples, herd-level specificity was 100% (95%CI: 99.6 - 100) for both schemes. Herd-level test sensitivities were 79.9% (95%CI: 77.3 - 82.3) and 82.0% (95%CI: 79.5 - 84.3) in 1998 and 1999, respectively.

In both survey years, all herds were classified as non-infected (i.e. < 20% ELISA-positive cattle). Likelihood ratios were 56.7 (0.170/0.003) and 1.69 (0.594/0.352), respectively. With pre-survey probabilities considered between 75% and 90%
(subjectively assessed from the history of IBR in Switzerland), the post-survey probabilities were > 95% and < 95% after the survey of 1998 and 1999, respectively. However, if we considered that the pre-1999 survey probability was higher than 90% (following the 1998 survey results), the 1999 survey would provide a post-survey probability > 95% which might be high enough to substantiate freedom of infection (if it is considered acceptable by decision-makers).

Discussion

These two selected examples illustrate how stochastic modelling can help planning future surveys. While the original model was developed to assess the properties of specific herd-level testing schemes and surveys, the approach can be used to find survey designs that have specified properties. In some instances, such as in the Johne's disease example, the model output shows the impact of testing with an imperfect test in low prevalence herds and suggests that alternative testing schemes be considered for future studies or certification programs.

With the IBR survey example, we identified that testing 5 cattle older than 2 years might have been sufficient in the Swiss context and that resources might have been spared in 1999. Our assessment shows that the approach to survey planning depends on the pre-survey probability of freedom of infection (i.e. our level of confidence), and, consequently, there is an opportunity to optimise the sampling strategy by using this information.

The model has been developed in an Excel spreadsheet to allow flexibility of use, and adaptation to many other animal health issues. We believe this approach can help planning future surveys and be very useful in the current decision-making process in animal health.

Reference


5 Audigé L, Doherr MD, Salman MD. A quantitative approach in declaring a country free of a disease, in: Proceedings of the Society for Veterinary Epidemiology and Preventive Medicine, Bristol, UK; 1999: 78-87