Animal & Plant Health Agency

Report of the incidence of bovine tuberculosis in cattle in 2014 - 2015 in the areas of Somerset and Gloucestershire exposed to two years of industry-led badger control

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Executive Summary

Purpose of the report

In 2013, badger culling licences were issued for two areas in England to groups of farmers and landowners for the purpose of preventing the spread of bovine tuberculosis. The policy was implemented with an aim of reducing the population of badgers, a known carrier of bovine tuberculosis (bTB), thereby reducing the potential for transmission between badgers and cattle, and therefore aiming for a subsequent reduction in bTB incidence in cattle. The purpose of this report is to provide an assessment of any association between the intervention and bTB incidence in cattle.

Methodology

Using routinely collected surveillance data, bTB incidence has been assessed in cattle herds located within the areas where industry-led culling is conducted (so called “intervention” areas), and compared to bTB in herds in ten comparison areas matched on key characteristics that affect bTB risk. The incidence of bTB in cattle has also been monitored in 2 km buffer areas surrounding the intervention areas and compared to incidence in similarly defined areas around the comparison areas. All areas have been compared for the three years prior to culling and the first two years since culling began. It is expected that there will be a time lag between any effect due to badger removal leading to decreased transmission of infection and any observable reduction in bTB incidence in cattle. The primary outcome used to compare the two areas was incidence per 100 herd years at risk. An average incidence rate was calculated for the comparison areas.

Results

The analysis showed different distributions of bTB incidents in the two intervention areas over time. In Year 2 incidence rate was lower in the Gloucestershire intervention area than the average rate across its comparison areas (9.2 versus 12.4 respectively), but more similar in the Somerset intervention area to the average rate across its comparison areas (14.0 versus 14.4 respectively) following a decrease in incidence in the Somerset area over the last two years (Figure 1). There were no statistically significant differences in incidence rate between both the combined central intervention areas and their combined comparison areas or between the combined intervention buffers and their combined comparison buffer areas across all reporting periods.

Interpretation

Differences between intervention and comparison areas have been observed across all time periods, and so cannot be attributed to the intervention. It is estimated that in order to be likely to observe statistically significant differences in bTB incidence should they exist, matched intervention and comparison areas will need to be observed for at least three years after culling begins, and that this increases to four years if only two intervention areas are licenced (Donnelly et al 2015). Therefore, it is unlikely that any significant differences would be observed in the first two years of follow-up should they exist. Additionally, this analysis does not account for other factors that are likely to influence bTB incidence. Further exploration of such factors is needed to better understand differences between the areas.

Conclusions

The badger culls currently being conducted are industry-led and therefore the areas in which culling is carried out were selected by stakeholders. This purposive selection and subsequent lack of selection of controls represents the needs of industry, but results in difficulties in assessing if any changes observed provide evidence of a cause-effect relationship between badger culling and bTB incidence. As such, the results presented here should be interpreted with caution. Further work is underway to explore the impact of adjusting for other factors likely to influence bTB incidence on the estimates derived here, and it is likely that estimates will change once biases are accounted for.

Introduction

Badgers are a known host species for *Mycobacterium bovis* (the causative agent of bTB) and there has been considerable debate over the use of culling to control the transmission of bTB between this wildlife reservoir and cattle. The results of the Randomised Badger Culling Trial (RBCT) conducted in England between 1998 and 2007 indicated that the incidence of confirmed bTB in cattle could be reduced by 23.2% (95% CI: 12.4% to 32.7%) over a four year period if culling was performed systematically over large areas and sustained for at least four years (Donnelly et al 2007). Culling badgers was found to be associated with both positive and negative effects on bTB incidence.

In 2013, culling licences were issued for two areas in England by Natural England under the Protection of Badgers Act 1992 to enable groups of farmers and landowners to cull badgers for the purpose of preventing the spread of bovine tuberculosis (Defra 2012, 2013). Criteria that licencees were required to meet included: an application area to be at least 150 km^2, at least 70% of the land to be accessible for culling, cattle herds subject to annual bTB testing and reasonable biosecurity to be in place. In addition, culling should plan to reduce the estimated badger population by 70% and be conducted for a minimum of four years (Defra 2013). The first year of culling took place in west Somerset and west Gloucestershire between August and November 2013, and the second year took place in the same areas between August and October 2014. Using a combination of cage trapping and controlled shooting of badgers, 341 badgers were culled in Somerset and 274 were culled in Gloucestershire in 2014 (Defra 2014b). The minimum number of badgers to be culled in order to achieve approximately 70% reduction in the population in Year 2 was estimated to be between 316 and 435 for Somerset, and between 391 and 840 for Gloucestershire (Defra 2014a). The calculation of these numbers and the considerable uncertainty around the population estimates are described in the Defra policy paper on setting the minimum and maximum numbers for Year 2 (Defra 2014a).

