The Risk of Additional BSE Cases in Herds that Undergo a "Cohort Cull"

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Introduction

There has been concern in Denmark regarding possible negative consequences of replacing whole herd culling with culling only cattle born plus or minus one year of the birth of a BSE case. By definition, whole herd culling eliminates all risk of further BSE cases in that herd. On the other hand, there is some evidence that a +/- 1-year cohort cull is nearly as effective. Cohort culling is preferred by some for economic, political, animal welfare and possibly other reasons. The purpose of this study was to estimate the risk of further BSE cases in herds that had undergone a cohort cull after a BSE case.

Methods

Monte Carlo simulation models were constructed to estimate the probability of the occurrence of additional cases in BSE affected herds that underwent a 1,1.5, or 2- year cull protocol. The probability of infection given exposure and the probability of becoming a clinical or test positive BSE case given infection were estimated for individual animals. Then the mean probabilities were used in a model to estimate the number of infections, the number of clinical cases and the number of test positive cases that would occur in a herd that experienced a BSE case.

Model assumptions

- All animals in the herd were exposed to BSE infectivity during the same seven day period;
- Given constant exposure to BSE infectivity, the probability that animal will become infected during its lifetime equals 1;
- The probability that an exposed animal will become infected during a given interval is determined by the age-dependent susceptibility;
- BSE infections are expected to become detectable with a rapid test 3 months before the onset of clinical signs;
- The age distribution in individual herds is the same as the age distribution in the standing population.

The major inputs were:

- Age at infection distribution of the index case (AI)[1]
- Incubation period distribution (IP)[1]
- Survival age distribution (Age)
- Test age distribution (Tage)
- Herd size distribution (Hsize)

Definitions

Index case – The first BSE case in a herd

1, 1.5, or 2-year cohort cull – Culling all animals born within plus or minus 1, 1.5 or 2 year(s) of the index case.

Older cohort – All animals born **more** than 1, 1.5, or 2 year(s) before the index case.

Younger cohort – All animals born **more** than 1, 1.5, or 2 year(s) after the index case.

Modules

• Individual animals

The age at infection (AI) of the index case was obtained by sampling from the age at infection cumulative probability distribution. The age at infection of the younger (AI_Y) and older cohorts (AI_O) were obtained by subtracting or adding 1, 1.5 or 2 years from the age at infection of the index case.

The probability of infection of the index case *(PI_{Ind})* , the younger cohort *(PI_Y)* and the older cohort *(PI_O)* was obtained with the Excel LOOKUP function where the probability of infection at a given age was looked up in a discrete probability distribution of the age of infection.

The expected age at onset of clinical BSE (EAO) was obtained by adding the age at infection (AI) and the incubation period (IP). EAO_Y and EAO_O were also calculated the same way.

The probability of a clinical index BSE case (CC_{Ind}) was obtained by comparing the EAO with the age (Age) of a living animal which was obtained by sampling form the cattle age distribution. If the EAO was less than the CowAge then clinical BSE would result. The proportion of iterations in which that occurred was the probability of a clinical BSE case given infection. Similar calculations were done for the younger and older cohorts.

The probability of a test positive index BSE case (TPC_{Ind}) was obtained by comparing the EAO with the age at testing (Tage) of an animal which was obtained by sampling from the age distribution of cattle that left the population for any reason. If the EAO was less than the Tage then clinical BSE would result. The proportion of iterations in which that occured was the probability of a test positive BSE case given infection.

The results of the simulations for individual animals are shown in Table 1.

