PROBLEMS IN DEVELOPING VALID DATA FOR PERFORMING MATHEMATICAL STUDIES OF BOVINE BRUCELLOSIS ERADICATION PROGRAMS.

Winthrop C. Ray *

Valid animal disease incidence and loss data, both within infected herds and in the national population of herds, is extremely important for sound epidemiological and cost-benefit studies of animal disease programs. This is especially important in estimating the coefficients used for mathematical simulation of disease. Studies of the United States (U.S.) brucellosis program, including studies by U.S. animal disease officials, the National Brucellosis Technical Commission (BTC), and a followup to the BTC study, have vividly demonstrated this. Problems associated with incomplete and inaccurate data have occurred despite the fact that brucellosis program data represents the most comprehensive set of animal disease data in the U.S.

SUFFICIENCY OF THE PROGRAM DATA

Brucellosis and tuberculosis program data are superior to any other animal disease morbidity and mortality data in the U.S. Summaries providing limited information on results of program testing for brucellosis have been published since 1934 (U.S. Department of Agriculture). Unfortunately, these summaries do not provide sufficient information to permit in-depth evaluation of program progress. Additional data must be gleaned from other program reports and records to use for this purpose. Furthermore, numerous changes in program methods and procedures throughout the history of these disease control and eradication programs have had a profound influence on the completeness and accuracy of the available data. Familiarity with the changes and the dates such procedures were instituted for the various States is imperative in order to properly interpret these data.

Frequently, brucellosis program changes were implemented on a State-by-State basis over a period of time which complicates the analysis of data collected during the transition. An example of this problem is the early history of the brucellosis or milk ring test (BRT) in the program. Evaluations on the efficacy of the BRT under U.S. conditions were conducted by research workers in Minnesota during the late 1940's (Roepke et al. 1948). Based upon these and other studies, some States quickly accepted the BRT in their programs. In February 1952, the State of Wisconsin completed its first round of the BRT and identified 41.5 percent of the 130,417 commercial dairy herds as suspicious of

*Chief Staff Veterinarian, Brucellosis Epidemiology, Cattle Diseases Staff, Veterinary Services, Animal and Plant Health Inspection Service, USDA, 6505 Belcrest Road, Hyattsville, MD 20782.

being affected with brucellosis (Schomisch 1967). This was virtually a complete canvas of commercial dairy herds in Wisconsin since the next agricultural census (1954) reported only 129,927 dairy herds in that State (Table 28, U.S. Bureau of the Census 1959).

Only 18 other States reported using the BRT in Fiscal Year 1952 (FY-52) and two of those, Arizona and Nevada, used the test for only 11 and two herds, respectively. The FY report shows that 454,732 milk samples were collected and tested. Of these, 135,967 were suspicious (29.9%). The 1954 U. S. Agricultural Census listed 814,663 commercial dairy herds in those 19 States indicating that not more than 55.8 percent of the herds were ring tested. The actual number of individual herds sampled is unknown because many herds were sampled more than once during the fiscal year.

It has been common practice to calculate brucellosis prevalence rates for dairy herds by computing the percent of herds suspicious to the BRT. Thus, it would appear that 41.5 percent of dairy herds in Wisconsin and 29.9 percent of dairy herds in the U.S. were infected in FY-52. Obviously, this is a misuse of these data. Although the BRT program was not accepted by all States until FY-59, incomplete BRT coverage is commonly overlooked when forming conclusions on the U.S. disease situation in commercial dairy herds prior to 1959. Even more important is the fact that only a relatively small percent (average of 22.8% for the last 15 years) of the BRT suspicious herds actually reveal reactors to subsequent blood tests. Because herd blood test results are not provided for BRT herds in the published FY statistical tables, those not well informed about program procedures tend to equate the terms suspicious and infected inappropriately. The best these published BRT data do is provide an index of change.