Although industry-led culling is an intervention policy and not a robustly designed scientific experiment, a methodology has been developed to assess the association between the intervention and incidence of bTB in cattle in the areas subject to culling and a surrounding buffer. To enable an assessment of any association between the intervention and bTB incidence, comparison areas matched to the intervention areas but where no culling has taken place have been identified. The methodology for selecting comparison areas has been developed and reported under Defra project SE3131. The incidence of bTB in cattle in the intervention areas and comparison areas in the first two years since culling began is compared here.

Methods

The methodology applied and definitions used for this analysis are as reported for the first year of culling in Annex 1 of the England bTB surveillance report for 2014 (APHA 2015).

Using routinely collected surveillance data on bTB in cattle, bTB is being assessed in cattle herds located within areas where industry-led culling is conducted (so called “intervention” areas), and compared to bTB in herds in comparison areas matched on key characteristics that affect cattle bTB risk. The hypothesis is that there will be an association between badger culling and bTB incidence. The incidence of bTB in cattle is also being monitored in 2 km buffer areas surrounding the intervention areas and compared to incidence in similarly defined areas around comparison areas. The hypothesis of this comparison is that the disruption of badger populations caused by culling will lead to increased ranging behaviour which may influence bTB incidence in the 2 km buffer area outside of the cull areas. These hypotheses are based upon the findings of the RBCT (Donnelly et al 2006; Woodroffe et al 2006).

The first culls in the first two areas to be licensed (west Somerset and west Gloucestershire) were conducted in autumn 2013 and the second year of culling took place in both areas during autumn 2014. In autumn 2015, a third year of culling took place in Somerset and Gloucestershire and the first year of culling took place in a new intervention area in Dorset. Surveillance data for the 12 months following the 2015 culls will be available for analysis in 2017.

The population of herds in each area at the baseline date (the start date of Year 1 in Table 2) is described in Table 1. The total number of herds across all 10 comparison areas is given along with the median number of herds per area.

Table 1 – The number of herds in each area at the baseline date (start of year 1)

Area		Number of herds at baseline date
Somerset	Central	154
	Buffer	88
	Comparison	1,863 (median = 173)
	Comparison buffer	1,199 (median = 118)
Gloucestershire	Central	215
	Buffer	121
	Comparison	1,713 (median = 174)
	Comparison buffer	1,008 (median = 104)
Total	Central	369
	Buffer	209
	Comparison	3,576 (median = 173)
	Comparison buffer	2,207 (median = 107)

Statistics describing bTB in cattle in each intervention area, in the 2 km-wide buffer area around each intervention area where no culling was conducted, and for the 20 comparison areas (10 per intervention area) were produced. Statistics for comparison areas were performed on data that had been averaged across the 10 comparison areas per intervention area. The time periods investigated were the first and second years following the baseline date and the periods 0-12 months, 12-24 months, and 24-36 months prior to the baseline date. For conciseness, these periods have been labelled as years (Table 2).

Table 2 – Start and end dates for each of the reporting periods used to assess cattle bTB in the Somerset and Gloucestershire intervention areas

Somerset			
Reporting period	**Description**	**Start Date**	**End Date**
3 years prior	The year which began three years prior to the intervention	26/08/2010	25/08/2011
2 years prior	The year which began two years prior to the intervention	26/08/2011	25/08/2012
1 year prior	The year prior to the intervention	26/08/2012	25/08/2013
Year 1	First year of the intervention	26/08/2013	25/08/2014
Year 2	Second year of the intervention	26/08/2014	25/08/2015
Gloucestershire			
Reporting period	**Description**	**Start Date**	**End Date**
3 years prior	The year which began three years prior to the intervention	03/09/2010	02/09/2011
2 years prior	The year which began two years prior to the intervention	03/09/2011	02/09/2012
1 year prior	The year prior to the intervention	03/09/2012	02/09/2013
Year 1	First year of the intervention	03/09/2013	02/09/2014
Year 2	Second year of the intervention	03/09/2014	02/09/2015

