Executive Summary

In 1998 the United States Department of Agriculture asked the Harvard Center for Risk Analysis to evaluate the robustness of U.S. measures to prevent the spread of bovine spongiform encephalopathy (BSE or "mad cow disease") to animals and humans if it were to arise in this country. BSE is a member of a family of diseases that includes scrapie in sheep and goats, chronic wasting disease in certain North American deer and elk, transmissible mink encephalopathy, and the human ailments Creutzfeldt-Jakob disease, variant Creutzfeldt-Jakob disease and Kuru.

We have developed a probabilistic simulation model to help characterize the consequences of introducing BSE into the U.S. *via* various means. Our model allows us to predict, for example, the number of newly infected animals that would result from introduction of BSE, the time course of the disease following its introduction, and the potential for human exposure to infectious tissues. We evaluate key processes and procedures that make the spread of disease more or less likely. Results are presented as distributions reflecting the probabilistic nature of the model and the processes simulated.

Our analysis finds that the U.S. is highly resistant to any introduction of BSE or a similar disease. BSE is extremely unlikely to become established in the U.S. For example, in a hypothetical scenario in which ten cattle infected with BSE are imported into the U.S., on average only three new cases of BSE would occur. Moreover, the disease is virtually certain to be eliminated from the country within 20 years after its introduction. These results assume that the conditions affecting the spread of BSE in the U.S. would remain unchanged for the 20 years following its introduction. The new cases of BSE would come primarily from lack of compliance with the regulations enacted to protect animal feed. The import of one sick animal yields on average less than one new BSE case in 20 years and the disease and the disease is likely to be quickly eliminated from the U.S. following its introduction. Similarly, there appears to be no potential for an epidemic of BSE resulting from scrapie, chronic wasting disease, or other cross-species transmission of similar diseases found in the U.S. Even if they existed, these hypothetical sources of BSE could give rise to only one to two cases per year. Similarly, if the disease does indeed occur spontaneously in cattle, as some have suggested, it would result in one to two cases per year with little spread.

Only a small amount of potentially dangerous tissues would reach the human food supply and be available for possible human consumption. We express the amount of infectivity in terms of cattle oral ID_{50}s for the purpose of quantifying both animal and human exposure to this agent. A cattle oral ID_{50} is the amount of infectious tissue that would, on average, cause 50% of exposed cattle to develop BSE. The relationship between human exposure quantified in terms of cattle oral ID_{50}s and likelihood of human disease is unknown, but European authorities suggest that the cattle disease may be 10 to 100,000 times less virulent in humans (SSC, 1999, SSC, 2000a). In the entire 20 year period following the import of ten BSE-infected cattle, the mean estimate for the amount of infectivity potentially available for human exposure is 35 cattle oral ID_{50}s. The greatest sources of infectivity include consumption of cattle brain, spinal cord, and meat derived from advanced meat recovery systems. Some potential exposure would result from the presence of spinal cord in certain bone-in cuts of beef, like T-bone steaks, and consumption of cattle intestines. Potential human exposure resulting from spontaneous disease or cross-species transmission of scrapie are predicted to be less than 100 cattle oral ID_{50}s over 20 years.

Even in an extreme case, which we characterize using the 95th percentile of the output distribution from the simulation, the import of ten animals leads to only 11 new cases of BSE over twenty years. The 95th percentile value for potential human exposure is 170 cattle oral ID_{50}s over 20 years, approximately five times the mean value. These predictions can be compared with the experience in the United Kingdom, where it is estimated that there were nearly one million infected animals and it is likely millions of cattle oral ID_{50s} available for potential human exposure.

Measures in the U.S. that are most effective at reducing the spread of BSE include the ban on the import of live ruminants and ruminant meat and bone meal from the UK (since 1989) and all of Europe (since 1997) by USDA/APHIS, and the feed ban instituted by the Food and Drug Administration in 1997 to prevent recycling of potentially infectious cattle tissues. This feed ban greatly reduces the chance that BSE will spread from a sick animal back to other cattle through feed. Our model reflects incomplete compliance with the FDA feed ban and we evaluate the potential risks of exceptions to the ban. Measures instituted in meat packing plants by the industry and USDA/FSIS have reduced the opportunity for infectious tissues to contaminate human food.

