What is normal? A field approach to characterizing health and management of the nation’s animal populations

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ABSTRACT

There is a growing demand for information about the health and well-being of animals on farms. Such information has many uses. In some instances such information is used locally by livestock owners and producers to gauge their position relative to their peers. In other instances the information can be used at a national or international level by policy makers and trade negotiators. Animal health companies use such information to target research and product development. Academicians and other educators use information on animal health to teach future members of the agricultural industries. In addition, consumers are asking more questions about the manner in which animals are raised and cared for on farms. With so many stakeholders with an interest in such information there is a need for objective data collected with credible methods covering a substantial proportion of the population of interest. Such efforts are unlikely to be accomplished by entities other than a nationally focused unit in the government. The United States Department of Agriculture’s National Animal Health Monitoring System (NAHMS) has been providing management and health-related data on the United States livestock and poultry populations for nearly 20 years.

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1. Historical perspective

As livestock numbers in the United States grew and there were more calls for an organized approach to disease control, the need for a central disease control authority, was recognized. The need to develop regulations for animal movement and to support coordinated disease control efforts led to the Animal Industry Act of 1884 which established the United States Bureau of Animal Industry (BAI), the predecessor to the current Animal and Plant Health Inspection Service (APHIS) of the United States Department of Agriculture (Wiser, 1987). Dr. Daniel Salmon was appointed as the first director of the new BAI. Over the years, since the establishment of the BAI with the subsequent continuation as APHIS, much of the effort has been on border protection, outbreak investigation (to the point of exclusion of a foreign animal disease), negotiation of requirements for trade in animals or animal products, approval of biological products, enforcement of animal care regulations, and disease control or eradication programs. There have been a number of important accomplishments due at least in part to the agency’s efforts over the years including the eradication of contagious bovine pleuropneumonia, eradication of the Texas cattle fever tick, and dramatic reductions in the occurrence of bovine tuberculosis and brucellosis (Stalheim and Moulton, 1987).

2. A new paradigm

With the control and/or elimination of a number of major diseases in the United States agency officials began to look to other uses of the federal animal health workforce. There was an on-going need for some core...
workforce to be available to complete the disease control efforts already underway, to be available to respond in case of an animal health emergency such as the incursion of a foreign animal disease and the ability to take on new disease control efforts as requested by stakeholders. This workforce had a broad geographic distribution and employed a large number of veterinarians and animal health technicians that were familiar with animal agriculture and that were trained in biological sample and data collection. Over time trade in animals and animal products has grown (Hueston, 1993). Furthermore, international traffic by people has increased dramatically. Agriculture has become more concentrated with larger capital investment. All of these factors have raised the potential for risk to animal health and the potential economic consequences for disease in livestock populations. In 1966, the National Academy of Sciences published a report on animal disease morbidity and mortality reporting (Popensiek and Budd, 1966). In developing that report they recognized some of the limitations of current systems for assessment of the well-being of livestock in the United States. The National Academy of Sciences released a second report in 1974 that called for the creation of a national system for animal health surveillance in the United States (Hutton and Halvorson, 1974). The report went on to explain in some detail what the newly established system should look like and what it should do. In response to these reports and subsequent discussions APHIS launched a series of state level pilot projects in collaboration with several Universities in 1983 to determine if the federal animal health infrastructure could be used to collect data to allow monitoring of health and management of livestock populations on farms (King, 1990). In 1989, based on the success of the pilot projects, the effort was transitioned to a national program with central design and coordination (King, 1990; Hueston, 1990). This national program became known as the National Animal Health Monitoring System (NAHMS). The NAHMS program is a USDA coordinated program that relies on the voluntary participation of livestock producers (Wineland and Dargatz, 1998). The individual participant’s responses to NAHMS surveys and the individual producer’s animals sample testing results are confidential. Results are only released in summary form that precludes the identification of an individual producer’s data. The program is non-regulatory, meaning that there are no regulatory consequences for the producers based on their participation. The program involves the collection of data on livestock health and management and in some cases biological samples are collected and tested. The objectives for each of the NAHMS studies are determined based on consultation with a diverse group of stakeholders that include livestock producers, veterinarians, members of allied industry groups, animal health officials, researchers, educators, and others (Hueston, 1990). Each NAHMS study evolves through five primary activity areas including needs assessment, study design, implementation, analysis, and information dissemination. During needs assessment input is sought from stakeholders regarding the critical information gaps not being filled by another entity. In general those areas that are prioritized for study involve the interface of two or more of the following areas: animal health, animal production practices, product wholesomeness, impacts on the environment, and animal welfare. During the design process the inference population is identified and a sampling strategy is developed to allow estimation of population parameters with reasonable confidence intervals. In the implementation phase the personnel involved in data collection are trained, potential participants are contacted, and data are collected (most commonly through personal interviews) and validated. Descriptive and inferential data analyses are completed using methods that account for the sampling design resulting in population estimates. Finally, in the dissemination phase information from the data collected are reported out to the stakeholders and other members of the public in the form of descriptive reports, information sheets, manuscripts in the scientific and lay literature and stakeholder announcements/releases. From the transition to a national program through 2007, 21 NAHMS studies have been implemented across a wide variety of commodity types (Table 1).