The primary outcome measure of interest was incidence rate calculated as the number of herd bTB incidents per 100 herd years at risk. Differences between the incidence rates in the combined intervention and comparison areas were investigated. Crude incidence rate ratios (IRRs) were calculated for both the central areas and buffer areas in each reporting period for 'Officially Tuberculosis Free status – withdrawn' (OTF-W) incidents only. 95% confidence intervals were calculated and p-values were obtained using the Fishers' exact test with a probability level of $p<0.05$ considered to be statistically significant.

Other measures of interest were also described and are presented in Appendix 1. These include:

- *Herd bTB prevalence* as the number of herds under movement restrictions (at a single time-point) due to an OTF-W incident *per 100 herds*;
- The *number of reactors* to the single intradermal comparative cervical test (SICCT skin test) or gamma interferon test *per incident* in each area. The number used is the median number of reactors throughout the whole duration of the incident, for OTF-W incidents that ended in the reporting period regardless of when they started;
- The median *duration* in days of OTF-W incidents that ended in each of the reporting years;
- *Method of detection* as the annual proportion of new OTF-W incidents detected by SICCT test surveillance compared to the number detected by slaughterhouse surveillance;
- *Recurrence of disease* which is described as the number and proportion of herds with a history of bTB in the previous three years which suffered any incident in the reporting period compared with the proportion of herds with no history of bTB which suffered any incident in the reporting period.

Results

Incidence rates were calculated for Year 1, Year 2, and for each of the three years prior to the cull. The incidence rates for the Somerset and Gloucestershire central intervention areas, and average figures for comparison areas, and their respective buffer areas are shown in Figure 1. The incidence rate in the Somerset central area declined in the first two years following commencement of the cull (Figure 1a). This trend was not reflected in the comparison area where the summary estimates were fairly stable across the five years. A decrease in incidence rate in the intervention buffer area was observed in Year 2. Little change was observed in the Gloucestershire central area or buffer area, or their comparison areas in the first two years since culling began (Figure 1b).

