**Results from the Randomised Badger Culling Trial
based on data downloaded in July 2013**

Summary:

In the time period from one year after the last proactive cull to 28 March 2013 (the post-trial period), the incidence of <u>confirmed</u> breakdowns **in the proactive culling areas** was 25.9% lower (95% CI: 10.9% to 38.4% lower) than in survey-only areas and in areas up to 2km outside proactive trial areas was 6.8% lower (95% CI: 31.2% lower to 26.4% higher) than in areas up to 2km outside survey-only areas. Analyses stratified by 6-month periods indicate that beneficial effects within trial areas remain in the latest 6-month period analysed (73 to 78 months post-trial). These latest results are consistent with a benefit of proactive culling which diminished but continued, albeit at a non-significant level, through this latest period (test for temporal trend p=0.034). However, the effects observed outside trial areas are consistent with no ongoing effects of proactive culling in these areas.

The post-trial results regarding **the effects of proactive culling** on <u>confirmed</u> breakdowns must, of course, be considered in the context of the smaller reduction seen inside proactive trial areas and the increased incidence seen outside proactive trial areas in the period from the end of the initial proactive cull until one year after the last proactive cull in each triplet.

In the time period from one year after the last proactive cull to 28 March 2013 (the post-trial period), the incidence of <u>unconfirmed</u> breakdowns **in the proactive culling areas** was 0.21% higher (95% CI: 27.4% lower to 38.3% higher) than in survey-only areas and in areas up to 2km outside proactive trial areas was 7.6% lower (95% CI: 39.9% lower to 42.1% higher) than in areas up to 2km outside survey-only areas.

Finally, in the time period from one year after the last proactive cull to 28 March 2013 (the post-trial period), well after the final reactive culling was undertaken in 2003, the incidence of <u>confirmed</u> breakdowns **in the reactive culling** areas was 8.2% lower (95% CI: 26.4% lower to 14.5% higher) than in survey-only areas.

Introduction:

In February 2010, Jenkins *et al.* published results (*PLoS ONE* 2010) for the period up to approximately 36 months starting one year after the last proactive cull (the "post-trial period"; 29.3 triplet-years). These 2010 results showed that benefits inside culled areas (in terms of confirmed breakdowns) diminished over time, and were no longer detectable by three years post-trial. On adjoining lands, a trend suggesting beneficial effects immediately after the end of culling was insignificant, and disappeared after 18 months post-trial. These results were updated online in May 2010 and subsequently, as comments attached to the *PLoS ONE* paper. These updated results, based on approximately additional 6 months of data in each case, indicated that the beneficial effects observed early post-trial within trial areas had reappeared.

Here I report results from the analysis of data from the end of the initial proactive cull up to 28 March 2013.

Methods:

Statistical methods were as previously published (Donnelly *et al. Nature* 2006, Donnelly *et al. IJID* 2007, ISG Final Report 2007, Jenkins *et al. IJID* 2008, Jenkins *et al. PLoS ONE* 2010). Log-linear Poisson regression was used to compare the numbers of confirmed breakdowns inside, and up to 2km outside, the proactive areas with those in and around the matched survey-only areas. Such analyses were also undertaken for unconfirmed breakdowns. Finally, an analysis was undertaken based on confirmed breakdowns inside the reactive areas with those in the matched survey-only areas. Cattle herd locations were taken from the national animal health information system obtained from the Animal Health and Veterinary Laboratories Agency (AHVLA) as of 28 August 2011.

As in Jenkins *et al.* 2010, the period from the end of the initial proactive cull in each triplet to a date one year after the last proactive cull in that triplet was defined as the "during-trial" period. This period totalled 55.7 triplet-years. Analyses also covered the period from the end of the during-trial period to 28 March 2013; this was called the "post-trial" period. The post-trial period consisted of 66.6 triplet-years.

Following estimation of effects of proactive culling on confirmed breakdowns by six-month interval in the post-trial period, I used weighted least squares regression to fit a linear trend (on a log scale) to the effects inside trial areas and tested this trend against the null hypothesis of no trend.

