SWINE AND DAIRY NATIONAL STUDY DESIGNS FOR ANIMAL HEALTH MONITORING

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The National Animal Health Monitoring System (NAHMS) is the component of USDA's Animal and Plant Health Inspection Service responsible for monitoring the health status of the nations livestock and poultry.

The first two national surveys conducted by NAHMS addressed swine and dairy in 1990 and 1991/1992 respectively. The design goals included: 1) estimates based on a statistically reliable probability sample, 2) coverage of at least 70% of the operations and animals in the US, and 3) sample size primarily determined on mortality estimation.

The first goal was achieved by buying the sampling frame services of the National Agricultural Statistics Service (NASS). NASS is responsible for USDA's estimation of livestock inventories and surveys swine producers on a quarterly basis while cattle producers are surveyed twice a year. Therefore, two options existed, both utilizing the NASS sampling frames: 1) sub-sample producers reporting on the NASS surveys or 2) select an entirely new sample. The designs utilized a multiple frame approach incorporating both a list frame and an area frame.

Commonly, a sampling frame may be thought of as a roster of units to be sampled. For example, a list of hog producers would constitute a list frame. One of the advantages of sampling from a list with an associated measure of size is that larger livestock operators can be selected with a higher probability to minimize impact of sampling variability. A problem with estimating from a list frame is that the list is necessarily incomplete.

The area frame is the actual land area which is divided into small sampling units. By definition, the area frame is complete and all items being surveyed have a chance of being selected by their association with the selected land area which has a known probability of selection. Area frame sampling based on land use is rather inefficient for livestock estimates due to the variation in herd size which is largely uncontrollable in the sampling process (except where land use and herd size are highly correlated). In addition, area frame sampling is very expensive, both in terms of frame construction and data collection.

The multiple frame estimation approach which combines the advantages of both the list and area frames. The list is very efficient particularly for large operations because it is possible to stratify based on size, while the area frame ensures complete coverage and can be used to estimate the list completeness. The basic disadvantage to the multiple frame approach is the complexity of handling list and area names and identifying the overlap between the frames. Those area names not found on the list represent the list incompleteness.

The estimation model used is:

$$X = Xa + pXa1 + qX'a1$$

where: Xa = the estimated total of the population not on the list frame estimated from the area frame (non-overlap area estimate).

$Xa1$ = the estimated total of the population included in both frames estimated from the area frame (overlap area estimate).

$X'a1$ = the estimated total of the population included in both frames estimated from the list frame (list estimate).

$$p + q = 1$$

Note, that Xa1 and X'a1 are two separate estimates of the sample population. In practice, the model uses $p=0$ and therefore $q=1$. This means that if an operation is on the list then it is represented by the list frame estimate. This model is often referred to as the screening estimator, which includes the area estimate of the list incompleteness plus the list estimate.

The name matching between list and area frames is a regular component of the NASS survey process. Therefore regardless of whether a sub-sample is drawn from an existing swine or dairy sample, or a new sample is selected from the same specie frame, the multiple frame intricacies are already in place. Sub-sampling from a data set of previously contacted producers brings both advantages and disadvantages. The previously reported data may be used as criteria for eligibility which does eliminate some unnecessary contacts. However, offsetting this advantage may be the increase in non-response brought on by "another government survey" syndrome. The pros and cons of using a new sample are essentially reversed which would include fewer good reports in relation to the total sample size but an expected higher response rate from those producers with the item of interest. The sub-sampling option was chosen to minimize the number of initial contacts.

The 70 percent or greater coverage of the US livestock industry in terms of both producers and animals was set as a goal in order to be able to make inferences to a significant proportion of the total. Significant budget reductions occur by targeting less than the full 100 percent coverage of the industries. This criteria was met by including or excluding entire states from the program. NASS list and area frame sample selection and data collection processes are all functional at the state level. In addition the NAHMS data collection system involving field Veterinary Medical Officers (VMO's) is organized at the state level. The optimum states to include would be those states contributing the most in terms of producers and number of animals until the 70 percent goal is reached. Since the NAHMS program is rather new this did not occur and some smaller states that were very interested in NAHMS were included to reach the goal. In addition, for swine a sample of the larger states was used in the design to increase the influential base.