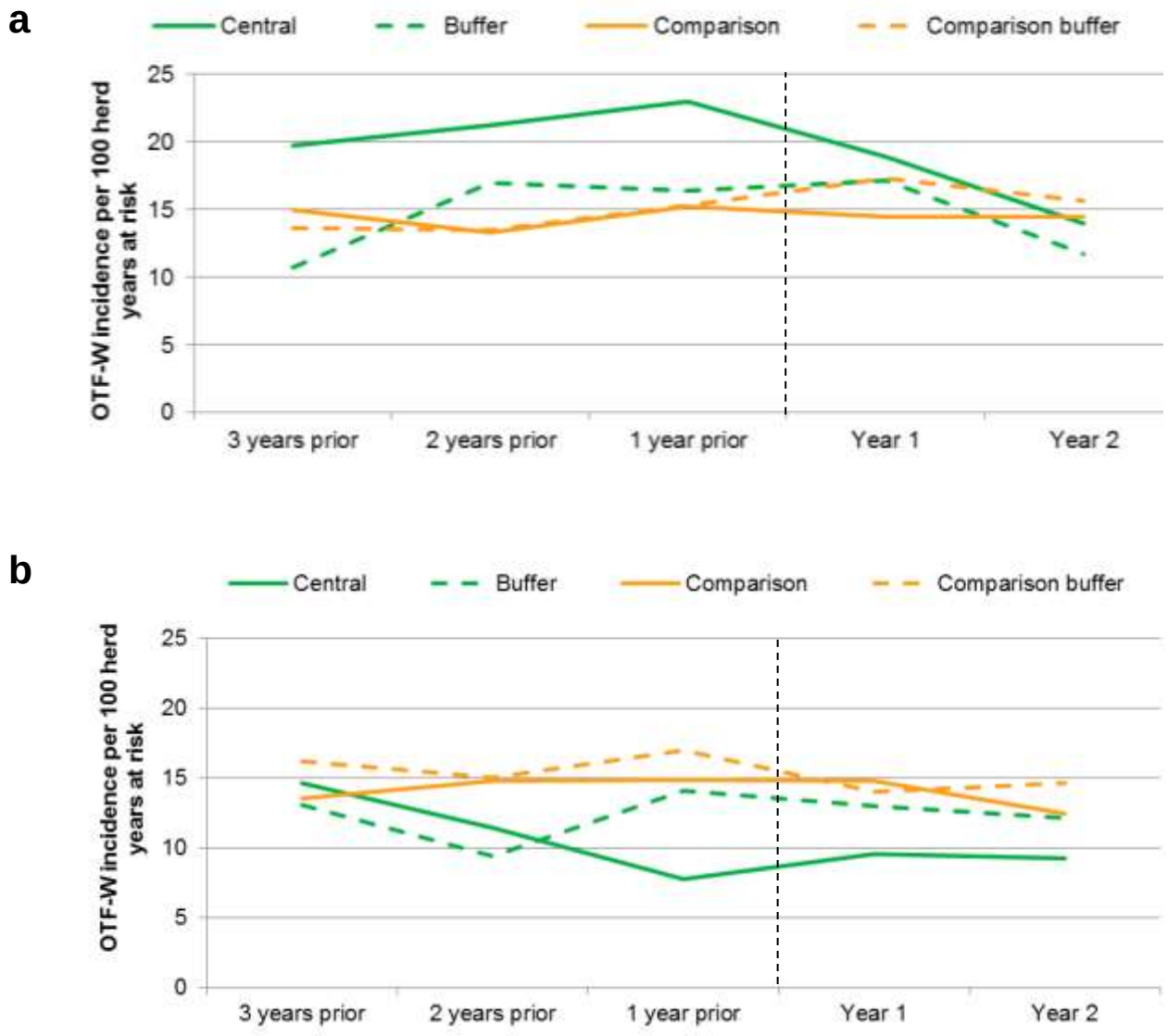

Figure 1 – Temporal changes in OTF-W incidence per 100 herd years at risk, at the end of the reporting period, in Somerset (a) and Gloucestershire (b) intervention areas, comparison areas, and their respective buffer areas. Black dashed line indicates the start of badger culling. Average data is shown for the comparison areas. (Raw data can be found in Appendix Table 3).

A comparison of OTF-W incidence rate per 100 herd years at risk between the combined central and comparison areas, and their respective buffer areas, is presented in Table 3. The 95% confidence interval spanned one for all IRRs and so there were no statistically significant differences in incidence rate between central and comparison areas or buffer and comparison areas across all reporting periods.

Table 3 – OTF-W incidence rates per 100 herd years at risk and unadjusted incidence rate ratios (IRR) for central and buffer areas versus comparison areas in Somerset and Gloucestershire combined.

Reporting period	Central	Comparison	IRR	95% confidence interval		P value
3 years prior	16.7	14.3	1.17	0.87	1.54	0.267
2 years prior	15.5	14.0	1.10	0.81	1.47	0.488
1 year prior	13.3	15.1	0.88	0.63	1.20	0.426
Year 1	13.2	14.6	0.90	0.65	1.22	0.519
Year 2	11.2	13.5	0.83	0.58	1.15	0.260
Reporting period	**Buffer**	**Comparison buffer**	**IRR**	**95% confidence interval**		**P value**
3 years prior	12.1	14.8	0.82	0.51	1.24	0.339
2 years prior	12.7	14.2	0.89	0.56	1.36	0.609
1 year prior	15.0	16.0	0.94	0.62	1.37	0.755
Year 1	14.7	15.7	0.93	0.61	1.37	0.743
Year 2	11.9	15.1	0.79	0.50	1.20	0.259

Discussion

The current badger cull policy was implemented with an aim of reducing the population of badgers, a known carrier of bTB, thereby reducing the potential for transmission between badgers and cattle, and therefore aiming for a subsequent reduction in bTB incidence in cattle. To be able to best evaluate if this policy could have a statistically significant effect on bTB incidence rates, a randomised controlled trial of the culling intervention would have been the most appropriate scientific study design. However, the current culls are delivered by industry. Therefore, the areas in which culling has and will be carried out are selected by stakeholders and so intervention is not randomised. The purposive selection of areas limits the usefulness of the data for assessing the cause-effect relationship between the culling intervention and cattle TB incidence rates, since the strength of the influence of confounding and other biases on the outcome cannot be effectively controlled. This means that any effects of the intervention on cattle TB incidence rate cannot be extrapolated to a wider population. Once more intervention areas have been added, it may be possible to draw generalisable inferences.

