The effects of annual widespread badger culls on cattle tuberculosis following the cessation of culling – Supplementary Information

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Geographical locations of the areas included in the RBCT

Figure S1 – Map of proactive (shaded), reactive (hatched) and survey-only (open) trial areas of the RBCT. Grey shading indicates parish testing intervals, which give an approximate index of local TB incidence; parishes with the lowest incidence are assigned four yearly testing (white) and parishes with the highest incidence are assigned annual testing (dark grey). Testing was conducted annually inside all trial areas. Data from reactive areas were not included in the analyses presented here; however the locations of these areas are shown because this influenced the inclusion of herds in 'neighbouring areas'. (Reproduced from the supplementary information to Donnelly CA, Woodroffe R, Cox DR, Bourne FJ, Cheeseman CL, Wei G, et al. Positive and negative effects of widespread badger culling on cattle tuberculosis. Nature 2006;439:843-6.)

2. Historical badger culling

The following is reproduced from the supplementary information to Donnelly CA, Woodroffe R, Cox DR, Bourne FJ, Cheeseman CL, Wei G, et al. Positive and negative effects of widespread badger culling on cattle tuberculosis. Nature 2006;439:843-6.

Badger culling has formed a component of British TB control policy since the 1970's[1-3]. Because the trial areas were placed in areas of high TB risk to cattle, most had been subject to some form of badger culling under previous policies. The 'gassing strategy' (1975-1981) killed badgers on land surrounding breakdown herds, primarily by pumping hydrogen cyanide into their setts. In the wake of concerns about welfare aspects of gassing, the 'clean ring strategy' was introduced in 1981. This involved cage trapping badgers on land occupied by affected cattle herds, then on adjoining land, expanding outwards until no further infected animals were captured. In 1986 this approach was replaced by the 'interim strategy' which involved culling badgers only on land occupied by affected cattle herds. The last 'interim' culls were performed in 1998, prior to the start of the RBCT. Capture methods used under the interim strategy were similar to those used in the RBCT, except that no closed season was in operation; instead, lactating females were immediately released[1] and in some cases the operations would be suspended until later in the year to avoid capture of further lactating females.

The numbers of badgers culled under the interim strategy in each trial area are shown in Table S1.

Table S1 The numbers of badger culled under the "interim strategy" (between 1986 and 1998) on land that subsequently fell inside RBCT areas

	Triplet										
Treatment	A	B	C	D	E	F	G	H	I	J	Total
Proactive	115	399	199	67	203	480	0	55	385	78	1,981
Survey-Only	186	342	319	14	239	240	0	31	38	0	1,409

3. Observed numbers of confirmed breakdowns by time period

Table S2 Numbers of confirmed breakdowns by time period, triplet and treatment. 'Baseline herds' refers to the number of herds in the trial area at the start of the initial cull in that triplet. Historic incidence is the number of confirmed breakdowns reported in the baseline herds in the period three years immediately prior to the initial cull in that triplet. Data are for herds inside trial areas only and are based on the VetNet database .

				Confirmed breakdown incidence					
				During-trial time periods				Post-trial time periods	
Triplet	Treatment	Baseline herds	Historic incidence	1[†]	2[†]	3[†]	4[†]	5[†]	6[†]
A	Proactive	71	33	20	10	4	6	4	1
A	Survey-only	89	33	22	12	8	25	9	0
B	Proactive	153	40	10	13	20	55	9	0
B	Survey-only	133	27	1	12	22	35	15	0
C	Proactive	107	15	7	3	10	14	3	0
C	Survey-only	173	27	13	17	17	51	17	6
D	Proactive	98	28	5	12	18	4	9	4
D	Survey-only	108	30	12	18	8	11	11	7
E	Proactive	116	25	5	10	4	23	9	0
E	Survey-only	101	28	10	18	10	29	15	6
F	Proactive	142	12	5	5	4	2	1	0
F	Survey-only	190	34	24	22	7	11	8	6
G	Proactive	245	26	25	23	4	31	7	6
G	Survey-only	131	15	13	4	10	27	10	8
H	Proactive	66	23	10	8	7	11	14	1
H	Survey-only	129	22	6	10	8	18	12	7
I	Proactive	107	30	10	11	6	11	9	3
I	Survey-only	98	19	5	5	12	9	12	3
J	Proactive	116	25	14	17	3	12	9	6
J	Survey-only	124	18	9	9	17	5	17	4

[†]Time included in each time period: 1 – From the end of the initial cull in that triplet to the end of the second cull, 2 – From the end of the second cull in that triplet to the end of the third cull, 3 - From the end of the third cull in that triplet to the end of the fourth cull, 4 – From the end of the fourth cull in that triplet to one year after the end of the last proactive cull in that triplet (i.e. the end of the during-trial period), 5 – From the end of the during-trial period to one year later, 6 – From one year after the end of the during-trial period to 6 January 2008.

Table S3 Numbers of confirmed breakdowns by time period, triplet and treatment. 'Baseline herds' refers to the number of herds in the trial area at the start of the initial cull in that triplet. Historic incidence is the number of confirmed breakdowns reported in the baseline herds in the period three years immediately prior to the initial cull in that triplet. Data are for herds in areas up to 2km outside the trial area boundaries and are based on the VetNet database .