3. Benefits of the NAHMS studies

The benefits of the information resulting from the NAHMS data collections are manifold. However, only a select few will be discussed here. The data provide the status of the occurrence of disease or disease agents in populations. The frequency of use of various types of production practices can be estimated. The data can be used to generate hypotheses to be evaluated through subsequent research projects. The data can be used to support the design of observational or experimental studies. Design of surveillance systems can benefit from the information available in the various NAHMS reports. The program can help to assess the effectiveness of

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education programs already in place and the need for additional efforts. Finally, the data from NAHMS studies can be used as inputs to build animal disease models.

3.1. Current status

Data collected by the NAHMS program characterize the occurrence of disease syndromes in populations. The results of the NAHMS studies can be used to understand the expected levels of disease and allow for recognition of emerging disease conditions. The NAHMS study results are important benchmarks for producers to know how they compare to their peers. Comparison over time may also signal when there is a need to change disease control efforts locally, regionally, or nationally.

Animal health status reported for dairy heifer and cow mortality from the NAHMS Dairy 2007 study (Fig. 1) show an estimated 5.7% of cows, 1.8% of weaned heifers, and 7.8% of unweaned heifers died during 2006 (USDA, 2007a). Stratification of the data by herd size and region can aid in the interpretation of such data and make them more comparable to a particular producer’s operation. Furthermore, such stratification may help to suggest hypotheses about factors related to the outcome being described.

In many instances the disease events can also be characterized based on the producer’s perception of the cause. Recognizing that producers are unable to make definitive diagnoses per se such information is at least helpful to categorize disease into syndromes that again may suggest what the underlying disease processes are. For example, from the same Dairy 2007 study the percentage of cows experiencing a variety of morbidity events was estimated (Fig. 2). Overall, the most common morbidity events were clinical mastitis (16.5% of cows), lameness (14.0% of cows), and infertility problems (12.9% of cows) (USDA, 2007a). Comparing such estimates from study to study (across years) allows some initial assessment of the stability in the occurrence of morbidity events and may be useful to identify or document the emergence of new disease conditions in the overall population.

When similar data are collected in studies of different commodities comparisons are also possible. The NAHMS program has collected fecal samples from animals in several studies. These fecal samples were then cultured to identify the presence of *Salmonella* spp. The results of the studies allow comparisons of prevalence of *Salmonella* spp. shedding in different types of livestock populations and also allow comparisons over time (Fig. 3) (USDA, 1995; USDA, 1997b; USDA, 2001a,b; USDA, 2005; E. Bush, USDA-APHIS-VS, CEAH, personal communication). In this instance, there is remarkable similarity in the overall animal level prevalence of *Salmonella* spp. from feces of animals in various production settings (e.g. swine, dairy, and feedlot) and over time with the exception of breeding beef cattle (cow-calf).

Costs of disease or disease control efforts are also frequently of interest to stakeholders. An example of disease control costs from one of the NAHMS studies is the estimated cost for equine infectious anemia testing in 1998. On average the cost to equine owners was $22.95 per animal compared to $27.33 per animal in 2005, or a 19.1% increase (USDA, 2007b). The cost of disease treatment in cattle feedlots was estimated from a 1999 study and ranged from $1.10 per affected animal for bullers (steers that are ridden by other steers) to $13.33 per affected animal for atypical interstitial pneumonia (USDA, 2000). These numbers taken together with measures of frequency of occurrence provide some insights into total treatment costs for specific disease syndromes.

3.2. Production practices

Population data on production practices can be used to identify needs for education, serve as benchmarks for comparison, and identify disease risk areas for risk analyses.

In the NAHMS Dairy 2002 study information was collected on biosecurity practices on dairy operations (USDA, 2004). From that study it was estimated that only 37.0% of operations that brought unweaned calves onto the operation used any type of quarantine for these animals. Fewer operations used quarantine for dairy heifers that were weaned but not yet bred (23.9%) and bred dairy heifers (19.6%). Risk of disease introduction appeared high based on the fact that, only 9.5% of operations bringing on lactating dairy cows and 7.1% of operations bringing on
non-lactating cows used some form of quarantine before introducing those animals into the herd. Estimates such as these highlight areas of risk for introduction of diseases onto operations and can be used to focus education efforts for livestock owners and producers.

3.3. Hypothesis generation

Large cross-sectional studies have advantages and some limitations. Data are accumulated from many production settings allowing representation of the diversity of production strategies across the USA. Data are collected on a large number of potential risk factors that can be evaluated. However, with cross-sectional studies assigning causal relationships is difficult. Misclassification is a real concern in these types of studies stemming from measurements taken at a single point in time, the possibility of bias such as recall bias, and in some cases the lack of laboratory confirmation of observations. Because of the large number factors to be evaluated spurious associations will be seen. For these reasons these types of studies are best suited for hypothesis generation rather than to provide definitive answers on the relationships between risk factors and outcomes.

