Title	A model of the effect of herd size on the outcome of tuberculin test
Authors(s)	O'Keeffe, James
Publication date	1993-03
Publication information	O'Keeffe, James. A Model of the Effect of Herd Size on the Outcome of Tuberculin Test. University College Dublin. Centre for Veterinary Epidemiology and Risk Analysis, March, 1993.
Series	Selected Papers, 1992
Publisher	University College Dublin. Centre for Veterinary Epidemiology and Risk Analysis
Item record/more information	http://hdl.handle.net/10197/8917

A Model of the Effect of Herd Size on the Outcome of the Tuberculin Test

J. O'Keeffe

Introduction

Recent studies carried out at the T.I.U. (See Six Month Check Test Survey, East Offaly Badger Project) have suggested herd size as an important risk factor for herds which have positive animals to the Single Intradermal Comparative Tuberculin Test (S.I.C.T.T.). This paper examines some theoretical influences of herd size on S.I.C.T.T. performance and compares actual results from past testing programmes with three theoretical models.

Methods

The Binomial Probability Formula[1] is used to predict the probabilities of successes in special two-outcome situations or trials.

It is informative to apply the formula[1] to a situation involving the testing of animals for the presence or absence of disease when the population of interest is assumed to be disease free. If each animal test is considered a trial, and if a "success" is defined as a false-positive, the Binomial Formula can be used to predict the number of herds which will have at least one false-positive animal given (i) the size of herd and (ii) the probability of a false-positive animal being identified each time the test is applied. If each animal in the herd is tested, the total animals in the herd defines the number of trials carried out in each situation. The probability of a false-positive, or success, is constant from test to test and is calculated from the formula:

Probability of at least one false-positive = (1 - Specificity)

The requirement that the trials are independent is fulfilled by assuming that finding a test-positive animal in a disease-free herd is not influenced by the results of any test carried out on another animal. For the purposes of this paper it is assumed that there are no effects attributable to clustering present.

Assuming a test specificity of (i) 0.998, (ii) 0.999 or (iii) 0.9995 each time the Single Intadermal Comparative Tuberculin Test (SICTT) is applied in a clear population, a positive result would occur with a probability of 0.002, 0.001 and 0.0005 respectively. Table 1 shows the percentage of herds in a clear population which would be expected to have at least one test positive animal, given the above probabilities and a range of different herd sizes, as derived using the Binomial formula[2].

---

[1] The Binomial is appropriate only if the trials comply with the following four characteristics:

(i) that there are a fixed number of trials.
(ii) that each trial has only two possible outcomes, success or failure.
(iii) that the probability of success is constant from trial to trial.
(iv) that all trials are independent.

[2] $P(r) = {^nC_r} \, p^r(q)^{n-r}$

$${^nC_r} = \frac{n!}{r!(n-r)!}$$

r	=	exact number of test positives per test
n	=	number of animal tests carried out
p	=	probability of a test positive animal being identified
q	=	probability of a test negative animal (1-P) being identified
${^nC_r}$	=	the number of combinations of n things taken r at a time

Table 1. Percentage of herds of different sizes in a disease -free population likely to disclose at least one false positive animal based on the Binomial Formula[2].

Herd Size	P=0.0005	P=0.001	P=0.002
20	0.99	1.96	3.85
40	1.96	3.85	7.4
80	3.84	7.4	13.66
120	5.65	10.6	18.9
160	7.39	13.6	23.3
200	9.05	16.4	26.8

As herd size increases, therefore, so will the expected frequency of disclosure of at least one test-positive animal in a disease-free herd. Thus, the percentage of herds with at least one reactor would be expected to increase as the size of the average herd in the population tested increases.

Using programme statistics of the period 1978 to 1991 for test types 1, 5, 7 and 8 the following were obtained:

(i) the average herd size tested per year

(ii) the actual herd prevalence per year and

(iii) expected herd prevalence per year given average herd size, three levels of test specificity (99.8%, 99.9% and 99.95%) and the assumption of no disease in the test population.

The results are tabulated in Tables 2 and 3 and are presented graphically in Fig. 1.