IMPROVING THE PROGRAM DATA

The Cooperative State-Federal Brucellosis Eradication Program currently supports a wide variety of recordkeeping methods. Individual State record systems vary from manual to nearly fully automated. A uniform record system was introduced in 1963 which would accommodate either manual or automated procedures. Since then, there have been frequent program changes. This has made it more difficult to monitor the implementation of the changes and to verify that recordkeeping procedures in each State are adequate to record and report the new data uniformly. Consequently, a new effort to standardize program records is in progress. A computerized national brucellosis information system is being designed to provide a comprehensive data base containing individual herd and animal information for each State. It is apparent, from the early efforts to clearly and precisely define terms such as market cattle (MCI) reactor for the national system, that the integration of the various State systems into a coordinated nationwide system will be difficult.

The need for updating the record system has been recognized for several years, especially when attempts were made to gather valid information for use in program effectiveness and cost-benefit analyses. This need was emphasized in the report of the BTC's 2-year study of the program (Anderson et al. 1978). Detailed analysis of program records in 12 States identified deficiencies in data retrieval capability and quality. The sheer volume of the files of brucellosis records precludes critical and detailed examination of each herd record or even a small sample of herd records regarding population, loss, or epidemiologic characterization. Frequently, it was observed that the vaccination status of tested animals was not recorded. Consequently, estimates of the protective value of calfhood vaccination for animals later exposed in an infected herd is of reduced value. Coefficients used in mathematical models for cost-benefit analyses based upon such estimates are likewise of reduced value. An attempt to correct this problem was made in a followup study to the BTC analysis. A special field survey was initiated to gather pertinent data affecting the estimates of coefficients for the various parameters in the mathematical model (Texas A&M Univ 1982). A less than adequate response from some regions will continue to impair the validity of the analyses of various alternate program stategies.

A failure to record vaccination data or to properly indicate the age, sex, or breed of an animal on the test record does not prevent the successful elimination of disease. It may, however, cause fallacious conclusions in a cost-benefit analysis or an epidemiologic model. Estimates of losses, costs, and outcomes should be obtained insofar as possible from experiments conducted under controlled conditions. These values should then be verified by field data obtained from affected populations.

When this is impossible because of a lack of documented information, the lack of such data should not stop the development of mathematical models. If estimates of the coefficents used in epidemiological simulations or cost-benefit analyses are based upon sound expert opinion, the models can provide useful information to the program managers. However, the user should be cognizant of the assumptions and, at least, of the most prominent variables influencing the analysis when evaluating the results. When more widely varying options are simulated, less precise estimates are usually satisfactory.

UNDERSTANDING THE PROGRAM DATA

The brucellosis data base contains many years of accumulated information involving millions of individual animals representing nearly every herd of breeding cattle in the United States. This vast data base represents virtually a 100 percent herd sample and can improve the validity of inferences made from the statistics. It cannot, however, compensate for lack of understanding of the program from which the data are derived. For example, the annual statistical tables indicate the number of herds tested on farms. However, the percent of herds tested which contain reactor animals does not represent the true herd infection rate because on-farm testing usually involves herds suspected of being infected.

Also, as a result of program modifications, the on-farm reactor rates prior to the BRT are not comparable to those after the start of the BRT. The on-farm reactor rates after the start of the BRT, but before the start of the market cattle identification and testing (MCI) test program are not comparable to those after the start of the MCI program. In a recent article, the authors failed to identify or emphasize this bias in their remarks and conclusions regarding the cattle herd infection rate in the U.S (Hubbert and Hagstad 1979).

Surveillance Programs

Brucellosis surveillance programs monitor the status of the cattle herds by testing animals or milk after leaving the farm. The BRT is conducted on bulk milk samples from commercial dairy herds at least three times and as many as 12 times annually. Under the MCI program, cows and bulls 2 years of age and older are sampled at slaughter in all States. Also, in all Class B and C and a few Class A States, all female cattle and bulls over 18 months of age; or if vaccinated with Strain 19 vaccine, 20 months of age for dairy and 24 months of age for beef; are sampled at livestock markets or on other changes of owner.

Only BRT suspicious herds; herds of origin of MCI reactors; herds in contact with an infected herd geographically, by interchange of animals, or by other evidence of contact; and known infected herds are required to be tested under the Uniform Methods and Rules for Brucellosis Eradication. On-farm herd test information includes all retests of infected herds so herds with reactors on several test dates contribute a disproportionate share to the reactor herd rate. Hence, on-farm herd test data as published in the FY statistical summaries grossly overestimate the prevalence of animal and herd infection.