OTF-W incidence was used as the primary outcome rather than total bTB incidence because this analysis was based on the assumption that we would be able to detect comparable effects on cattle bTB to those observed during the RBCT, and the RBCT only showed an association between OTF-W incidence and culling (Donnelly et al 2007). As in Year 1, the descriptive analysis showed different distributions of OTF-W incidents in the two intervention areas, with incidence rate across the reporting periods being generally lower in the Gloucestershire intervention area than in the comparison areas, but higher in the Somerset intervention area than in the comparison areas. These differences, can be observed across all time periods (i.e. prior to as well as after the introduction of the intervention), and so cannot be attributed to the intervention.

A reduction in OTF-W incidence rate per 100 herd years at risk in the Somerset intervention area compared to the Somerset comparison area might appear to indicate an impact of the intervention in this area. However, bTB incidence in this area has been variable over recent years. Further exploration of the data adjusting for other factors that are likely to influence bTB incidence is needed to determine if this reduction is associated with the intervention. The lack of variability in temporal incidence trends in the comparison areas for both Somerset and Gloucestershire may be due to the larger number of herds used in these summary estimates.

The results of the RBCT indicated that an increase in cattle bTB incidence is possible in the buffer areas due to perturbation of the badger population (Donnelly et al 2006; Woodroffe et al 2006). This has not been observed in this analysis, but this cannot be interpreted as definitive evidence against such an effect, since in the current study there are various biases involved and it has low statistical power (Donnelly et al 2015).

The provision of farm-level risk advice in the cull areas in 2014 (Paterson 2014) meant that the intervention differed between Year 1 and Year 2. This programme may have had a beneficial effect in reducing transmission of bTB, dependent on take up. This means that any positive or negative effects on bTB incidents detected in Year 2 may be attributable only to the risk management advice or only the badger culling, or their combined effects. It is not possible to determine the independent effect of badger culling on bTB incidence as farms in the comparison areas did not received the risk management advice (Donnelly et al 2015).

The purpose of this report was to provide an assessment of any association between the intervention and bTB incidence in cattle. The selection of matched comparison areas for intervention areas was an attempt to alleviate the issues of non-randomised selection. However, this may have introduced other biases due to incomplete matching. It has been estimated that in order to be likely to observe statistically significant differences in the incidence of OTF-W herd incidents, matched intervention and comparison areas will need to be observed for at least three years after culling begins, and that this increases to four years if only two intervention areas are licenced (Donnelly et al 2015). Therefore, it is unlikely that significant differences would have been

observed in the first two years of follow-up, should they exist. In autumn 2014, badger culling was carried out in three intervention areas, with Dorset conducting its first year of intervention. Future reports will therefore include data for more areas. Given the lack of power with the present data, and the simplicity of the unadjusted calculations performed, it is not possible to robustly conclude that there is or is not an association between the intervention and bTB incidence in cattle from the results presented here. Further work is underway to explore the impact of adjusting for other factors likely to influence bTB incidence on the estimates derived here, and it is likely that estimates will change once biases are accounted for.

In addition to the comparability of areas and the lack of power, analyses are limited by the fact that there is likely to be a time lag between any effect due to badger removal leading to decreased transmission of infection and any observable reduction in bTB incidence in cattle (More et al 2007). Also, initial difficulties in reducing the pre-cull population of badgers by 70% or in achieving homogeneous spatial coverage of culling, as seen in Year 1 (AHVLA 2014) and Year 2 (Defra 2014b), will reduce the effectiveness of the culls compared to the RBCT and pose a risk of an adverse effect on cattle disease.

It is important that the results presented here are interpreted in light of the limitations discussed. The long-term value of information from monitoring industry-led culling will depend on the conduct of the cull, the number of areas eventually licensed and the extent to which other parts of the bTB control policy remain stable. The results presented here provide some preliminary information as to the impact of the first two years of the badger culls in Somerset and Gloucestershire. Continued delivery of the intervention in these areas, and further roll out of the intervention to other areas will enable better assessments to be made of the impact of the policy on bTB incidence in cattle.