Table 2. Tuberculin Test Statistics, 1978 to 1991

Year	No. of herd tests (Types 1, 5, 7, 8) ('000)	Average Herd Size	Actual Herd Prev- alence
1978	175.7	31.5	4.07%
1979	126.4	33.8	3.31%
1980	217.3	30.9	2.26%
1981	180.6	30.6	2.39%
1982	88.9	32.1	2.89%
1983	168.4	33.7	2.36%
1984	79.2	39.5	3.15%
1985	151.9	38.1	2.84%
1986	125.4	42.2	3.71%
1987	170.6	39.1	3.48%
1988	229.2	38.6	2.94%
1989	233.8	41.3	4.54%
1990	214.9	43.4	4.78%
1991	84.1	56.1	7.36%

Table 3. Expected herd prevalence assuming a disease free population, standard interpretation and three levels of test specificity.

Year	Projected herd prev. at p=0.002	Projected herd prev. at p=0.001	Projected herd prev. at p=0.0005
1978	5.68%	2.79%	1.55%
1979	6.12%	3.16%	1.61%
1980	5.70%	2.94%	1.49%
1981	5.64%	2.90%	1.47%
1982	5.85%	3.02%	1.53%
1983	6.16%	3.18%	1.62%
1984	7.08%	3.68%	1.88%
1985	6.87%	3.56%	1.81%
1986	7.47%	3.89%	1.99%
1987	6.99%	3.63%	1.92%
1988	6.94%	3.61%	1.84%
1989	7.38%	3.78%	1.93%
1990	7.58%	3.95%	2.02%
1991	9.30%	4.92%	2.52%

The size of the average herd tested each year has risen steadily since 1978 with a particularly marked increase in 1984 and again in 1991 (Fig. 2). The programs from 1984-90 focused testing on high risk herds (categorised) with some herds being tested more than once each year. Because high risk herds are also the larger herds this

testing strategy 1984 - 90 explains the '84 - '90 increase in the size of the average herd size tested in these years.

The 1991 increase is again a result of a change in testing strategy implemented that year. Testing was targeted toward disease as closely as possible with the result that some herds in clear areas were not tested that year. The untested element that year would have comprised the smaller herds resulting in the average size of herds tested rising to 56. The important point is that the average size of herds tested each year differs from the average herd size in the national herd size since 1984 (Table 4).

Table 4. **C.S.O. estimate of the average herd size compared with tuberculin test data, 1977-1991**

Year	C.S.O.	Scheme
1977	30.8	–
1979	31.3	33.8
1981	30.8	30.6
1983	31.9	33.7
1985	33.0	38.1
1987	32.2	39.1
1989	35.0	43.4
1991	n/a*	56.1

n/a* = Not available

The population tested in 1991 is not directly comparable with populations tested in previous years. Because the herds tested were larger and also because testing was focused on the high risk element of the population the observed herd prevalence would need to be adjusted before it could be compared with results from other years.

The observed prevalence (Fig.1) provides an interesting comparison for the prevalence one would expect of a disease free population at the average herd size for the year, using different levels of test specificity and standard test interpretation. Because the herd prevalence observed between 1980 and 1988 was below the expected level at Specificity 99.9% one would have to assume that either (i) the population that is, the national herd, was disease-free or (ii) the estimate of test specificity at 99.9% is too low. That the population was diseased is beyond doubt, and for this reason the estimate for specificity was increased to 99.95%. Likewise, the 99.8% level of specificity is totally meaningless as a baseline, as the observed herd prevalence was considerably below that expected for a disease-free population over the study period.

The level of specificity assumed for the tuberculin test is crucial because it determines the baseline for disease modeling. If the baseline is set too high then the true disease levels will be underestimated, leading to a premature relaxation of control efforts. An unrealistically low baseline will result in frustration due to lack of success at attaining an impossible goal. For these reasons a baseline which is defendable on biological grounds is imperative.

Developments in the agriculture industry are characterised by a trend toward intensification (Sheehy and Christiansen, 1991). Herd size will increase, therefore, in the future. This underlying trend needs to be allowed for when interpreting future statistics for herd prevalence. The increase in the baseline trend for 1990 and 1991 (Fig. 1) attributed solely to increases in the size of the average herd tested needs to be taken into account when interpreting actual outcome. The apparent increase in herd prevalence will always be greater than the actual increase.

At the herd level, in addition to the effects of true prevalence, the test sensitivity and specificity, the herd sensitivity and specificity are functions of the number of animals tested in the herd and the "cut-off point" number of reactors chosen to indicate presence of disease. The test will thus become more efficient at correctly identifying diseased herds as herd size increases. The inverse relationship of sensitivity and specificity tends to hold at the level of the herd so, as size increases, the likelihood of more false-positive herds also increases. Consequently, at a yet to be determined true prevalence of disease the threshold number of test positive animals required to declare a herd as positive for disease needs to be adjusted upward (Martin et al., 1992).