MCI Surveillance: An important indicator of program progress is the MCI reactor rate. At the present time, the MCI reactor rate represents test results on animals from nearly every commercial beef or dairy herd except during the herd building years of the cattle cycle. Comparisons of MCI reactor rates from year to year are valuable for measuring progress in the control and elimination of infection. This is especially true in the high incidence areas in spite of some recognized deficiencies in this surveillance method.

To properly evaluate the significance of the MCI reactor rate, the size and marketing patterns of the national herd must be considered. During 1975-78, large numbers of mature cattle were sold for slaughter as the cattle industry moved rapidly to reduce the national cattle population (Beal 1982). As a result, the percent of the cattle population tested increased greatly and included samples from herds that usually did not sell mature cattle directly to slaughter. Many previously unknown infected herds were found during this period and the program moved forward by reducing brucellosis in the national herd.

The cattle cycle is now in a different phase and livestock owners are again increasing the size of their herds and fewer animals are offered for sale. This has decreased the probability that infection will be detected early. Therefore, while the MCI reactor rate may appear to be decreasing, the prevalence of brucellosis in the national herd could actually be increasing at certain times in this cycle. This could happen if a substantial percentage of owners of infected herds were not culling nonproductive adult animals. Unless other disease detection methods located such herds, foci of brucellosis would persist and serve as sources for spread to other herds. Local conditions may exist which run counter to the national trend. For example, in calendar year 1981, the size of beef herd in the 11 high incidence States declined by 0.093 percent in contrast to a national increase of 1.647 percent (Beal ibid). This local decrease was attributed to the drought conditions in some Southern States.

One must also bear in mind that market patterns are not random for areas or for individual producers. Therefore, all slaughter establishments, including small custom kill establishments, need to participate in the MCI program. In addition, the livestock owner commonly culls his herd of nonproductive animals. This introduces a bias favoring detection of infected animals that have aborted, had weak or dead calves, were difficult breeders, or were lame and unthrifty. Nonrandom culling is a significant factor and favors detection but does not necessarily result in early detection of disease within the herd.

The MCI reactor rate may also greatly overstate the level of animal infection in the population. The MCI reactor rate is obtained by dividing the number of serologic reactors found in marketing channels by the total number of market animals tested. In 31 low incidence States (including the Virgin Islands) during FY-81, relatively few MCI reactors were disclosed with approximately one MCI reactor out of 71 resulting in the detection of an infected herd. In the 10 States with a relatively high prevalance rate, one infected herd was located for every eight MCI reactors found (Table 1). Residual vaccinal titers, heterospecific antibody titers, infections due to Strain 19, and multiple MCI reactors from an individual infected herd contribute to the overestimation of the prevalance of brucellosis.

Each MCI reactor is investigated in an attempt to locate and test the source herd. Some herds of origin are not tested when investigation indicates virulent brucella infection is unlikely to be present. The number of infected herds found upon testing the herds of origin of MCI reactors is likewise much lower in the 31 low incidence States (one infected herd out of every 28 tested) than in the 10 high prevalence States (one infected herd out of every two tested). See Table 1.

Table 1. Market Cattle Identification (MCI) Program Data for FY-81

Prevalence Level For Groups of States	Number of MCI Tests	Number of MCI Reactors	Herds of Origin Tested	Inf Herds Found	MCI Reactor Rate in Percent	Ratio of MCI React's To Infected Herds Found	Ratio of Herd Tests To Infected Herds Found
	(a)	(b)	(c)	(d)	(b/a)	(b/d)	(c/d)
Low[a]	3,498,110	3,993	1,555	56	0.115	71:1	28:1
Moderate	3,218,906	6,088	1,823	334	0.190	18:1	5:1
High	5,155,674	39,577	11,954	5,268	0.768	8:1	2:1
Total	11,872,690	49,658	15,332	5,658			

[a]11 Moderate States include Col., Ga., Idaho, Ill., Iowa, Kan., Neb., Nev., N. Mex., S. Dak., and P. R. 10 High States include Ala., Ark., Fla., Ky., La., Miss., Mo., Okla., Tenn., and Tex. 31 Low States = Remainder including Virgin Islands