I also calculated the weighted average impact of proactive culling on confirmed breakdowns for a range of circular culling areas assuming the same baseline incidence and the same herd density in the culling area and up to 2km outside the culling area.

Results:

Results of proactive culling on confirmed breakdowns

In the post-trial period to 28 March 2013, the incidence of <u>confirmed</u> breakdowns inside the proactive trial areas was 25.9% lower (95% CI: 10.9% to 38.4% lower) than that inside survey-only trial areas. Analyses stratified by 6-month periods indicate that beneficial effects within trial areas remain in the latest 6-month period analysed (73 to 78 months post-trial). These latest results are consistent with an ongoing, but diminishing, benefit of proactive culling continuing through this latest period (test for temporal trend p=0.034).See table 1 and figure 1 for proactive results from inside trial areas.

In the post-trial period to 28 March 2013, the incidence of <u>confirmed</u> breakdowns was 6.8% lower (95% CI: 31.2% lower to 26.4% higher) in areas up to 2km outside proactive trial areas than on lands up to 2km outside survey-only areas. Dividing the post-trial period into 6 monthly periods, the effects observed outside trial areas are consistent with no ongoing effects of proactive culling on these adjoining lands. See table 2 and figure 1 for proactive results from outside trial areas.

In summary, these latest results are consistent with an ongoing, but diminishing, post-trial benefit of proactive culling on <u>confirmed</u> breakdowns inside proactive trial areas continuing up to 7.5 years after the final proactive culls. (Note that 78 months (6.5 years) post-trial is equivalent to 7.5 years after the final proactive culls.)

Assuming 5 years of annual proactive culls and an additional 6.5 years of time, the smallest circular area for which the 95% confidence interval for the overall effect excludes zero is 102km^2. See figure 2.

Results of proactive culling on unconfirmed breakdowns

In the time period from one year after the last proactive cull to 28 March 2013 (the post-trial period), the incidence of <u>unconfirmed</u> breakdowns in the proactive culling areas was 0.21% higher (95% CI: 27.4% lower to 38.3% higher) than in survey-only areas and in areas up to 2km outside proactive trial areas was 7.6% lower (95% CI: 39.9% lower to 42.1% higher) than in areas up to 2km outside survey-only areas.

Results of reactive culling on confirmed breakdowns

In the time period from one year after the last proactive cull to 28 March 2013 (the post-trial period), well after the final reactive culling was undertaken in 2003, the incidence of <u>confirmed</u> breakdowns **in the reactive culling** areas was 8.2% lower (95% CI: 26.4% lower to 14.5% higher) than in survey-only areas.

Further work:

Further analysis may be undertaken to explore further how long the estimated effect lasts.

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Imperial College London, 16 October 2013

Table 1 Estimated effects of proactive culling on the incidence of <u>**confirmed**</u> 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 6-month period post-trial and include breakdowns **from the end of the initial proactive cull to 28 March 2013**. During-trial results include all breakdowns from the end of 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 in the ISG Final Report. The post-trial results include all reported breakdowns from one year after the last proactive cull (in each triplet) to 28 March 2013 and use the download from July 2013.