Conclusion

1. Test specificity should be considered to be 99.95% for the population tested under Test Types 1, 5, 7 and 8.

2. Herd prevalence statistics should be adjusted to take account of herd size.

3. If direct comparisons are to be made between herd prevalence observed for different years, then adjustments to equalise for differences in the population tested between years are likely to be required.

4. For management purposes statistics for test results should include data based on standard reactors. Estimates of true disease prevalence will be biased upward when calculated on apparent disease prevalence which includes non-standard reactor animals.

References

Martin, S.W., Shoukri, M. and Thorburn, Meg A. (1992).
Evaluating the status of herds based on tests applied to individuals.
Preventive Veterinary Medicine, 14: 33-43.

Sheehy, S.J. and Christiansen, K.H. (1991).
In "Cost Benefit Analysis of Irish Bovine Tuberculosis Eradication Schemes".
University College Dublin.

Acknowledgment

Figure 1. Comparison of actual outcome of tuberculin testing programmes during the period 1978-1991 with levels of herd prevalence predicted from models relating to the apparent specificity of the tuberculin test.
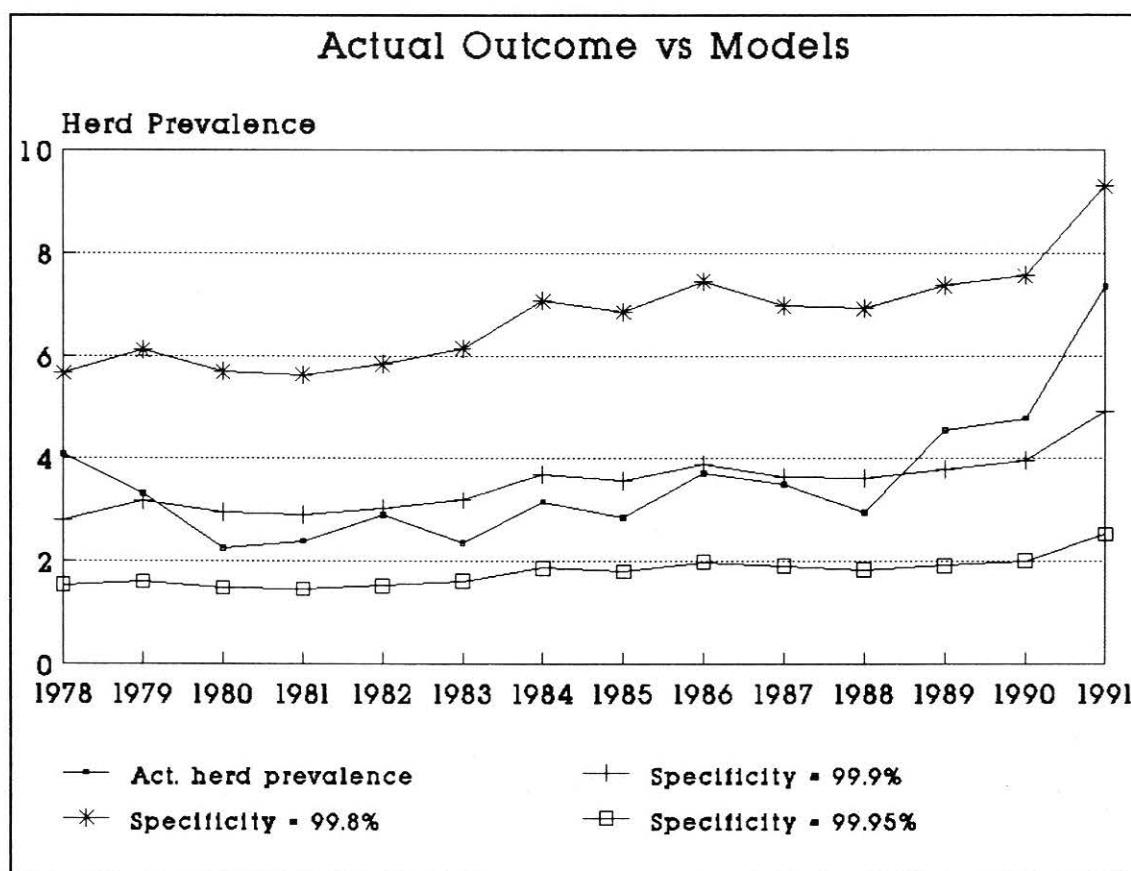
Figure 2. The average herd size in Ireland each year during the period 1978-1991, based on tuberculin test data.

Average herd size of herds tested