	1-YEAR CULL			1.5-YEAR CULL			2-YEAR CULL		
Code	**Mean**	**50th**	**95th**	**Mean**	**50th**	**95th**	**Mean**	**50th**	**95th**
AI	0.676	0.415	2.728	0.676	2.728	2.728	0.676	0.415	2.728
AI_Y	0.203	0.000	1.727	0.125	0.000	1.226	0.047	0.000	0.727
AI_O	1.677	1.416	3.729	2.177	1.916	4.228	2.677	2.416	4.729
IP	5.537	5.377	7.937	5.537	5.377	7.937	5.537	5.377	7.937
EAO_{Ind}	6.213	5.954	9.273	6.213	5.959	9.277	6.213	5.959	9.277
EAO_Y	6.835	6.600	10.12	6.332	6.097	9.620	5.832	5.613	9.120
EAO_O	7.214	6.959	10.23	7.714	7.462	10.75	8.214	7.962	11.25
PI_{Ind}	0.020	0.029	0.029	0.020	0.029	0.029	0.020	0.029	0.029
PI_Y	0.002	0.000	0.014	0.001	0.000	0.003	0.000	0.000	0.001
PI_O	0.002	0.002	0.003	0.001	0.001	0.002	0.000	0.000	0.001
Age	3.013	2.577	7.329	3.013	2.577	7.328	3.013	2.577	7.328
Tage	5.043	4.718	9.509	5.043	4.718	9.509	5.043	4.718	9.509
CC_{Ind}	0.122	0.000	1.000	0.124	0.000	1.000	0.124	0.000	1.000
CC_Y	0.097	0.000	1.000	0.124	0.000	1.000	0.159	0.000	1.000
CC_O	0.073	0.000	1.000	0.054	0.000	1.000	0.040	0.000	0.000
TPC_{Ind}	0.346	0.000	1.000	0.346	0.000	1.000	0.346	0.000	1.000
TPC_Y	0.176	0.000	1.000	0.217	0.000	1.000	0.258	0.000	1.000
TPC_O	0.231	0.000	1.000	0.184	0.000	1.000	0.148	0.000	1.000

•The Herd

The number of animals in the younger cohort and older cohorts was read from the cumulative herd size distribution with the LOOKUP function in Excel after generating the age at infection of the index case.

The number of BSE infected animals in the younger (N_Y) and older cohorts (N_O) was simulated with a Binomial(N,PI) PDF where N was the number of animals in the younger ond older cohorts, respectively and PI was the mean probability of infection of the cohorts, respectively (from the individual animal module).

The number of clinical cases in the younger cohort (CC_Y and CC_O) was simulated with a Binomial (N_Y, CC_Y) where Cc_y was the mean probability of a clinical case in the younger cohort (from the individual animal module).

The number of test positive cases in the younger cohort (TPC_Y and TPC_O) was simulated with a Binomial (N_Y, TPC_Y) where TPC_y was the mean probability of a test positive case in the younger cohort (from the individual animal module).

The probability of an an additional BSE case (P_{Missed}) in the event of a cohort cull was the proportion of iterations when there was 1 or more clinical or test positive case in the younger or older cohorts.

The results are shown in Table 2.

	1-YEAR CULL			1.5-YEAR CULL			2-YEAR CULL		
		Percentiles			Percentiles			Percentiles	
Code	**Mean**	**50th**	**95th**	**Mean**	**50th**	**95th**	**Mean**	**50th**	**95th**
NI_Y	0.0048	0.0000	0.0000	0.0019	0.000	0.000	0.0007	0.000	0.000
NI_O	0.0846	0.0000	1.0000	0.0379	0.000	0.000	0.0158	0.000	0.000
CC_Y	0.0003	0.0000	0.0000	0.0002	0.000	0.000	0.0001	0.000	0.000
CC_O	0.0077	0.0000	0.0000	0.0030	0.000	0.000	0.0006	0.000	0.000
TPC_Y	0.0025	0.0000	0.0000	0.0012	0.000	0.000	0.0003	0.000	0.000
TPC_O	0.0464	0.0000	0.0000	0.0166	0.000	0.000	0.0049	0.000	0.000
P_{Missed}	**0.0576**	**0.0000**	**1.0000**	**0.0210**	**0.000**	**0.000**	**0.0069**	**0.000**	**0.000**
Y_{Missed}	0.0031	0.0000	0.0000	0.0012	0.000	0.000	0.0007	0.000	0.000
O_{Missed}	0.0548	0.0000	1.0000	0.0198	0.000	0.000	0.0062	0.000	0.000
$\%H_{BC}$	0.2613	0.2531	0.3511	0.3678	0.351	0.507	0.4643	0.443	0.609
P_{NoCull}	0.1328								

Conclusions

Because of the uncertainty associated with the model inputs the results must be interpreted with caution. However, the results suggest that there is a non-negligble risk of additional BSE cases should a 1 year cohort cull policy be adopted. Additonal cases were associated with larger herds and were more likely in animals that were born before the index case. A 1.5 or 2 year cull policy would reduce but not eliminate the risk.

Reference

1. Arnold, M. & Wilesmith, J. (2004). Estimation of the age-dependent BSE infection of dairy animals in Great Britain. *Preventive Veterinary Medicine,* 66:35-47.