Specific pathways or practices that would contribute the most to the spread of BSE if it were introduced into the U.S. relate to compliance with the FDA feed ban and include misfeeding on the farm and the mislabeling of feed and feed products prohibited for consumption by cattle. The disposition of cattle that die on the farm would also have a substantial influence on the spread of BSE if this disease were introduced into the U.S. Factors that influence potential human exposure include the handling of brain and spinal cord in processing plants and how well inspectors would detect animals with BSE at slaughter.

Our model is not amenable to formal validation because there are no controlled experiments in which the introduction and consequences of BSE introduction to a country has been monitored and measured. However, as a test of the model's plausibility, we modeled the small BSE outbreak identified in Switzerland following the introduction of BSE infectivity from the UK. Working with experts in Switzerland, we identified appropriate values for model parameters necessary to appropriately characterize that country's practices and procedures and then simulated the introduction of BSE infectivity. Our simulation took into account risk management actions, such as feed bans instituted by the Swiss. The model's predictions were reasonably close to empirical observations. For example, the model predicted that during the Swiss outbreak, there would be 170 animals that developed clinical signs of disease. To date, the Swiss have detected 398 animals with BSE. The time course of the outbreak predicted by the model also reasonably resembled the pattern observed in Switzerland. The ability of the model to reasonably replicate the magnitude and time course of the Swiss outbreak gives some confidence in the structure of our model, especially in light of the many unknown factors associated with this episode.

We also evaluated the potential for BSE to have entered the U.S. prior to the 1989 ban on the import of UK cattle. BSE has not been detected in the U.S. despite 12 years of active surveillance of high-risk animals. Yet several groups, including the European Union in their Geographically Based Risk Assessment of the U.S. (SSC, 2000b), have highlighted the 334 animals brought into the U.S. from the UK between 1980 and 1989. These animals were imported as breeding stock, not as beef or dairy production animals. This fact is likely to have reduced their potential for exposure to BSE before their export from the UK. In addition, none of these animals came from a farm on which there was a case of BSE in animals from the same birth cohort (same birth farm and year). Many came into the U.S. before BSE was even a recognized disease (the first case was confirmed in the UK in 1986). The USDA has identified and traced the disposition of these animals and has verified that 161 were disposed of in a manner that poses no risk to humans or other animals. However, the Department has not been able to conclusively make this determination for the remaining 173 animals. Using data identifying the year of birth, the year of import, the date of the animal's last known sighting, and information characterizing the time course of the disease following infection, we have estimated the theoretical amount of BSE infectivity that could have theoretically been introduced into the U.S. from these 173 animals. We then used this estimate in our model to predict the possible consequences in the U.S.

Our analysis concludes that there is more than an 80% chance that the import of these animals resulted in no exposure of U.S. cattle to BSE infectivity. Even if U.S. animals were exposed to BSE, there is a significant chance that the exposure resulted in no new cases of disease. Our analysis indicates that there is only a small chance that BSE spread to U.S. cattle but that the number of cases was sufficiently small to avoid detection by U.S. government surveillance. The analysis also shows that if these imports did introduce BSE into the U.S., measures taken by the government and industry during the last five years will have arrested the disease and begun to eradicate it.

Our evaluation of potential risk mitigation actions highlights potential measures to further reduce the already low likelihood that BSE could spread to cattle or contaminate human food if it were to arise. Prohibiting the rendering of animals that die on the farm, possibly of BSE, removes a great deal of potential contamination in the animal feed chain and reduces average predicted cases of BSE following introduction of ten infected cattle by 77%. Implementation of a UK-style ban on specified risk material (*e.g.*, spinal cords, brains, vertebral columns) from both human food and animal feed reduces the predicted number of BSE cases in cattle by 80% and the potential human exposure by 95%. These measures serve as examples of the types of evaluations of alternative risk management strategies that can be conducted using the model.

In summary, measures taken by the U.S. government and industry make the U.S. robust against the spread of BSE to animals or humans should it be introduced into this country. Preventing sick animals or contaminated feed from entering the country, ensuring compliance with the FDA feed ban, and reducing the potential for infectious tissues to enter the animal or human food supply will ensure that these risks remain low. If BSE has been introduced into the U.S., as has been suggested by some observers, the course of the disease has been arrested and it is destined for eradication by the measures currently in place.