				Confirmed breakdown incidence					
				During-trial time periods				Post-trial time periods	
Triplet	Treatment	Baseline herds	Historic incidence	1[†]	2[†]	3[†]	4[†]	5[†]	6[†]
A	Proactive	60	24	10	8	3	6	4	0
A	Survey-only	70	19	5	5	1	14	7	0
B	Proactive	153	16	6	8	13	55	14	0
B	Survey-only	69	15	3	6	13	28	7	1
C	Proactive	118	10	5	7	7	21	6	0
C	Survey-only	122	14	3	11	6	27	12	7
D	Proactive	48	5	2	5	9	1	8	0
D	Survey-only	58	19	4	6	5	3	8	5
E	Proactive	96	11	4	8	3	14	4	0
E	Survey-only	76	17	5	10	7	12	8	0
F	Proactive	61	1	2	2	1	12	0	1
F	Survey-only	129	21	11	11	6	15	7	3
G	Proactive	165	3	12	11	3	9	7	3
G	Survey-only	138	15	7	8	3	21	8	7
H	Proactive	71	16	14	8	6	23	4	3
H	Survey-only	94	14	7	6	5	11	11	0
I	Proactive	69	11	3	8	8	6	3	1
I	Survey-only	64	15	4	1	4	2	5	0
J	Proactive	120	18	12	9	10	8	12	10
J	Survey-only	103	5	7	5	5	8	6	5

[†]Time included in each time period: 1 – From the end of the initial cull in that triplet to the end of the second cull, 2 – From the end of the second cull in that triplet to the end of the third cull, 3 - From the end of the third cull in that triplet to the end of the fourth cull, 4 – From the end of the fourth cull in that triplet to one year after the end of the last proactive cull in that triplet (i.e. the end of the during-trial period), 5 – From the end of the during-trial period to one year later, 6 – From one year after the end of the during-trial period to 6 January 2008.

Table S4 Numbers of confirmed breakdowns by time period, triplet and treatment. 'Baseline herds' refers to the number of herds in the trial area at the start of the initial cull in that triplet. Historic incidence is the number of confirmed breakdowns reported in the baseline herds in the period three years immediately prior to the initial cull in that triplet. Data are for herds inside trial areas only and are based on the RBCT database .

				Confirmed breakdown incidence					
				During-trial time periods				Post-trial time periods	
Triplet	Treatment	Baseline herds	Historic incidence	1[†]	2[†]	3[†]	4[†]	5[†]	6[†]
A	Proactive	61	33	20	11	4	8	5	1
A	Survey-only	77	37	22	11	8	28	9	0
B	Proactive	132	41	11	13	19	60	9	0
B	Survey-only	114	27	1	12	25	39	16	0
C	Proactive	103	19	8	5	12	18	6	0
C	Survey-only	169	30	13	20	20	54	19	8
D	Proactive	71	27	4	12	17	4	5	2
D	Survey-only	71	28	10	16	10	11	12	8
E	Proactive	91	25	7	12	4	26	8	1
E	Survey-only	83	28	12	16	9	24	15	5
F	Proactive	113	12	5	5	4	3	1	0
F	Survey-only	184	38	28	27	8	17	9	6
G	Proactive	180	19	25	22	2	33	8	6
G	Survey-only	109	15	15	5	12	29	14	9
H	Proactive	56	22	10	10	6	11	14	1
H	Survey-only	117	26	9	11	9	18	14	6
I	Proactive	84	34	12	11	7	12	9	5
I	Survey-only	80	18	6	3	11	10	11	1
J	Proactive	118	30	16	19	5	12	9	6
J	Survey-only	123	17	9	9	18	6	16	6

[†]Time included in each time period: 1 – From the end of the initial cull in that triplet to the end of the second cull, 2 – From the end of the second cull in that triplet to the end of the third cull, 3 - From the end of the third cull in that triplet to the end of the fourth cull, 4 – From the end of the fourth cull in that triplet to one year after the end of the last proactive cull in that triplet (i.e. the end of the during-trial period), 5 – From the end of the during-trial period to one year later, 6 – From one year after the end of the during-trial period to 6 January 2008.

Table S5 Numbers of confirmed breakdowns by time period, triplet and treatment. 'Baseline herds' refers to the number of herds in the trial area at the start of the initial cull in that triplet. Historic incidence is the number of confirmed breakdowns reported in the baseline herds in the period three years immediately prior to the initial cull in that triplet. Data are for herds in areas up to 2km outside the trial area boundaries and are based on the RBCT database .

				Confirmed breakdown incidence					
				During-trial time periods				Post-trial time periods	
Triplet	Treatment	Baseline herds	Historic incidence	1[†]	2[†]	3[†]	4[†]	5[†]	6[†]
A	Proactive	24	14	7	6	3	5	1	0
A	Survey-only	33	9	5	1	1	7	2	0
B	Proactive	68	10	6	5	6	34	7	0
B	Survey-only	49	11	3	4	7	16	5	2
C	Proactive	59	3	6	3	1	17	1	0
C	Survey-only	52	7	4	6	3	20	6	4
D	Proactive	24	3	2	4	6	2	6	0
D	Survey-only	22	7	1	4	4	1	6	3
E	Proactive	26	5	0	5	1	6	0	0
E	Survey-only	43	14	4	8	5	12	2	1
F	Proactive	18	0	0	2	0	1	0	0
F	Survey-only	53	12	6	3	3	5	0	1
G	Proactive	54	3	6	4	0	7	3	2
G	Survey-only	39	7	4	3	1	11	2	2
H	Proactive	33	7	9	3	4	11	1	0
H	Survey-only	44	7	4	5	2	7	8	0
I	Proactive	44	4	2	4	4	4	3	1
I	Survey-only	31	10	2	2	2	1	4	0
J	Proactive	58	12	4	4	5	4	8	5
J	Survey-only	45	6	1	4	5	1	5	1

[†]Time included in each time period: 1 – From the end of the initial cull in that triplet to the end of the second cull, 2 – From the end of the second cull in that triplet to the end of the third cull, 3 - From the end of the third cull in that triplet to the end of the fourth cull, 4 – From the end of the fourth cull in that triplet to one year after the end of the last proactive cull in that triplet (i.e. the end of the during-trial period), 5 – From the end of the during-trial period to one year later, 6 – From one year after the end of the during-trial period to 6 January 2008.

