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Evaluation of Different Cow Cull Scenarios on the National Prevalence of Bovine Spongiform Encephalopathy

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Introduction

Various cow cull regimes for potentially infected BSE animals have been put forward by different observers and interested parties. The lack of substantive epidemiological and demographic information in the public domain has resulted in proposals for a range of options without full consideration of the costs and effect of these measures. To address this issue, a series of options based on different culling scenarios have been evaluated with a view to informing the debate. These scenarios were based on data collected up to the end of 2000 and assumed that the assumption that the culling would be carried out at the start of 2001.

Objectives of study

To evaluate the effectiveness, efficiency and scale of different cow culling scenarios for BSE in terms of protecting human health and safeguarding animal health status.

Methodology

Scenario development

Based on the epidemiological information currently available, the animal groups at greatest risk of developing clinical signs of BSE were identified. These data were used to develop scenarios that would illustrate the range of the effectiveness and efficiency of any proposed culling programme. The risk factors which were considered in the development of the scenarios were:

- Age - animals aged 5 and 6 years are at greater risk of developing the disease than are other age groups.
- Geographical location - 21% of the clinical cases in the period 1989-2000 were located in Cavan or Monaghan.
- Enterprise type - cattle in dairy herds generally have a higher risk of developing the disease than animals in suckler herds. This may be due to the nature of their diet and other factors such as production pressure.

Based on these risk factors the following scenarios were examined:

- Removal of all cattle born before 1998
- Removal of all cattle born before 1996
- The removal of particular birth cohorts[1] throughout the country

[1] A birth cohort consisted of the animals born in a particular calendar year. For example, all animals born in 1996 were considered to belong to the 1996 birth cohort.

- The removal of particular birth cohorts from dairy enterprises only throughout the country

- The removal of particular birth cohorts in Counties Cavan and/or Monaghan

- The removal of particular birth cohorts from dairy enterprises in Counties Cavan and/or Monaghan

- A feed cohort cull, i.e. the selective culling of animals that were likely to have been fed contaminated batches of feed

  Under this scenario, the aim was to examine the impact of identifying and culling animals that received concentrate feed from the same batch as confirmed BSE cases. However, detailed examination of this scenario was not proceeded with because of the difficulty of identifying contaminated batches of feed. There were a number of reasons why such batches could not be identified:

  1. Because of the long interval between an animal becoming infected and developing clinical signs, it would not be possible to identify the batch of feed that was the source of infection. Both farmer records and milling records would not support such an action.

  2. Most of the infected animals would have been fed a number of different batches of feed during the first year of their lives, the most likely time of infection. Even if all of these batches could be identified, it would not be possible to determine which one was contaminated.

  It would also be difficult to identify other animals that were fed from the same batch. In addition, it was concluded that a feed cohort cull would be much more difficult to implement than a geographical cull. A geographically targeted cull would address this issue to a considerable extent, as the source of exposure of such cases was most likely a common feed supply.

- Prevention of animals born before 1997 from entering the food chain
  Under this latter scenario, no culling policy is specifically implemented for BSE. However, animals that are culled in line with normal farm management practices will not be allowed to enter the food chain if they were born before 1997. This procedure would continue until all animals born before 1997 are removed from the cattle population. The only difference between this scenario and current practice is that no animals born before 1997 would be allowed to enter the food chain. Currently, such animals are allowed to enter the food chain if they have passed a *post-mortem* test for BSE.

Scenario evaluation
Strategies for the control of BSE should be designed to maximise the number of future BSE cases prevented, while minimising the costs in terms of the number of animals culled. Each scenario was evaluated in terms of the following:

Scale – the number of cattle culled

Effectiveness – the proportion of future cases prevented

Efficiency - the number of animals culled per future case prevented

Because of the long incubation period, some animals incubating BSE are slaughtered before they develop clinical signs of the disease. Other animals progress to the clinical stage of the disease. A cow culling programme could prevent both non-clinical and clinical cases. In this paper, the number of future cases prevented is expressed separately for the two categories.