3.4. Study design

In designing studies (experimental or observational) the question of the expected occurrence of disease in the underlying population often arises when considering required sample sizes and study power. Results from the NAHMS studies can assist those designing such studies by providing this information. Another component of research proposals is the question of the expected economic impact from disease. Again NAHMS studies often can provide this background information.

3.5. Surveillance system design

There is a growing need for efficient surveillance systems for animal health. The design of efficient surveillance systems requires data. Information on the underlying level of disease to be detected and the potential for variation in the level of disease is needed to set sample sizes. If targeted surveillance is to be used information on the size of the target population is needed. Even without targeting of the surveillance system, information about production practices and health in the general population can help to identify the proportion of the total population
that will be under surveillance. Furthermore, periodic data from the NAHMS studies can be used to evaluate the potential need for surveillance system re-design based on contemporary management and demographics.

After the first discovery of an animal with bovine spongiform encephalopathy in the United States a decision was made to enhance the surveillance efforts to determine how many other cases could be found. Targeted surveillance was selected as the optimal approach but there was a need to identify the size of the potential target population. This information was available from the NAHMS studies and was very useful in identifying the needed resources to carry out the enhanced surveillance effort and also to retrospectively gauge the success of the program by comparing the total number of sampled animals with the expected size of the population based on historic data. From the NAHMS Dairy’02 study (USDA, 2002) and the Beef’97 study (USDA, 1997a) the estimated number of mortalities (including euthanasia) due to unknown causes, lameness, injury, incoordination, or severe depression was determined. This estimated population of approximately 250,000 animals was then used in designing the program and subsequent evaluation plan.

3.6. Education

Education is critical to facilitating change. In considering disease control efforts, producer activities will be limited by their understanding of the issue. Monitoring change in production practices or health is also important in determining the success and milestones for programs in response to education programs.

Dairy producers’ knowledge of Johne’s disease has been assessed over time through collection of data in three NAHMS studies. Since the mid-1990s, there have been extensive educational efforts aimed at raising dairy producers awareness and understanding of this disease. All of this has been done in an effort to facilitate control. From 1996 to 2007 the proportion of dairy producers that had not heard of the disease declined and those considering themselves knowledgeable rose (Fig. 4) (J. Lombard, USDA-APHIS-VS, CEAH, personal communication). In addition, the proportion of operations participating in Johne’s control programs rose, presumably at least in part due to the education efforts (Fig. 5) (J. Lombard, USDA-APHIS-VS, CEAH, personal communication).

3.7. Disease modeling

Increased efforts have been devoted to development of sophisticated infectious animal disease simulation models. Technology enhancements have allowed for the development of complex simulation models and for identification of the likely scale and scope of disease outbreaks, identify and evaluate potential control scenarios, and aid in preparedness by understanding the needs for resources to control an outbreak. Basing these models on data rather than assumptions can improve their performance. The types of data needed include population demographics, production practice data, and the level of biosecurity

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**Fig. 3.** Percent of fecal samples culture positive for *Salmonella* spp. in various production systems.

**Fig. 4.** Percent of dairy operations by reported level of knowledge regarding Johne’s disease and year.
practiced. For example, information on numbers of animal shipments, sources of animals, and types of animals that move from operation to operation are all important parameters to include in disease models. The use of various biosecurity practices can help to mitigate some of the risks for disease transmission. Factors such as use of quarantines, use of pre-arrival testing, and use of vaccines may all be important in accurately modeling potential disease outbreaks.

An example of a simulation model being developed is the North American Animal Disease Spread Model (Anonymous, 2007). The primary impetus for development of this model is to study what would happen in the event of the introduction of Foot and Mouth disease into North America. However, the framework of the model could also be adapted to other disease conditions of interest. Data from NAHMS reports on animal movements by animal class, including numbers of shipments, types of destinations, source types, and distances traveled, are being used to refine the model. In addition, the use of biosecurity practices will be helpful to understand the potential for undetected introduction into herds. As the model is applied to other disease conditions, potentially including endemic diseases, information on other disease control efforts such as the use of specific vaccines will be important.

Another benefit of the NAHMS program that is difficult to quantify is that it allows veterinarians in the state and federal workforce to remain connected to the animal agriculture sector and to interact with producers through a venue other than an outbreak investigation or regulatory setting. The veterinarians gain experience and knowledge making them more effective in the event of an outbreak and the producers and owners gain some respect for the veterinarians through these interactions.

4. Discussion and conclusion

The NAHMS program has been a unique and effective way for government and stakeholders to partner in improving the health and well-being of animals. This goal has been accomplished through the collection, analysis, and interpretation of field data on a scale not easily attainable by other entities. Furthermore, the benefits of the field data have accrued through the use of the information by a diverse group of stakeholders including individual participating producers, other producers and producer organizations, researchers, individuals from allied industry, educators, animal health officials, risk assessors, and policy makers.

Conflict of interest

Dr. Dargatz does not have a financial or personal relationship with other people or organizations that could inappropriately influence or bias the paper entitled “What is normal? A field approach to characterizing health and management of the nation’s animal populations”.

References