4. Results based on locations from the RBCT databas e

Cattle herd locations were taken from two alternative databases, the national animal health information system VetNet, and a separate database set up specifically for the RBCT. Analyses were performed using both of these two databases separately. These databases were used to identify herds inside, and up to 2 km outside, trial area boundaries. The VetNet database provided more complete data on herds outside trial areas, because the RBCT database did not include all farms on neighbouring land, hence results presented in the main text are based on the VetNet location database. Here we present results based on the RBCT database - see tables S6-8.

Table S6 – Estimated effects of proactive culling on the incidence of confirmed cattle TB breakdowns inside trial areas. Analyses adjust for triplet, baseline herds, and historic TB incidence (over three years). Results split by cull sequence during-trial and by year post-trial and include breakdowns from the initial cull to 6 January 2008 . During-trial results include all confirmed breakdowns from the initial proactive cull (in each triplet) to one year after the last proactive cull (in each triplet) and use the January 07 data download as reported in the ISG Final Report. The post-trial results include all reported confirmed breakdowns from one year after the last proactive cull (in each triplet) to 6 January 2008 and use the download from 6 January 2008. All results are based on locations from the RBCT database .

	Proactive effect				Overdispersion	
	estimate	95% CI		p-value	factor	p-value
1st to 2nd cull	2.0%	(-27.9%	44.3%)	0.91	1.31	0.001
2nd to 3rd cull	-1.1%	(-29.8%	39.2%)	0.95		
3rd to 4th cull	-43.8%	(-61.8%	-17.5%)	0.003		
After 4th cull to end of during-trial period	-23.8%	(-41.4%	-1.0%)	0.042		
First year of post-trial period	-49.6%	(-65.9%	-25.5%)	0.001		
Second year of post-trial period	-58.5%	(-79.0%	-17.9%)	0.011		
All during-trial period combined	-17.4%	(-27.2%	-6.2%)	0.003	0.79	0.74
All post-trial period combined (1st and 2nd year combined)	-54.7%	(-66.0%	-39.8%)	<0.001	0.88	0.61
1st cull to 6 January 2008	-26.0%	(-34.0%	-17.0%)	<0.001	1.01	0.42

Table S7 – Estimated effects of proactive culling on the incidence of confirmed cattle TB breakdowns up to 2km outside the trial area boundary . Analyses adjust for triplet, baseline herds, and historic TB incidence (over three years). Results split by cull sequence during-trial and by year post-trial and include breakdowns from the initial cull to 6 January 2008 . During-trial results include all confirmed breakdowns from the initial proactive cull (in each triplet) to one year after the last proactive cull (in each triplet) and use the January 07 data download as reported in the ISG Final Report. The post-trial results include all reported confirmed breakdowns from one year after the last proactive cull (in each triplet) to 6 January 2008 and use the download from 6 January 2008. All results are based on locations from the RBCT database .

	Proactive effect				Overdispersion	
	estimate	95% CI		p-value	factor	p-value
1st to 2nd cull	63.5%	(-1.7%	171.9%)	0.058	1.05	0.30
2nd to 3rd cull	36.0%	(-17.5%	124.4%)	0.23		
3rd to 4th cull	4.9%	(-39.4%	81.7%)	0.86		
After 4th cull to end of during-trial period	36.6%	(-4.1%	94.6%)	0.084		
First year of post-trial period	-24.1%	(-54.8%	27.6%)	0.30		
Second year of post-trial period	-40.9%	(-77.2%	53.4%)	0.28		
All during-trial period combined	35.3%	(5.8%	73.0%)	0.016	1.00	0.44
All post-trial period combined (1st and 2nd year combined)	-50.9%	(-75.1%	-3.5%)	0.039	0.90	0.58
1st cull to 6 January 2008	19.7%	(-1.9%	46.2%)	0.077	0.91	0.56

Table S8 – Estimated effects of proactive culling on the incidence of confirmed cattle TB breakdowns inside trial areas and up to 2km outside the trial area boundary . Analyses adjust for triplet, baseline herds, and historic TB incidence (over three years). Results split by distance from the trial area boundary and include breakdowns from the initial cull to 6 January 2008 . During-trial results include all confirmed breakdowns from the initial proactive cull (in each triplet) to one year after the last proactive cull (in each triplet) and use the January 07 data download as reported in the ISG Final Report. The post-trial results include all reported confirmed breakdowns from one year after the last proactive cull (in each triplet) to 6 January 2008 and use the download from 6 January 2008. All results are based on locations from the RBCT database .