The effectiveness and efficiency of the different scenarios were evaluated in terms of the future cases prevented in addition to those cases that would be prevented by the current control measures. For example, the analysis took into account the number of non-clinical cases that would be detected as a result of the *post-mortem* testing programme. The net benefit from each of the proposed culling strategies in terms of the number of non-clinical cases prevented was the number of non-clinical cases prevented from entering the food chain as a result of the cull less those that would have been detected by the *post-mortem* diagnostic test.

Data requirements

Model data

To evaluate culling policies that might be implemented in the future, model predictions were required for the number of cases likely to arise in future years from both targeted and untargeted animal groups. A model developed by Dr. Yudi Pawitan, Department of Statistics, University College Cork was used.

Demographic data

Information on the age distribution of the Irish cattle population was obtained from the annual Livestock Survey carried out by the Central Statistics Office. The survey records, on December 1st each year, the number of cattle in the age classes 0-12, 12-24 and over 24 months. The survey does not provide information on the age structure of the cattle population over two years old. More detailed age profiles were obtained from the Irish Dairy Records Co-op Annual Report (1993) for 177,605 dairy cows in 1993. These data were used to estimate the age distribution of the national cow population. Note that this dataset ignored males (which make up a negligible fraction of the population over 3 years of age) and did not include suckler herds. On average, dairy cows are younger than suckler cows. Information on the type of dairy herd included in the study was not available. It is likely that the sample was taken from high producing dairy herds. The culling rate in such herds is generally higher than normal giving rise to a lower than average mean age.

The number of dairy cows in the cattle population of Ireland in December 2000 was reported to be 1,238,300 in the Livestock Survey carried out by the Central Statistics Office. During the period 1989 to 2000, 413 (71%) of the 580 clinical cases recorded in Ireland were reported from dairy enterprises. It was assumed that cases from dairy herds would constitute the same proportion of future cases.

Information on the cattle population of Counties Cavan and Monaghan was obtained from a database kept by the Department of Agriculture, Food and Rural Development. Figures of 249,933 and 215,667 were obtained for the total number of cattle in Counties Cavan and Monaghan, respectively, in December 2000. It was assumed that the proportion of these animals that were cows was the same as for the national population, i.e. 36.5%. The age distribution of cows in Cavan and Monaghan was calculated in the same way as for the national population. During the period 1989 to 2000, 62 (11%) of the 580 cases were reported from herds in County Cavan and 58 (10%) were reported from herds in County Monaghan. It was assumed that cases from Cavan and Monaghan would constitute the same proportion of future cases.

Using these assumptions, it was possible to estimate the number of future cases in dairy herds and in counties Cavan and Monaghan and to examine the effectiveness and efficiency of various culling programmes.

Sensitivity of the post-mortem diagnostic test
It was assumed that the sensitivity of the post-mortem diagnostic test, e.g. the Enfer test, is 100% for animals that are within 12 months of developing clinical signs and zero for other pre-clinical cases. Estimates on the number of pre-clinical cases that would be slaughtered within 12 months of developing clinical signs were obtained from the model. It was not possible to obtain estimates for shorter time periods from the model.

Reporting level
During the period, 1989 to 2000, the detection of cases of BSE was based on mandatory reporting and investigation of clinically suspect cattle, i.e. passive surveillance. Generally, cases were reported by herd owners or by private veterinary practitioners. The effectiveness of passive surveillance depends on a number of factors such as the appropriateness of the case definition, the variability of clinical signs, the level of disease awareness among farmers and veterinary practitioners, consequences of reporting diseased animals (such as the loss of the entire herd), the compensation offered and the properties of the diagnostic tools (Doherr *et al.,* 2001). For a variety of diseases in animals and humans, passive surveillance underestimates the incidence of clinical cases. It is difficult to quantify the level of reporting of clinical cases in Ireland. Estimates of changes in reporting levels during the period 1989 - 2000 were obtained from the model. Two possible levels of reporting were examined for 2001 and subsequent years:
a) The level of reporting would be the same as 2000.
b) The level of reporting would be twice that of 2000.