	Triplet years	Proactive effect			Overdispersion	
		estimate	95% CI		p-value	Factor	p-value
1st to 2nd cull	12.6	-2.1%	(-29.1% | 35.2%)	0.90		
2nd to 3rd cull	13.2	-11.3%	(-35.2% | 21.3%)	0.45		
3rd to 4th cull	8.4	-37.0%	(-55.6% | -10.7%)	0.009		
After 4th cull to end of during-trial period	21.5	-29.6%	(-45.0% | -9.8%)	0.005		
Months 1-6 of the post-trial period	5.0	-49.3%	(-68.7% | -18.0%)	0.006		
Months 7-12 of the post-trial period	5.0	-32.1%	(-57.3% | 8.1%)	0.103		
Months 13-18 of the post-trial period	5.0	-49.8%	(-67.3% | -22.8%)	0.002		
Months 19-24 of the post-trial period	5.0	-23.8%	(-48.6% | 12.8%)	0.17		
Months 25-30 of the post-trial period	5.0	-29.0%	(-54.0% | 9.6%)	0.12	1.17	<0.001
Months 31-36 of the post-trial period	5.0	-10.9%	(-41.9% | 36.6%)	0.60		
Months 37-42 of the post-trial period	5.0	-25.9%	(-50.5% | 10.8%)	0.14		
Months 43-48 of the post-trial period	5.0	-20.0%	(-49.2% | 26.1%)	0.34		
Months 49-54 of the post-trial period	5.0	-18.9%	(-47.6% | 25.8%)	0.35		
Months 55-60 of the post-trial period	5.0	-21.2%	(-48.0% | 19.4%)	0.26		
Months 61-66 of the post-trial period	5.0	-16.5%	(-43.0% | 22.5%)	0.36		
Months 67-72 of the post-trial period	5.0	-30.1%	(-54.6% | 7.8%)	0.11		
Months 73-78 of the post-trial period	4.8	-22.7%	(-50.8% | 21.4%)	0.26		
All during-trial period combined	55.7	-23.2%	(-32.7% | -12.4%)	<0.001	0.67	0.87
All post-trial period combined	66.6	-25.9%	(-38.4% | -10.9%)	0.001	1.74	0.003

Table 2 Estimated effects of proactive culling on the incidence of <u>**confirmed**</u> 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, by 6-month period post-trial and include breakdowns **from the end of the initial proactive cull to 28 March 2013**. During-trial results include all breakdowns from the end of 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 in the ISG Final Report. The post-trial results include all reported breakdowns from one year after the last proactive cull (in each triplet) to 28 March 2013 and use the download from July 2013.

	Triplet years	Proactive effect			Overdispersion	
		estimate	95% CI		p-value	Factor	p-value
1st to 2nd cull	12.6	40.3%	(-6.9% | 111.6%)	0.11		
2nd to 3rd cull	13.2	19.9%	(-18.5% | 76.3%)	0.36		
3rd to 4th cull	8.4	15.8%	(-24.2% | 77.0%)	0.50		
After 4th cull to end of during-trial period	21.5	12.2%	(-15.1% | 48.2%)	0.42		
Months 1-6 of the post-trial period	5.0	-18.46%	35.53%	-50.94%	0.43		
Months 7-12 of the post-trial period	5.0	-31.31%	23.91%	-61.92%	0.21		
Months 13-18 of the post-trial period	5.0	-21.60%	28.85%	-52.30%	0.34		
Months 19-24 of the post-trial period	5.0	32.74%	111.98%	-16.88%	0.24		
Months 25-30 of the post-trial period	5.0	5.59%	76.21%	-36.73%	0.84	1.13	0.004
Months 31-36 of the post-trial period	5.0	-5.39%	61.24%	-44.48%	0.84		
Months 37-42 of the post-trial period	5.0	11.63%	87.65%	-33.59%	0.68		
Months 43-48 of the post-trial period	5.0	-11.21%	45.09%	-45.67%	0.64		
Months 49-54 of the post-trial period	5.0	-2.21%	59.67%	-40.10%	0.93		
Months 55-60 of the post-trial period	5.0	-9.36%	49.40%	-45.01%	0.70		
Months 61-66 of the post-trial period	5.0	7.00%	71.04%	-33.06%	0.78		
Months 67-72 of the post-trial period	5.0	34.61%	126.58%	-20.03%	0.26		
Months 73-78 of the post-trial period	4.8	15.35%	96.10%	-32.15%	0.60		
All during-trial period combined	55.7	24.5%	(-0.6% | 56.0%)	0.057	1.26	0.13
All post-trial period combined	66.6	-6.8%	(-31.2% | 26.4%)	0.65	2.28	<0.001