Both studies involved completion of general management questionnaires by NASS enumerators and a consent form for the producers agreeing to have their names turned over to NAHMS for further contact. Once the name was turned over, VMO's visited the farm periodically over a 3 month period. Producers were asked to provide data additionally on questionnaires, as well as to keep morbidity and mortality diaries on those animals born during the three months. Biologic sampling was done by the VMO and test results provided back to the producers. Water supplied to the farrowing house was tested as were blood samples collected from sows in the farrowing house. Blood samples were also taken from dairy calves, growth measurements were taken and milk replacer supplementation was evaluated.

Study Design of the National Cow/Calf health and Productivity Audit (CHAPA)

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This paper discusses the sample design for a beef study conducted by the National Animal Health Monitoring System (NAHMS), USDA:APHIS:Veterinary Services. The NAHMS program mission is to collect and analyze the animal health data to provide scientifically sound and current information on the health status of the U.S. livestock and poultry. NAHMS had addressed three major commodities thus far (swine 1990, dairy 1991-1992, beef cow/calf 1993). The general design approach is to select a sub-sample from an existing sample of producers used to estimate livestock inventories by the National Agricultural Statistics Service (NASS).

In January of each year the National Agricultural Statistics Service (NASS) conducts a survey of livestock producers across the United States in order to estimate inventories of cattle, sheep, goats, and production parameters of these farm enterprises. The sample for January 1992 survey was a multiple frame (list and area) stratified random sample. From a list frame of approximately 1.6 million names 70,000 operations were selected. From the area frame with approximately 15,400 segments available, 7,000 operations were selected for a total sample size of approximately 77,000. This sample served as the first phase of data collection for the National cow/calf health and productivity audit (CHAPA). Producers who were contacted in January 1992 and known to be out of business were ineligible to be selected in further phases of the study. The sample for the January survey is stratified within each state based on herd size. In addition, a priority ranking or strata within state is used in the actual selection process. Strata definitions are roughly according to herd size. Since this is a multipurpose survey separate strata are also defined for different species. The stratification and priorities are such that a single producer can only be grouped into one stratum. Note that producers are placed in the highest number stratum for which they qualify. Since the anticipated sample size within state for the CHAPA was too small to support the large number of strata normally used for the January survey and since cow/calf operations were the only species of interest for the CHAPA all of the producers were re-stratified into strata corresponding to the projected number of cattle in the cow/calf operation based on historical data. The entire sampling frame was re-stratified for two purposes: 1) to identify only beef producers on interest to the study and 2) to generate population counts for the new strata. The NASS maintains historical control data on all of the list and frame members on total cattle (TC), milk cows (MC), cattle on feed (for the slaughter market) (COF), and total sheep. Since historical data specifically for beef cow numbers were not available the number of beef cattle on the operation was projected using the formula:

$$BC = TC - 2(MC) - COF$$

where,
BC = beef cattle
TC = total cattle
MC = milk cows
COF = cattle on feed

This projected number of beef cattle was used to group operations into more appropriate herd size strata. The herd size strata by state are shown in table 2. Phase 2 of the sampling for CHAPA involved the selection of a sample from these newly created strata within states. This sampling process used Chromy's procedure within strata in order to control the distribution of the sample with regard to key variables and to achieve efficiency in the variance estimates of parameters.

If only re-stratification of phase 1 sampling were done, members of a particular post-stratum would have unequal probabilities of selection and hence unequal weights for analysis purposes. Chromy's procedure is a sequential sample selection procedure that is essentially a probability proportional to size sampling method. The size variable is the analysis weight for the observation. The effects of sampling selection in this manner are 1) to equalize the probability of selection (and analysis weights) within stratum and 2) to allow for some control over sample distribution with regard to attributes of the observation. In this case the attributes used in sampling protocol were response status to the NASS January survey, season of calving (spring v fall), and herd size. Since the entire sample selected for January 1992 survey was eligible for selection in phase 2, with the exception of those known to be out of business it was desirable to exercise some control over the proportion of the coming from the January 1992 inaccessible, refusals, and respondents. Further, since phase 3 of the study was to focus on the spring calving beef operations in 18 of the largest cow/calf states we wanted to assure an adequate representation of this segment of the industry in the subsequent samples. These 18 states account for 70 percent of the beef cows that have calved as of January 1992. For the

January 1992 respondents, the calving season status was known and the herd size was based on reported data. For January 1992 inaccessible, and refusal calving season status was not known. The herd size was based on the projected historical beef control data (BC).