In this paper, the term "higher reporting" will be used for the assumption of an increase in reporting levels in 2001 and subsequent years compared to 2000 and "lower reporting" will be used for the assumption that the reporting level in 2001 and subsequent years will be the same as 2000.

The European Commission has decided that all of the Member States have to implement a targeted-screening of all fallen stock and all emergency-slaughter cows for BSE from July 1st 2001. For this reason, the higher reporting assumption is more likely to be correct.

Results
The scenarios examined varied considerably in scale, effectiveness and efficiency. Based on an analysis of the clinical cases that were reported in the period 1989 – 2000, Dr. Pawitan's model predicts that 582 cases of BSE would be disclosed in the period 2001 - 2010 in animals born between 1990 and 1997 inclusive. These would consist of 398 clinical and 184 non-clinical cases. These predictions are based on the assumption that the reporting level of clinical cases in the period 2001-2010 would be twice that of 2000, The model predicts that 93 of the 184 non-clinical cases would be slaughtered within 12 months of developing clinical signs and would, therefore, be detected by the *post-mortem* diagnostic test, leaving 91 non-clinical cases that would escape detection.

The total removal of all animals born before 1998 would involve the culling of approximately 2.07 million cows and would remove all future clinical and non-clinical cases.

The total removal of all animals born before 1996 would involve the culling of approximately 1.1 million cows and would remove 127 of the 199 future clinical cases assuming lower reporting in 2001-2010 and 253 of the 398 future clinical cases assuming higher reporting in 2001-2010 (Table 1). The proportion of clinical cases removed would be 63.6% and would be the same under the assumptions of lower reporting and higher reporting. The culling of this cohort would prevent 45 non-clinical cases, assuming a higher level of reporting in 2001-2010 (Table 2).

The culling of the 1995 birth cohort would involve the removal of 317,000 cows and would remove 59 of the 199 future clinical cases assuming lower reporting in 2001-2010 and 119 of the 398 future clinical cases assuming higher reporting in 2001-2010 (Table 1). The proportion of clinical cases removed would be 30% and would be the same under the assumptions of lower reporting and higher reporting. The culling of this cohort would prevent 22 non-clinical cases, assuming a higher level of reporting in 2001-2010 (Table 2).

The estimated number of future clinical cases in dairy enterprises is 283 assuming the higher reporting level in 2001-2010. A cull of the 1995 birth cohort would prevent 85 cases, 21% of all future cases nationally (Table 1). The culling of this cohort would prevent 15 non-clinical cases (Table 2). It would involve the culling of 162,111 cows.

The estimated number of future clinical cases in Cavan is 43 assuming the higher reporting level in 2001-2010. A cull of the 1994, 1995 and 1996 birth cohorts would prevent 33 clinical cases, approximately 8% of all future cases. The culling of these cohorts would prevent 7 non-clinical cases. The estimated number of future cases in Monaghan is 40 assuming the higher reporting levels in 2001-2010. A cull of the 1994, 1995 and 1996 birth cohorts would prevent 31 clinical cases, approximately 8 % of all future cases. The culling of this cohort would prevent 7 non-clinical cases. A cull of the 1994, 1995 and 1996 birth cohorts in both counties would yield 16% of future clinical cases (Table 1).

The estimated number of future clinical cases in dairy enterprises in Cavan and Monaghan is 60 assuming the higher reporting levels in 2001-2010. The culling of the 1995 birth cohort in dairy herds in Counties Cavan and Monaghan would involve the removal of 11,635 cows. Such a culling programme would remove 4% of the future clinical cases and 2% of the future non-clinical cases. A cull of the 1994, 1995 and 1996 birth cohorts would involve the removal of 35,407 cows and would yield 12% of future clinical cases (Table 1).

Table 1. Number of clinical cases prevented by culling of different birth cohorts.