Figure 1 Estimated effects of proactive culling on the incidence of confirmed cattle TB breakdowns inside trial areas and up to 2 km outside trial area boundaries. The estimated effects of proactive culling are stratified by time periods defined by the timings of the culls during the trial, and by 6-month periods from 1 year after the last proactive cull (post-trial period). The black line shows the estimated effects inside the trial areas and the dotted red line shows the estimated effects in the neighbouring areas. These figures are also shown in Tables 1 and 2. The green line shows a fitted trend.
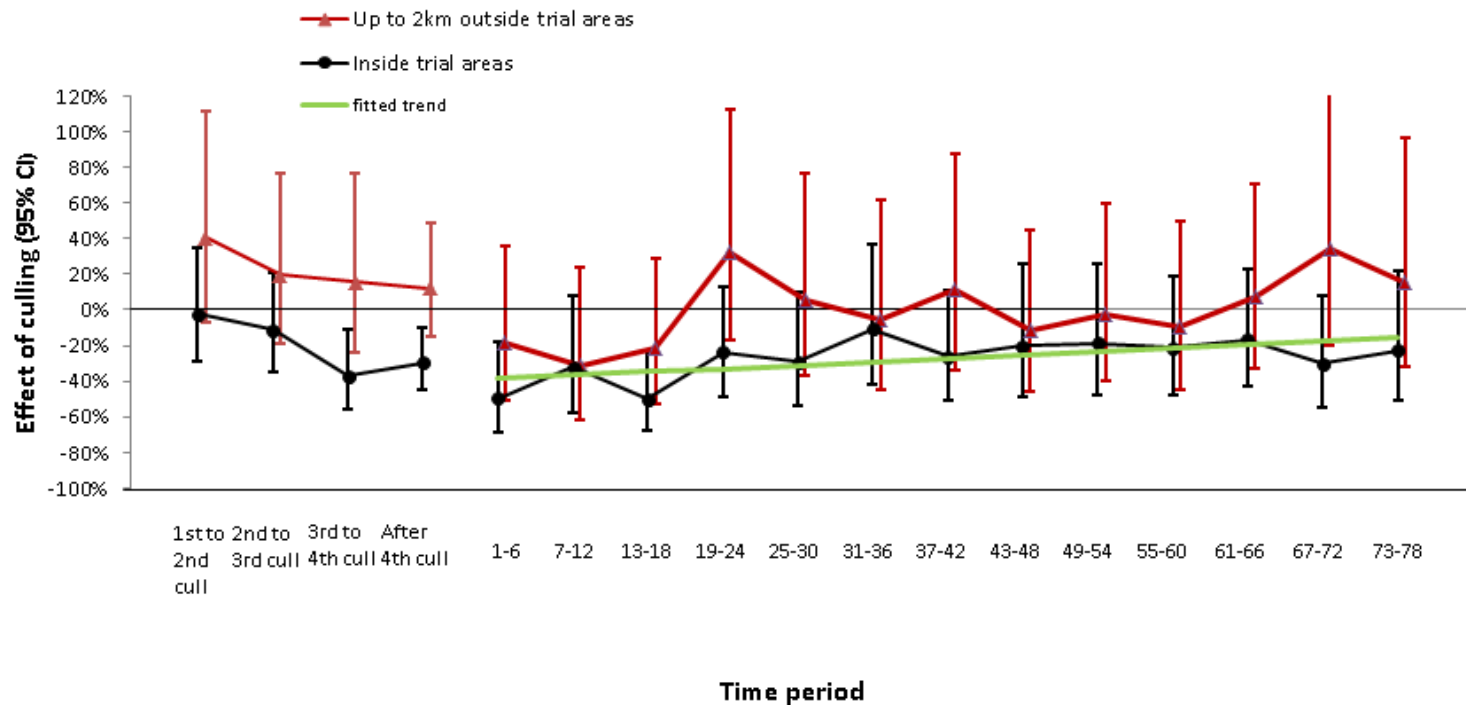
Figure 2 The net percentage change in the number of confirmed herd breakdowns inside and within 2km outside of circular culling areas up to 600km² in size. This takes into account the estimated impacts during trial and post trial both inside and within 2km outside of the culling area and the uncertainty associated with these estimates.