Using the above protocol 4994 operations were selected for contact and a Computer Assisted Telephone Interview (CATI) system was used. Five CATI calling centers were used to contact the producers in the 48 contiguous states. Of those selected 857 were inaccessible and 540 refused to participate in the interview leaving 3597 producers which provided information on their operation. Of these 3597, 1058 producers indicated that they had no cows and were considered ineligible for the survey leaving 2539 producers who participated in the interview and provided information on management and health of the herds.

The general design of CHAPA was to select a sample of producers from across the United States with 1 or more beef cows to be contacted for the Computer Assisted Telephone Interview (CATI) (phase 2). From these participants all producers with at least five beef cows or replacement heifers, that calved at least 50 percent of their females in the spring of 1992, and were from one of the 18 largest cow/calf states were eligible for the next phase (phase 3) of the survey. These eligible producers were then contacted by a NASS enumerator by personal interview to collect data on production practices and to obtain informed consent to release their name to personnel from the Animal and Plant Health Inspection Service (APHIS). Producers for which informed consent was obtained were then contacted by APHIS veterinarians to collect data on animal health and productivity by way of three interviews at six month intervals.

Of the 2539 producers who participated in the CATI, 1223 were eligible for phase 3 of the study. From this sample, 784 producers responded and provided informed consent, nine responded and were out of business, four were out of business and known to have zero cows or replacement heifers, four were still in business but known to have zero cows or replacement heifers currently, 350 refused, 56 were inaccessible but known to be in business, and 15 responded but did not provide consent to release their names to APHIS.

THE NATIONAL DAIRY HEIFER REPLACEMENT PROJECT: DEMOGRAPHICS AND HEALTH STATUS OF THE U.S. DAIRY HEIFER POPULATION

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Information regarding dairy replacement heifers has been recognized as one of the greatest needs of the U.S. dairy industry. With this in mind, the USDA:APHIS:Veterinary Services:National Animal Health Monitoring System developed the National Dairy Heifer Replacement Project (NDHEP) to assess the health status and associated management practices of preweaned replacement heifer calves. The National Agricultural Statistics Services list and area frame was utilized to probability select dairy producers in 28 states. Data were collected on-farm by NASS enumerators and APHIS:VS Veterinary Medical Officers on each of the selected respondent farms. These data included herd management data, heifer evaluation activities, and producer daily logs of health and treatment events in preweaned calves. Point estimates were expanded to represent the population eligible for selection in the study (dairy operations with 30 or more cows in 28 states - representing 78% of the US dairy cow population. Variances were computed accounting for the complex multiple frame survey design using Survey Data Analysis (SUDAAN) software.

Ninety-one percent of dairy operations were Grade A dairies and Holstein comprised the main breed in 95 percent of herds. The reported mean rolling herd average milk production yield was 16,703 lbs and the reported mean calving interval was 12.8 months. Day-to-day decisions were made by one individual on 73 percent of operations and by partners on 26 percent of operations. The highest level of formal education possessed by the operator included: grade school (10% of producers), high school (60%), some college (13%), BA or BS degree (10%), graduate school (1%), and technical school (6%).

Hand-written record-keeping systems were used on over 88% of operations, and 58% used Dairy Herd Improvement Association and 14% used computers on-farm for record-keeping. Sixty percent of operations used hand-written records as the primary record-keeping source, indicating the reliance of producers on this traditional form of system.

Ninety-five percent of producers used veterinarians as sources of information for making health-care decisions related to calf rearing and for 83% of producers, veterinarians were the most important source of this type of information. Dairy magazines and journals were used by producers for making health-care decisions on 48% of operations and Cooperative Extension or university personnel on 20% of operations.

While the operator had the major responsibility for feeding and health-care of preweaned dairy heifers on most operations (48%), other family members were the major calf-raisers on many (spouse 24%, son or daughter 15%). The primary calf-raiser was male on 70% of operations.

Colostrum management is an extremely critical management factor for the neonatal dairy calf, since a calf must receive essential immunoglobulin and nutrients from colostrum in her first feeding to survive. Over 33% of dairy producers allow calves to receive their first feeding of colostrum during nursing rather than hand-feeding, with a resultant loss of control over the amount of colostrum the calf receives. In addition, 59% of these producers allowing calves to receive first colostrum from the dam do not routinely assist during first nursing. For those producers hand-feeding first colostrum, 26% hand-feed 2 quarts or less during the first 24 hours, an amount likely to lead to failure of passive transfer of immunoglobulin in Holstein calves.