		Lower reporting	Higher reporting	
Scenario	**No. culled**	**Clinical cases prevented in 2000-2010**	**Clinical cases prevented in 2000-2010**	**Percent**
All animals born before 1998	2,072,000	199	398	100
All animals born before 1996	1,150,100	162	253	64
National cull of 1995 birth cohort	317,000	59	119	30
National cull of 1995 birth cohort in dairy enterprises only	162,111	42	85	21
Cull of 1994-96 birth cohort in Counties Cavan and Monaghan	67,463	32	64	16
Cull of 1994-96 birth cohort in dairy herds in Counties Cavan and Monaghan	35,407	23	47	12

Table 2. Number of non-clinical cases prevented by culling of different birth cohorts.

		Lower reporting	Higher reporting	
Scenario	**No. culled**	**Cases prevented**	**Cases prevented**	**Percent**
All animals born before 1998	2,072,000	45	91	100
All animals born before 1996	1,150,100	22	45	49
National cull of 1995 birth cohort	317,000	11	22	12
National cull of 1995 birth cohort in dairy enterprises only	162,111	8	15	8
Cull of 1994-96 birth cohort in Counties Cavan and Monaghan	67,463	6	13	7
Cull of 1994-96 birth cohort in dairy herds in Counties Cavan and Monaghan	35,407	5	9	5

The highest efficiency would be obtained by the removal of cows from the 1994-96 birth cohort in dairy enterprises in Counties Cavan and Monaghan. Assuming lower reporting in 2001, such a culling would yield an efficiency of 1,269 animals culled per case prevented under the lower reporting assumption and 635 under the higher reporting assumption (Table 3). The cases include future clinical and non-clinical cases.

Table 3. Efficiency of culling programmes for different birth cohorts expressed as the number of animals culled per case (clinical and non-clinical) prevented.

		Lower reporting		Higher reporting	
Scenario	**No. culled**	**Cases prevented**	**No. culled per case prevented**	**Cases prevented**	**No. culled per case prevented**
All animals born before 1998	2,072,000	244	8478	489	4239
All animals born before 1996	1,150,100	149	7735	298	3868
National cull of 1995 birth cohort	317,000	70	4516	140	2258
National cull of 1995 birth cohort in dairy enterprises only	162,111	50	3243	100	1622
Cull of 1994-96 birth cohort in Counties Cavan and Monaghan	67,463	39	1744	77	872
Cull of 1994-96 birth cohort in dairy herds in Counties Cavan and Monaghan	35,407	28	1269	56	635

Prevention of animals born before 1997 entering the food chain

Under the higher reporting assumption, the model predicts that 309,000 animals born before 1997 would be slaughtered in 2001 and that 41.4 of these would be incubating BSE. The exclusion of all such animals from the food chain would have an efficiency of 7,464 exclusions per case prevented from entering the food chain (Table 4). The efficiency of excluding animals born before 1997 from the food chain would decrease in subsequent years.

The model predicts that 1,176,000 animals born before 1997 would be slaughtered in the period 2001- 2006 and that 69 of these would be infected with BSE and would pass a *post-mortem* test. The exclusion of all such animals from the food chain would have an efficiency of 17,093 exclusions per case prevented from entering the food chain.

Table 4. Removal of all animals born before January 1st, 1997 from the food chain Efficiency of the procedure expressed as the number of animals removed per case prevented, by year of slaughter.

		Lower reporting		Higher reporting	
Year of slaughter	No. of cows slaughtered	Cases prevented	No. culled per case prevented	Cases prevented	No. culled per case prevented
2001	309,000	21	14,928	41	7,464
2002	268,000	9.3	28,817	19	14,409
2003	222,000	3.4	65,294	7	32,647
2004	173,000	<1	192,222	2	96,111
2005	123,000	<1	1,230,000	<1	615,000
2006	81,000	0		0	
	1,176,000	34.4	34,186	69	17,093

Discussion

The aim of this study was to evaluate the likely effectiveness, efficiency and scale of different cow culling programmes for BSE. In the absence of other sources of information, the analysis and modelling of reported cases, as described above, can provide a valuable insight into the relative merits of different culling regimes. However, the results of the study should be treated with caution for the following reasons:

- There was a degree of uncertainty about some of the model parameters, particularly the baseline level of reporting of clinical cases in 2000.