BRT Surveillance: The BRT program has been adversely affected by changes in milk marketing patterns. Many States are unable to certify that all commercial dairy herds have been sampled on each complete BRT round BRT because recording of negative results was discontinued through necessity. Milk marketing patterns have become more complex as more and larger dairy processing associations are formed. The associations have a network of milk processing plants, any of which could receive milk from any patron in the association. Under this system, it is possible to miss a particular patron repeatedly. For example, if patron "X" ships milk to plant "B" on the day samples are collected from plant "A" and then ships his milk to plant "A" while collections are made at plant "B", his herd will not be included in that round of the surveillance program. Without appropriate records, this situation could continue for several BRT rounds without the deficiency being detected. The reverse can also happen for some herds to be sampled two or more times during a single BRT round.

Interpretation of Infected Herd Data

The number of newly infected herds located during the fiscal year is a frequently used gauge of progress. In this program, newly infected herds are defined as those which did not have reactors during the previous fiscal year. This definition is not necessarily the same as the epidemiologic definition for newly infected herds. To illustrate the difference, assume a herd had reactors during FY-80 on each of three herd tests. This herd would be classified as newly infected in FY-82 if it did not have reactors during the previous fiscal year (1981). In this example, reactors are disclosed on the last herd test performed in FY-80. In FY-81, the herd is not retested and, consequently, no reactors are disclosed. The herd remains under quarantine throughout FY-81. The herd is again tested in FY-82 with reactors disclosed. By definition, this herd would be listed as newly infected in FY-82 because no reactors were found in FY-81; however, epidemiologically, the herd is listed as chronically infected with long intervals between herd tests. While theoretically possible, it is unlikely that this particular example would actually occur.

The total number of herds found to have reactors during a fiscal year is also tabulated. This statistic includes newly infected herds as defined plus those infected herds which also had reactors identified during the previous fiscal year. Comparisons of the number of newly infected herds to the total number of infected herds in an area is important in evaluating control of spread, success of efforts to eliminate infection, and as an indication of the number of premises that can serve as focal points for further spread of disease.

Confusion between the terms "accumulated infected herds," "newly infected herds," and "quarantined herds" frequently results in misuse or misinterpretation of program data. The number of quarantined herds is listed at the end of each month and represents all herds under quarantine on a given date because of on-farm reactors. Herds usually remain under quarantine for at least 120 days after removal of the last reactor. During this period, the herd must have two consecutive negative herd tests. The quarantined herd data greatly underestimates the total number of infected herds found during the fiscal year but does provide a better indication of the current status within a particular State or region.

As mentioned above, many program statistics tend to overestimate the prevalence of brucella infection because they are based on MCI or BRT tests. In spite of this, there are indications that underestimation of infection may also be a problem. The actual total number of infected herds in States not testing all contact herds is probably 50-100 percent higher than shown because of the lag in detecting these herds by the MCI test. Another factor that influences estimates of infection in an area is the omission of herds which have sold out but which revealed several MCI reactors. Since these reactor herds are no longer in existence, they often are not counted in calculations to determine the prevalence of brucellosis for the area.

SUMMARY

The more complex the data and the greater the number of people in each State involved in collecting, interpreting, sorting, tabulating, and analyzing the data the greater the probability that similar program operations and procedures will be reported differently on monthly reports. Such differences are difficult to detect and correct. The validity of data depends upon standard interpretations and reporting. Relatively simple tabulations of MCI reactors are adversely affected when States use different classification criteria or if branded and tagged on-farm reactors are included in the MCI reactor totals.

Comparisons of MCI reactor rates for various States under such conditions can result in drawing erroneous conclusions on the disease incidence in these areas. Uniformity in reporting field data is very difficult to obtain due to frequent personnel changes in program record sections, incomplete understanding of the information to be tabulated, and differences among individual States on aspects emphasized in the brucellosis program. Differences between States in reporting program information is expected to be minimized when the updated data base management system is fully implemented.

In conclusion, a massive data bank exists for brucellosis, but better ways are needed for managing storage and retrieval of information if it is to be effectively used in program analyses and epidemiologic modeling. Thorough knowledge of all facets of the program and its data will continue to be a prerequisite for interpreting critical program information.

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