	Proactive effect				Overdispersion	
	estimate	95% CI		p-value	factor	p-value
Inside trial areas						
0-1km inside	-17.1%	(-33.1%	2.8%)	0.088		
1-2km inside	-23.2%	(-41.5%	0.6%)	0.055		
2-3km inside	-27.5%	(-48.0%	1.0%)	0.058	1.25	0.003
3-4km inside	-22.7%	(-50.8%	21.3%)	0.26		
4-5km inside	-82.6%	(-97.4%	14.1%)	0.068		
Up to 2km outside the trial area boundary						
0-0.5km outside	11.4%	(-23.5%	62.3%)	0.57		
0.5-1km outside	-8.6%	(-37.0%	32.5%)	0.63	1.17	0.035
1-1.5km outside	-3.0%	(-37.2%	49.8%)	0.89		
1.5-2km outside	29.5%	(-41.5%	186.6%)	0.52		

5. Results outside treatment areas

Trial area boundaries were delineated mainly along property boundaries, so that herds could in principle be classified unambiguously as located inside or outside the trial area. Treatment areas, within which culling was conducted, were slightly larger than trial areas, and were delineated according to the estimated boundaries of social group territories so that all badgers using farms inside the trial areas could be targeted. As a consequence, some culling was conducted on land immediately neighbouring trial areas, but outside their boundaries. Results in the main text reflect those based on areas inside and outside of trial area boundaries to give a conservative estimate of the effect in the areas up to 2km outside the boundaries (since some of this land was actually culled). Results shown here are based upon areas inside and outside of treatment area boundaries (Tables S9-11) and are based on locations in the VetNet database.

In the during-trial period there was a borderline significant (p=0.057) trend suggesting that incidence in herds on land neighbouring proactively culled trial areas (up to 2km outside trial area boundaries) was 24.5% higher (95% CI: 0.6% lower to 56.0% higher) than that among herds on land neighbouring survey-only trial areas[1]. In the same time period, if we further exclude any area that was up to 2km outside the trial area boundary but within the treatment area, there was a significant (p=0.040) effect indicating higher incidence in herds on land neighbouring proactively culled treatment areas (and within 2km of the trial area boundary) as compared to herds on land neighbouring survey-only treatment areas. Incidence was 29.3% higher outside treatment areas (95% CI: 1.1-65.3% higher).

[1] Results from the proactively culled trial areas relative to the survey-only trial areas were published in 2006[4] after 46.6 'triplet-years' of data had accumulated. The effect seen in the areas neighbouring proactively culled trial areas at that time indicated that incidence was 29% higher (95% CI: 5.0-58% higher) than on land neighbouring survey-only trial areas. This was a significant difference (p=0.015) and slightly stronger in magnitude than the effect seen at the end of the during-trial period due to a non-significant trend for the detrimental effect in neighbouring areas to decrease over time[5].

Table S9 – Estimated effects of proactive culling on the incidence of confirmed cattle TB breakdowns inside treatment areas. Analyses adjust for triplet, baseline herds, and historic TB incidence (over three years). Results split by cull sequence during-trial and by year post-trial and include breakdowns from the initial cull to 6 January 2008 . During-trial results include all confirmed breakdowns from the initial proactive cull (in each triplet) to one year after the last proactive cull (in each triplet) and use the January 07 data download as reported in the ISG Final Report. The post-trial results include all reported confirmed breakdowns from one year after the last proactive cull (in each triplet) to 6 January 2008 and use the download from 6 January 2008. All results are based on locations from the VetNet database .

	Proactive effect				Overdispersion	
	estimate	95% CI		p-value	factor	p-value
1st to 2nd cull	3.3%	(-27.3%	46.8%)	0.86		
2nd to 3rd cull	-6.6%	(-33.9%	32.1%)	0.70		
3rd to 4th cull	-34.4%	(-55.2%	-4.0%)	0.030	1.34	<0.001
After 4th cull to end of during-trial period	-26.5%	(-43.5%	-4.5%)	0.021		
First year of post-trial period	-42.5%	(-60.8%	-15.9%)	0.004		
Second year of post-trial period	-56.2%	(-77.3%	-15.6%)	0.014		
All during-trial period combined	-18.3%	(-25.9%	-9.9%)	<0.001	0.81	0.71
All post-trial period combined (1st and 2nd year combined)	-47.2%	(-58.6%	-32.6%)	<0.001	0.95	0.50
1st cull to 6 January 2008	-24.9%	(-32.4%	-16.7%)	<0.001	0.97	0.48

Table S10 – Estimated effects of proactive culling on the incidence of confirmed cattle TB breakdowns outside treatment areas and within 2km of the trial area boundary . Analyses adjust for triplet, baseline herds, and historic TB incidence (over three years). Results split by cull sequence during-trial and by year post-trial and include breakdowns from the initial cull to 6 January 2008 . During-trial results include all confirmed breakdowns from the initial proactive cull (in each triplet) to one year after the last proactive cull (in each triplet) and use the January 07 data download as reported in the ISG Final Report. The post-trial results include all reported confirmed breakdowns from one year after the last proactive cull (in each triplet) to 6 January 2008 and use the download from 6 January 2008. All results are based on locations from the VetNet database .

	Proactive effect				Overdispersion	
	estimate	95% CI		p-value	factor	p-value
1st to 2nd cull	52.0%	(-9.0%	153.9%)	0.11	1.30	0.017
2nd to 3rd cull	22.7%	(-22.7%	94.9%)	0.39		
3rd to 4th cull	20.4%	(-28.7%	103.2%)	0.49		
After 4th cull to end of during-trial period	26.0%	(-11.9%	80.3%)	0.21		
First year of post-trial period	-20.7%	(-50.7%	27.6%)	0.34		
Second year of post-trial period	-30.8%	(-71.6%	68.7%)	0.42		
All during-trial period combined	29.3%	(1.1%	65.3%)	0.040	1.31	0.10
All post-trial period combined (1st and 2nd year combined)	-26.2%	(-48.6%	5.9%)	0.099	1.01	0.41
1st cull to 6 January 2008	15.0%	(-6.8%	41.9%)	0.19	1.28	0.12

Table S11 – Estimated effects of proactive culling on the incidence of confirmed cattle TB breakdowns inside treatment areas and outside treatment areas and within 2km of the trial areas. Analyses adjust for triplet, baseline herds, and historic TB incidence (over three years). Results split by distance from the trial area boundary and include breakdowns from the initial cull to 6 January 2008. During-trial results include all confirmed breakdowns from the initial proactive cull (in each triplet) to one year after the last proactive cull (in each triplet) and use the January 07 data download as reported in the ISG Final Report. The post-trial results include all reported confirmed breakdowns from one year after the last proactive cull (in each triplet) to 6 January 2008 and use the download from 6 January 2008. All results are based on locations from the VetNet database.