From retrospective data, the mean reported age of calves at weaning was 7.9 weeks and the mean reported preweaned dairy heifer calf death loss was 7.8 percent. The primary cause of death was scours in 50% of herds, and respiratory disease in 18% of herds. Respiratory disease was the primary cause of death in dairy heifer calves from weaning to first calving on 31% of operations, unknown cause on 22%, and diarrhea on 11% of operations.

ERROR PROFILE OF THE NATIONAL SWINE SURVEY

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The control and prevention is predicated on accurate knowledge of when, where, and under what conditions disease occurs (Schroeder 1945). In the past, animal disease statistics collected by State and Federal animal health officials were found to be unreliable, inconsistent, and non-additive (King 1945). Five years after the information of the National Animal Health Monitoring System (NAHMS), the National Swine Survey (NSS) was launched. The NSS represented the first nationally coordinated effort to obtain statistically reliable data on disease occurrence, production parameters, and the frequency of management practices and facility characteristics (King 1990; Hueston 1990a). The use of a statistically valid study design permits the estimation of measured variables for the national population.

Traditionally, the sampling variance of these will also be calculated and used as an estimate of the "error" in the study. However, many other factors contribute to the quality of data collected besides that due to random variation (Convers and Traugott 1986). The operationalization of a survey design involves the dynamic interaction of a corp of interviewers and a sample of respondents via a questionnaire. The non-sampling errors introduced by these three key players and their interactions are often of greater consequence to the accuracy of a measure than is sampling variance (Groves 1989; Converse and Traugott 1986).

The total survey error for a given statistic is referred to as the mean square error. It consists of those errors which vary over hypothetical trials of a survey (variance) and those errors which are constant (bias) for all implementations of a survey (Farver 1985; Kish 1965; Groves 1989). The sources of error are identical for both 'variance' and 'bias'. Errors of nonobservation are those errors arising because measurements were not taken on part of the population. These include coverage error, nonresponse error, and sampling error. Errors of observation are deviations of the answers of respondents from their true values on the measure (Groves 1989). The four components of the measurement process, which make up errors of observation, are the interviewer, the respondent, the questionnaire, and the mode of communication (mail, face, interview) (Groves 1989).

This paper will highlight methods of analysis used for the assessment of nonsampling errors in the NSS. Specifically, the measurement of correlates of survey errors and the calculation of response error.

METHODS

In order to gain insight into the nonsampling errors affecting the NSS, three adjunct studies were undertaken. The North Carolina Swine Study was used to assess the reliability of the NSS by comparing point estimates. [Bush et. al. 1993a] Two additional studies were carried out to assess the variability in implementation of the NSS between states, with particular attention to the assessment of factors contributing to nonsampling error. These two questionnaires were distributed to the two respective stages of field implementation of the NSS: NAHMS coordinators and field Veterinary Medical Officers (VMO's). Since many of the known causes of nonsampling errors are related to the interviewers (VMO's), they are a valuable source for identifying the presence and reason for such errors. [Lavin 1989]

RESULTS/DISCUSSION

The first approach taken was to measure the known or suspected correlates of the sources of nonsampling errors. The unanticipated situations most often contribute to the introduction of error through either the interviewer, respondent, or inappropriate use of the questionnaire. Delineation of the ultimate source is often difficult if not impossible. Situations which did occur frequently that may effect the survey interview was the presence of more than one respondent. Half of the interviewers had about one farm on average where this situation was encountered. The presence of a relative or employer is likely to effect the responses given in an interview. The interviewing of differing respondents on subsequent visits occurred infrequently. (Table 2) However, according to VMO's, over 30 percent of respondents showed a change in the quality of data collected over the three month study (Table 3) with the exception of farm expenditures, very few quantitative responses were considered to be of poor quality. Thus, the inherent effects of the respondent as an essential part of the interview are confounded with the simple response variable of a respondent and the quality of responses given.

A second source of errors of observation is the interviewer. Interviewer effects likely to have a large effect on variable errors are the inappropriate reading of questions and coding of responses.

Inconsistent wording of questions occurred most frequently for the SHR (9.85 % of questions vs. 8% and 5% for FFR and EIER respectively.). A likely explanation is the subjective nature of Section 2 of the questionnaire, inviting increase latitude in both wording and coding of responses. The EIER experienced a large number of interviewers resorting to showing the question to the producer. This is due to the complex structure of most of the questions which were laid out in table formats. The result was a combination of error sources from the questionnaire itself, leading to variations in mode of communication, as well as interviewer and respondent effect.