- The demographic data used in the study may not be fully representative of the Irish cattle population. An alternative source of data was a database maintained by the Department of Agriculture, Food and Rural Development. This contains the date of birth of all animals born in Ireland since mid 1996. A comparison between the Department of Agriculture database and the data used in the study of the age distribution of the cow population born after 1996 showed a smaller proportion of cows in the 2-4 year-old age groups in the Department of Agriculture database. Because of some recording difficulties, the Department of Agriculture database cannot be considered completely reliable in regard to the earlier data. Also, it does not provide any information of the age distribution of cows born before 1996.

The culling scenarios examined were generally less effective and less efficient than similar scenarios examined in the UK due to the higher prevalence of BSE in the UK cattle population. An age-targeted culling programme of 2 million animals born between October 1990 and June 1993 by January 1st 1997 was predicted to prevent 56% of the cases predicted to arise in the years 1997-2001 (Donnelly *et al.*, 1997). The efficiency of such a programme was predicted to be 523 animals culled per case prevented. A similar age-targeted culling programme in Ireland of animals born between 1994 and 1996 would involve the removal of 964,000 cattle. It would remove 155 (78%) clinical cases and would have an efficiency of 5,182 animals removed per case culled at the lower reporting rate in 2001 and 2,591 animals removed per case culled at the higher reporting rate. The most efficient cull identified in the current study was the removal of cows born between 1994 and 1996 in dairy herds in Counties Cavan and Monaghan. This would involve the removal of 35,407 cattle and have an efficiency of 1,269 and 635 for the lower and higher reporting rates respectively.

The reason for the lower levels of effectiveness and efficiency in the scenarios considered here is that the prevalence of BSE in Ireland was considerably lower in Ireland than in the UK. In 1996 and 1997 a number of measures were introduced to prevent cattle being exposed to the BSE agent through contaminated feed. The level of exposure was reduced significantly from 1996 and it is believed that the BSE agent was negligible from 1/1/98. Consequently the number of animals incubating BSE in the population at the end of 2000 was very low. In such a situation, the number of non-incubating animals removed in a culling programme would be large relative to the incubating animals.

In the results section, information on the clinical and non-clinical cases was presented separately. The culling programme would accelerate the decline in clinical cases of BSE. This is important in terms of the marketing of Irish beef and in boosting consumer confidence. However, it is likely that the culled animals would be subjected to a *post-mortem* test at the time of culling and some would be positive. The decline in the number of clinical cases would be offset to some extent by an increase in the reported number of non-clinical cases. The prevention of clinical cases would have no obvious public health benefits assuming that the measures currently in place to prevent such animals from entering the food chain are being operated correctly.

If the existing measures which are in place for food safety purposes are fully implemented, the culling of animals in the pre-clinical stage of the disease would not provide any known additional consumer protection. However, it would protect against any shortfall that might occur in the implementation of the existing control measures and it would be another way of ensuring that tissues from animals that may have been exposed to the agent would not enter the food chain.

The effectiveness and efficiency of the proposed culling strategies would depend on the time at which they were implemented. In this study, it was assumed that the measures were implemented on 1/1/2001. The accuracy of the figures given above would decrease as time progresses.

An evaluation of different culling scenarios would also need to consider the capacity of abattoirs and rendering plants to cater for the increased number of cattle that would need to be processed as a result of the cull.

In this study, the scale, effectiveness and efficiency of various scenarios were examined. The next step in the evaluation would be to carry out a cost benefit analysis. The costs of a cull measure should be assessed in terms of the disposal of the animals/carcasses in question and the long-term impact any significant population effect would have on the productive output of the national herd. The benefits of the cull in terms of public health could be quantified using the method described by Cousens *et al.* (1997) and subsequently adapted by Cohen *et al.* (1999). If possible, the impact of the removal of BSE infected animals on the beef and dairy markets would also be quantified. Other potential benefits could also be quantified. For example, the disclosure of a positive diagnostic test result in an animal being sent for routine slaughter would give rise to considerable financial losses for the abattoir concerned. A cull would prevent such losses.

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