	Proactive effect				Overdispersion	
	estimate	95% CI		p-value	factor	p-value
Inside treatment areas						
0-1km inside	-20.3%	(-34.8%	-2.5%)	0.027		
1-2km inside	-23.0%	(-41.5%	1.3%)	0.062		
2-3km inside	-33.2%	(-52.8%	-5.4%)	0.023	1.34	<0.001
3-4km inside	-30.8%	(-59.2%	17.3%)	0.17		
4-5km inside	-53.4%	(-87.8%	78.0%)	0.26		
Outside treatment areas and within 2km of the trial areas						
0-0.5km outside	-11.7%	(-37.6%	25.0%)	0.48		
0.5-1km outside	19.1%	(-10.1%	57.8%)	0.22	1.04	0.31
1-1.5km outside	2.5%	(-23.7%	37.7%)	0.87		
1.5-2km outside	12.4%	(-18.8%	55.6%)	0.48		

6. Correlation between estimates of effect by dista nce from the trial area boundary

It should be noted that because estimates of treatment effect for different distances inside the trial area boundary are correlated with each other (due to spatial proximity) the confidence intervals could be somewhat too narrow, However, detailed examination of the covariances and correlations between the estimates of treatment effect by distance showed that the correlations were very small and hence unlikely to substantially affect our confidence intervals.

Table S12 Variance-covariance matrix for parameter estimates for the proactive versus survey-only treatment effect by 1km bands inside the trial areas. All results are based on locations from the VetNet database . Diagonal entries are variances of the estimated treatment effect in each stratum and off-diagonal entries are the covariances between the estimated treatment effects in two strata.

	0-1km inside	1-2km inside	2-3km inside	3-4km inside	4-5km inside
0-1km inside	0.0071				
1-2km inside	0.00021	0.011			
2-3km inside	-0.000021	0.000017	0.018		
3-4km inside	-0.000041	0.0000076	0.00024	0.041	
4-5km inside	0.000015	0.00021	0.00014	-0.00019	0.26

Table S13 Correlation matrix for parameter estimates for the proactive versus survey-only treatment effect by 1km bands inside the trial areas. All results are based on locations from the VetNet database . These correlations are calculated directly from the variances and covariances in table S12.

	0-1km inside	1-2km inside	2-3km inside	3-4km inside	4-5km inside
0-1km inside	1				
1-2km inside	0.023	1			
2-3km inside	-0.002	0.001	1		
3-4km inside	-0.002	0.000	0.009	1	
4-5km inside	0.000	0.004	0.002	-0.002	1

Table S14 Variance-covariance matrix for parameter estimates for the proactive versus survey-only treatment effect by 0.5km bands up to 2km outside the trial area boundary. All results are based on locations from the VetNet database . Diagonal entries are variances of the estimated treatment effect in each stratum and off-diagonal entries are the covariances between the estimated treatment effects in two strata.

	0-0.5km inside	0.5-1km inside	1-1.5 inside	1.5-2km inside
0-0.5km inside	0.0071			
0.5-1km inside	0.00021	0.011		
1-1.5km inside	-0.000021	0.000017	0.018	
1.5-2km inside	-0.000041	0.0000076	0.00024	0.041

Table S15 Correlation matrix for parameter estimates for the proactive versus survey-only treatment effect by 0.5km bands up to 2km outside the trial area boundary. All results are based on locations from the VetNet database . These correlations are calculated directly from the variances and covariances in table S14.

	0-0.5km inside	0.5-1km inside	1-1.5 inside	1.5-2km inside
0-0.5km inside	1			
0.5-1km inside	0.023	1		
1-1.5km inside	-0.002	0.001	1	
1.5-2km inside	-0.002	0.000	0.009	1

7. Effect of parish testing interval on the post tr ial results

Under routine surveillance, testing intervals are defined at the parish level according to the local baseline incidence of cattle TB. In the course of the RBCT, all herds inside the trial areas were assigned to one-year testing, but this was not required after the end of the trial and some herds had been moved over to longer testing intervals by January 2008 (i.e. during the post-trial period). As proactive culling had reduced cattle TB incidence inside culling areas, re-assignment of testing intervals could potentially have affected the herds inside proactive areas more than those inside survey-only areas, and could potentially induce a transient bias making the proactive treatment appear to be experiencing lower incidence because fewer herd tests were being performed. To test this hypothesis, we looked for a difference between treatments (proactive versus survey-only) in terms of the proportion of herds still on annual testing (as of 6 January 2008), adjusting for triplet. Parallel analyses also adjusted for the log of the incidence in the three years prior to the initial cull in that triplet and the number of herds in that trial area at the start of the RBCT. There was no significant difference between the proportions of herd on annual testing between the two treatments inside the trial areas or in the areas up to 2km outside trial areas (Table S16).