Finally, there is the affect of the mode of communication. Given identical respondent and questionnaire, responses will vary depending on the mode of communication (mail, phone, face to face interview). Approx. 25% and 60% of the FFR and EIER were given to the producer prior to the visit. In many cases, this resembles a mail survey instead of a face to face interview. Errors due to mode of communication have been documented.

The second approach to the quantitative assessment of nonsampling errors, specifically errors of observation, involved the calculation of the Index of Inconsistency. Each of the 712 farms participating in the NSS completed three questionnaires over the three month period. A total of 3566 serum samples were also collected from up to 10 sows per farm. Producers monitored a total of 33,519 females using farrowing diary cards to collect information on health events for sows, gilts, and piglets. Frequently, data was collected on a specific variable through several different questions. These multiple indicators of the same construct, permit the calculation of the Index of Inconsistency which estimates the level of response error.

The index of inconsistency for several such variables is given in Table 4. The first 15 indices look at the consistency of responses, both within and between questionnaires, for identical variables. For example, a farm responding 'not applicable' to a question of whether a change of coveralls is required of employees should also respond 'N/A' to a question of whether a change of boots is required of employees. These indices ranged from 6.75 to 60.5 with most falling in the 20-35 range. The rest of Table 4 calculated the consistency between routine preventive and vaccination practices reported on the Swine Health Report (SHR) and actual recording of the particular event on the diary cards or blood collection sheets. For example, a farm which indicates that it routinely gives piglets an iron shot should have recorded on the diary cards at least one piglet receiving an iron shot. For the consistency or reporting routine vaccination practices on the SHR and again at the time of blood collection, indices ranged from 69.8 to 113. For consistency of routine preventive practices reported in the SHR and diary cards, indices ranged from 39.4 to 92.8 for piglets and 80.4 to 161 for sows/gilts.

The first group of indices revealed a moderate level of response error. Further study is needed to determine factors influencing this index. The two highest indices were for consistency of multiple indicators from different questionnaires. It is reasonable to expect better consistency of responses within an interview than between interviews. Furthermore, responses to many of these questions were misclassified. The number if interviewers not correctly coding responses as 'No' or 'N/A' contributed to the response variance affecting these measures. For those questions comparing stated vaccination practices for the farm and whether a particular sow was vaccinated, the index of inconsistency tended to be high. The high level of response error can be attributed to the ecologic fallacy. As pointed out by Waltner-Toews et al. [Waltner-Toews et al.], there is often a discrepancy between farm policy and the application of that particular practice to an individual animal. The discrepancies can be attributed to a large number of farms which responded 'Yes' to the use of vaccinations on the SHR yet were classified 'No' for at least one sow being vaccinated based on the diary card data. Although no more than 10 sows were sampled for blood collection, they were typically a representative sample and should be of sufficient number to be exposed to routine practices. What remains undetermined in this investigation is whether the individual sows failed to be vaccinated despite a farm policy of vaccination or if there was simply a failure to report/record individual vaccination on the diary cards. The same pattern existed for routine preventive practices. Practices which were common for most farms such as clipping needle teeth, docking tails, and giving iron shots had lower indices. Many factors may attribute to this high level of error. Some routine preventive practices may be performed only 2-3 times a year and therefore may not have been done during the three month study period e.g. deworming and mange/lice treatment. Other practices, however, may be stated as being a routine practice when they are in fact not.

The post survey questionnaires in this study substantiate the opportunities available for error to affect the validity of statistics/estimates via effects ushered in via the respondent, interviewer, questionnaire, or mode of communication. Evaluating correlates of measurement error can shed further light on the validity of a study, particularly those parts which may prove most useful in modeling, and the areas requiring better design, planning, or training. Empirical measures exist for assessing measurement error such as unit and item nonresponse and the index of inconsistency. Further research is needed to study the association of these correlates with empirical measures of error (e.g. response rates, index of inconsistency).

The interaction of the interviewer-respondent-questionnaire serves as a portal of entry for variable and fixed errors. These variable errors may greatly exceed the variable errors due to sampling. The ability to evaluate correlates of these errors and to even obtain empirical assessments of measurement error should be taken into account in a greater number of epidemiological studies. Sampling error is an inadequate measure of total survey error. Greater application of these techniques, common in other disciplines, needs to become routine in the realm of veterinary epidemiological studies.