In the areas up to 2km outside the trial areas, there was a non-significant trend for the herds on land neighbouring proactively culled trial areas to have a higher proportion of herds on annual testing (as of 6 January 2008) than herds on land neighbouring survey-only areas (Table S16). This would be expected since a higher incidence in cattle herds on land neighbouring proactively culled trial areas was observed during the RBCT and this would have influenced the testing intervals applied to these herds (note that while all herds inside trial areas were put onto annual testing during the RBCT, the herds on land neighbouring trial areas had testing intervals which were adjusted in response to local breakdown incidence rates in line with national practice). The fact that the trend is for herds on land neighbouring proactive areas to be more likely to be on annual testing (as of 6 January 2008), than herds on land neighbouring survey-only areas, indicates that differences in testing intervals were not responsible for the apparently lower incidence observed among herds on land neighbouring proactively culled trial areas, relative to those on land neighbouring survey only areas, observed in the post-trial period.

Table S16 The odds ratios comparing the proportions of herds on annual testing as of 6 January 2008 between proactive and survey-only trial areas

	Odds ratio (proactive compared to survey only)			Overdispersion	
	odds ratio	95% CI	p-value	factor	p-value
Inside trial areas					
Adjusting for triplet	0.99	(0.68 1.44)	0.95	1.77	<0.001
Adjusting for triplet, past incidence and baseline herds	1.05	(0.74 1.49)	0.78	1.61	0.012
Up to 2km outside the trial area boundary					
Adjusting for triplet	1.33	(0.87 2.03)	0.19	1.88	<0.001
Adjusting for triplet, past incidence and baseline herds	1.47	(0.92 2.36)	0.11	1.88	<0.001

In fact, there was a similar non-significant trend for the herds on land neighbouring proactively culled trial areas to have a higher proportion of herds on annual testing at the start of the RBCT (the initial proactive cull in each triplet) than herds on land neighbouring survey-only areas (Table S17). Note the considerable overdispersion apparent in these data. However, these differences in testing intervals did not generate the elevated incidence observed among herds on land neighbouring proactively culled trial areas, relative to those on land neighbouring survey only areas, observed in the during-trial period. After adjustment for the log-transformed proportion of herds on annual testing at the start of the RBCT, the incidence of confirmed cattle herd breakdowns estimated to be 24% higher (95% CI: 3.8% lower to 59% higher, p=0.097) on land neighbouring proactive areas than that on land neighbouring survey-only trial areas. Furthermore, there was no evidence of an interaction between the proactive treatment effect (among herds on land neighbouring trial areas in the during trial period) and the log-transformed proportion of herds on annual testing at the start of the RBCT (p=0.93).

Table S17 The odds ratios comparing the proportions of herds on annual testing as of the initial cull in each triplet between proactive and survey-only trial areas in areas up to 2km outside the trial area boundary

	Odds ratio (proactive compared to survey only)			Overdispersion	
	odds ratio	95% CI	p-value	factor	p-value
Adjusting for triplet	1.60	(0.61 4.21)	0.34	3.17	<0.001
Adjusting for triplet, past incidence and baseline herds	2.17	(0.75 6.24)	0.15	2.97	<0.001

8. Further investigation of post-trial results usin g the VetNet and RBCT databases

Treatment effects seen using the VetNet database and the RBCT database in the areas up to 2km outside trial areas, while in the same direction, were somewhat different in size. With both databases, there was a trend in the post-trial period towards lower incidence on lands neighbouring proactively culled trial areas than on lands neighbouring survey-only areas. Using the VetNet database, this effect was 22.7% lower (95% CI: 44.3% lower to 7.3% greater) and using the RBCT database, 50.9% lower (95% CI: 75.1% to 3.5% lower). To investigate the robustness of these analyses, we stratified by distance from the trial area boundary and forced the slope associated with the natural logarithm of the number of baseline herds (adjusted for in the regression) to equal 1 (by setting it to be an "offset"). We compared these results to those seen in which the slope associated with the natural logarithm of the number of baseline herds was estimated within the regression.

Tables S18 and S19 show results using the VetNet and RBCT databases respectively. Results using the VetNet database appear robust; overall results are consistent with those seen in the main analyses and overall results are within the range of those obtained from the distance-stratified analyses. Results using the RBCT database to identify herds inside trial areas are similarly consistent. However, results for lands outside but neighbouring trial areas are less so. The overall result outside trial areas using the RBCT database (25.1% lower incidence) is now more consistent with estimates obtained using the VetNet database (22.7% or 22.2% lower incidence, Table 2 of the main text and Table S16, respectively) than that obtained using RBCT database without specifying an offset (50.9% lower incidence, Table S6). Furthermore, among the models with number of baseline herds to be an offset fitted using the RBCT database, the overall result outside trial areas (25.1% lower incidence) is outside the range of estimates obtained from the distance-stratified analyses (34.3% to 48.5% lower incidence) potentially suggesting a source of variation unexplained by the model. Thus, we conclude for the areas outside trial areas that the results obtained using the VetNet database are most reliable.

Table S18 – Estimated effects of proactive culling on the incidence of confirmed cattle TB breakdowns inside trial areas and outside trial areas and within 2km of the trial are as. Analyses adjust for triplet, baseline herds, and historic TB incidence (over three years) and set the number of baseline herds to be an offset (i .e. with the slope forced to equal 1) . Results split by distance from the trial area boundary and include breakdowns from one year after the last proactive cull to 6 Ja nuary 2008 . These post-trial results include all reported confirmed breakdowns from one year after the last proactive cull (in each triplet) to 6 January 2008 and use the download from 6 January 2008. All results are based on locations from the VetNet database .

	Proactive effect				Overdispersion	
	estimate	95% CI		p-value	factor	p-value
Inside trial areas						
0-1km inside	-28.4%	(-52.8%	8.7%)	0.12		
1-2km inside	-48.9%	(-70.8%	-10.7%)	0.018		
2-3km inside	-67.1%	(-83.8%	-33.1%)	0.002	1.12	0.073
3-4km inside	-27.9%	(-71.2%	80.7%)	0.49		
4-5km inside	-70.4%	(-97.7%	278.3%)	0.35		
Overall	-45.7%	(-63.3%	-19.6%)	0.002	1.45	0.032
Outside trial areas and within 2km of the trial are as						
0-0.5km outside	-16.9%	(-54.5%	51.9%)	0.55		
0.5-1km outside	-40.3%	(-65.5%	3.4%)	0.066	1.01	0.45
1-1.5km outside	-27.6%	(-60.7%	33.4%)	0.30		
1.5-2km outside	-15.3%	(-55.2%	60.3%)	0.064		
Overall	-22.2%	(-40.3%	1.5%)	0.064	0.86	0.66

Table S19 – Estimated effects of proactive culling on the incidence of confirmed cattle TB breakdowns inside trial areas and outside trial areas and within 2km of the trial are as. Analyses adjust for triplet, baseline herds, and historic TB incidence (over three years) and set the number of baseline herds to be an offset (i.e. with the slope forced to equal 1). Results split by distance from the trial area boundary and include breakdowns from one year after the last proactive cull to 6 January 2008. These post-trial results include all reported confirmed breakdowns from one year after the last proactive cull (in each triplet) to 6 January 2008 and use the download from 6 January 2008. All results are based on locations from the RBCT database.

	Proactive effect				Overdispersion	
	estimate	95% CI		p-value	factor	p-value
Inside trial areas						
0-1km inside	-35.5%	(-56.9%	-3.7%)	0.032		
1-2km inside	-57.1%	(-76.5%	-21.8%)	0.006		
2-3km inside	-55.9%	(-76.2%	-18.4%)	0.009	1.05	0.27
3-4km inside	-59.2%	(-83.9%	3.1%)	0.058		
4-5km inside	-53.4%	(-96.2%	477.1%)	0.55		
Overall	-46.4%	(-63.8%	-20.7%)	0.002	1.48	0.025
Outside trial areas and within 2km of the trial are as						
0-0.5km outside	-34.4%	(-73.2%	61.0%)	0.36		
0.5-1km outside	-34.3%	(-69.7%	42.7%)	0.28	1.12	0.084
1-1.5km outside	-37.4%	(-76.8%	69.1%)	0.36		
1.5-2km outside	-48.5%	(-88.9%	139.0%)	0.40		
Overall	-25.1%	(-56.0%	27.4%)	0.29	1.15	0.23

9. Change in overall effects with size of culled area assuming constant effect across the trial area

In the main text, we estimated that the 95% confidence interval for the average effect across the entire affected area only excluded detrimental effects when culling targeted circular areas of 119 km^2 or more (taking into account the estimated detrimental effect in areas neighbouring the targeted areas and the estimated beneficial effects inside). This estimated area assumed a linear trend for the effect of culling to vary with distance from the boundary of the targeted area (going deeper inside the targeted area). Here we show parallel analyses assuming a constant effect of culling across the targeted area (see Figure S2). The effects of five annual proactive culls are predicted to be, on average, beneficial over the period following the initial proactive cull (during-trial and post-trial periods combined) across the entire affected area (the targeted area and the neighbouring area) for culling targeted at circular areas larger than 18 km^2 (Figure S2) and the 95% confidence interval for the average effect across the entire affected area only excluded detrimental effects for culling targeted at circular areas of 110 km^2 or more.

Figure S2 – Effects of varying the size of the area targeted for badger culling on the projected impacts on confirmed cattle TB incidence. Red shading shows the 95% confidence interval for the overall impact (combining the impacts inside and up to 2km outside the targeted area) of culling targeted at circular areas of different sizes; blue shading shows the impact inside the targeted area only. The estimated overall effect is for increased incidence when culling targets areas less than 18km^2, moving to a decreased incidence when areas of more than 18km^2 are targeted. The effect of decreased overall incidence is statistically significant for areas over 110km^2. Likewise, on average culling is expected to lead to an overall reduction in cattle TB incidence of 10% if targeted at areas larger than 88km^2, with the expected reduction significantly greater than 10% for areas over 443km^2.

10. Land access with the proactive trial areas

The following is reproduced and adapted from the supplementary information to Donnelly, C.A., Wei, G., Johnston, W.T., Cox, D.R., Woodroffe, R., Bourne, F.J., Cheeseman, C.L., Clifton-Hadley, R.S., Gettinby, G., Gilks, P., Jenkins, H.E., Le Fevre, A.M., McInerney, J.P. and Morrison, W.I. Impacts of widespread badger culling on cattle tuberculosis: concluding analyses from a large-scale field trial. Int J Infect Dis. 11(4): p. 300-8 (2007).

There were three levels of consent for landholders enrolled in the RBCT: consent for surveying and culling ('culling' land), consent for surveying but not culling ('survey' land) and refusal of all access ('refusal' land). Additionally, each trial area contained land for which no landholder could be identified ('unsigned' land).

The complete data on consent for each land parcel and/or cattle herd at the outset of the RBCT are no longer available. As landholders were able to change consent status at any point during the RBCT, the databases (either tabular or GIS) were designed to reflect these changes, with the data field recording consent being overwritten with each change in consent status. This was accomplished within the database by associating a date with the consent recorded for the landholder. Thus, in any given snapshot of the data there would be four classes of landholders:

1. landholders that were present at the outset of the RBCT and have not changed consent since the initial proactive cull (i.e. the date the landholder was enrolled to the RBCT and the date associated with the consent are both before the initial proactive cull)
2. landholders that were present at the outset of the RBCT and did change consent since the initial proactive cull (i.e. the date the landholder was enrolled to the RBCT was before the initial proactive cull but the date associated with the consent was after the initial proactive cull)

3. landholders that were enrolled after the start of the RBCT and have not changed consent (i.e. the date the landholder was enrolled to the RBCT was after the initial proactive cull and the date associated with the consent was 14 days after the date of enrolment)
4. landholders that were enrolled after the start of the RBCT and did change consent (i.e. the date the landholder was enrolled to the RBCT was after the initial proactive cull and the date associated with the consent was >14 days after the date of enrolment)

As changes to consent are relatively rare (approximately 2% of landholders per year changed consent between March 2003 and March 2005), a reasonable approximation of the initial consent status of most landholders may be constructed using the information from the earliest available snapshot (April 2001). Using this approach, 5955 of the landholders listed in the RBCT database as being inside the trial area boundaries were assigned their original consent status whereas only 79 landholders appeared to have changed consent (numbers of landholders are totalled for all treatments).

The land area attributed to each landholder was recorded in a GIS database; the earliest information available dated from Nov 2002. Consent was assigned to land parcels according to the consent recorded for the listed landholder as of April 2001, or if the landholder was not listed in April 2001, the consent as recorded in Jan 2003 (the next earliest available data). No later consent information was considered. All land parcels within the treatment areas of the triplets not attributed to a landholder as of Nov 2002 were recorded as ‘unsigned’.

As for previous analyses of cattle herd TB incidence, two alternative datasets were used. The first comprised those herds that were attributed to landholders in the database maintained for the study; these are designated ‘RBCT herds’. The second dataset included herds for which the point coordinate recorded with their herd record in the State Veterinary Service’s VetNet system mapped inside RBCT trial areas; these are designated ‘VetNet herds’. These two datasets overlapped considerably; however, each identified herds not contained within the other.

Consent was assigned to RBCT herds on the basis of the April 2001 database snapshot. Landholders that were enrolled to the trial after April 2001 were assigned the consent recorded for them in the first of the quarterly database snapshots (commencing in Jan 2003) in which they appeared (unless there was evidence of a change to their consent status between the date they were enrolled and the date of the snapshot in which case, the change was noted). The consent status of VetNet herds was determined by the consent of the location within the trial areas where the herd mapped.

The herds within these strata could be resolved based on their consent and whether there was evidence of a change of consent into five categories:

- Cull – where the herd was associated with 'cull' land and there was no evidence of change in consent following the initial proactive cull;
- Change to Cull – where the herd was associated with 'cull' land but there was evidence of change in consent following the initial proactive cull;
- Survey or Refusal – where the herd was associated with 'survey' or 'refusal' land and there was no evidence of change in consent following the initial proactive cull;
- Change to Survey or Refusal – where the herd was associated with 'survey' or 'refusal' land but there was evidence of change in consent following the initial proactive cull;
- Unsigned – where the herd was associated with 'unsigned' land (by definition, only VetNet herds could be classified as unsigned)

We consolidated these five strata conservatively by assuming that any herds recorded as having switched to survey or refusal following their initial cull had allowed culling at the time of the initial cull. Similarly, we assumed that any herds recorded as having switched to cull following their initial cull were either survey or refusal at the time of the initial cull. This allows stratification of land (and thus associated herds) into three categories:

- Accessible – a combination of the ‘Cull’ and ‘Change to Survey or Refusal’ categories.
- Inaccessible - Survey or Refusal combined – a combination of the ‘Survey or Refusal’ and ‘Change to Cull’ categories.
- Inaccessible - Unsigned – as before.

The areas within the trial area boundaries accessible and inaccessible for culling are presented in Table S20 in line with the following definitions:

- Accessible – herds with ‘cull’ consent since the start of the RBCT or those that had changed to either ‘survey’ consent or ‘refusal’ consent.
- Inaccessible – herds with ‘survey’, ‘refusal’ or ‘unsigned’ consent status at the outset of the RBCT or that had changed to ‘cull’ consent.

The proportion of inaccessible land within proactive trial areas varied from 15% to 50% (30% overall; Table S20) with 73% of inaccessible land falling within 200m of accessible land.

Table S20 – Areas of accessible and inaccessible land within trial area boundaries of each proactive trial area.

Proactive treatment area	Initial cull date	Total trial area (km^2)	Accessible land area (km^2) (% of trial area)	Inaccessible land area (km^2) (% of trial area)
A	Jan 2000	95.7	76.1	19.6
			80%	20%
B	Dec 1998	99.8	86.6	13.3
			87%	13%
C	Oct 1999	105.1	85.9	19.2
			82%	18%
D	Dec 2002	98.8	72.2	26.6
			73%	27%
E	May 2000	105.2	66.5	38.8
			63%	37%
F	Jul 2000	95.7	48.8	46.8
			51%	49%
G	Nov 2000	101.9	66.8	35.1
			66%	34%
H	Dec 2000	95.3	60.8	34.5
			64%	36%
I	Sep 2002	99.8	62.7	37.1
			63%	37%
J	Oct 2002	100.7	75.6	25.1
			75%	25%
Total		998.1	702.0	296.0
			70%	30%

11. References

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