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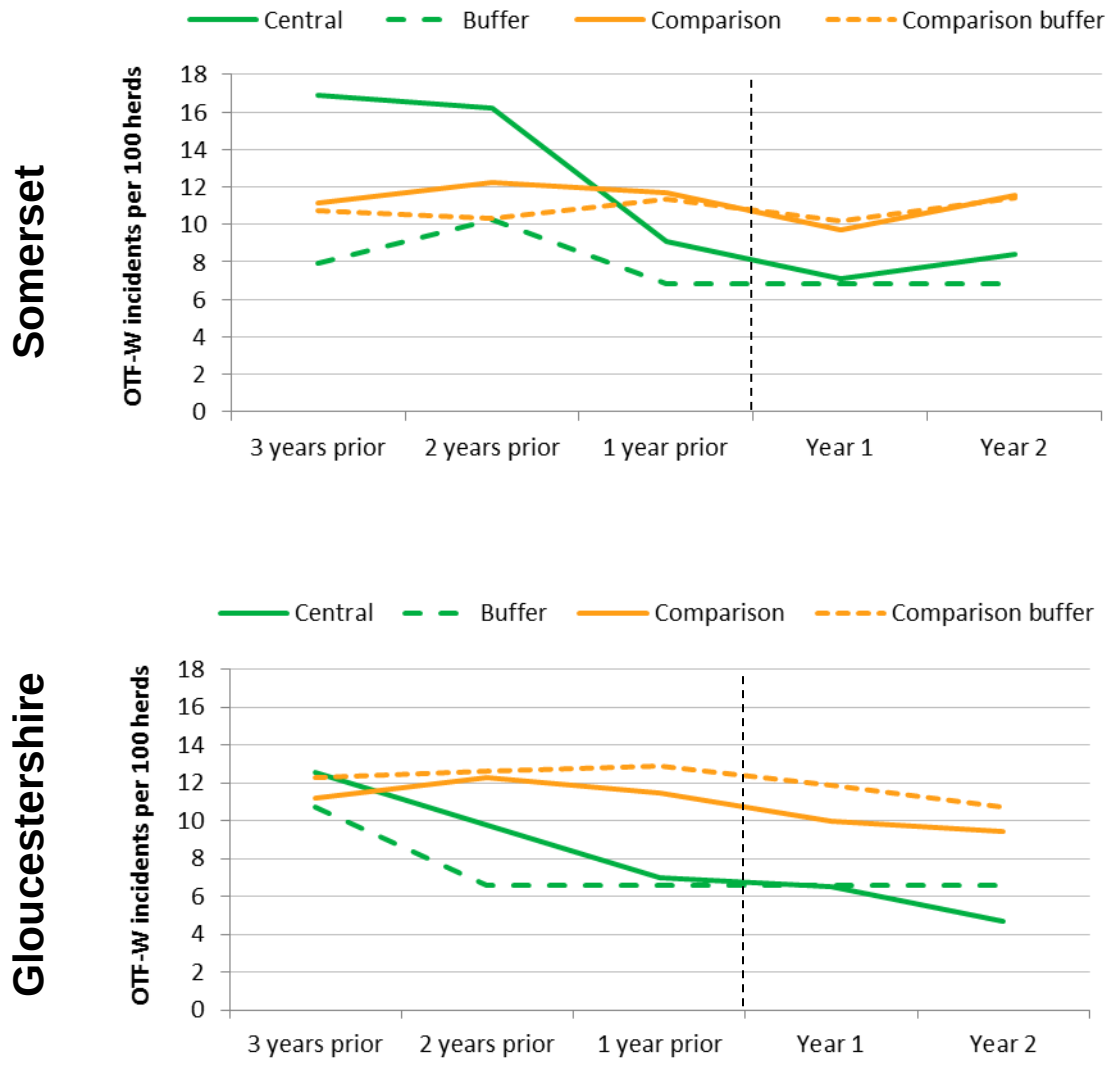
Appendix 1 - Secondary outcome measures

Herd bTB prevalence

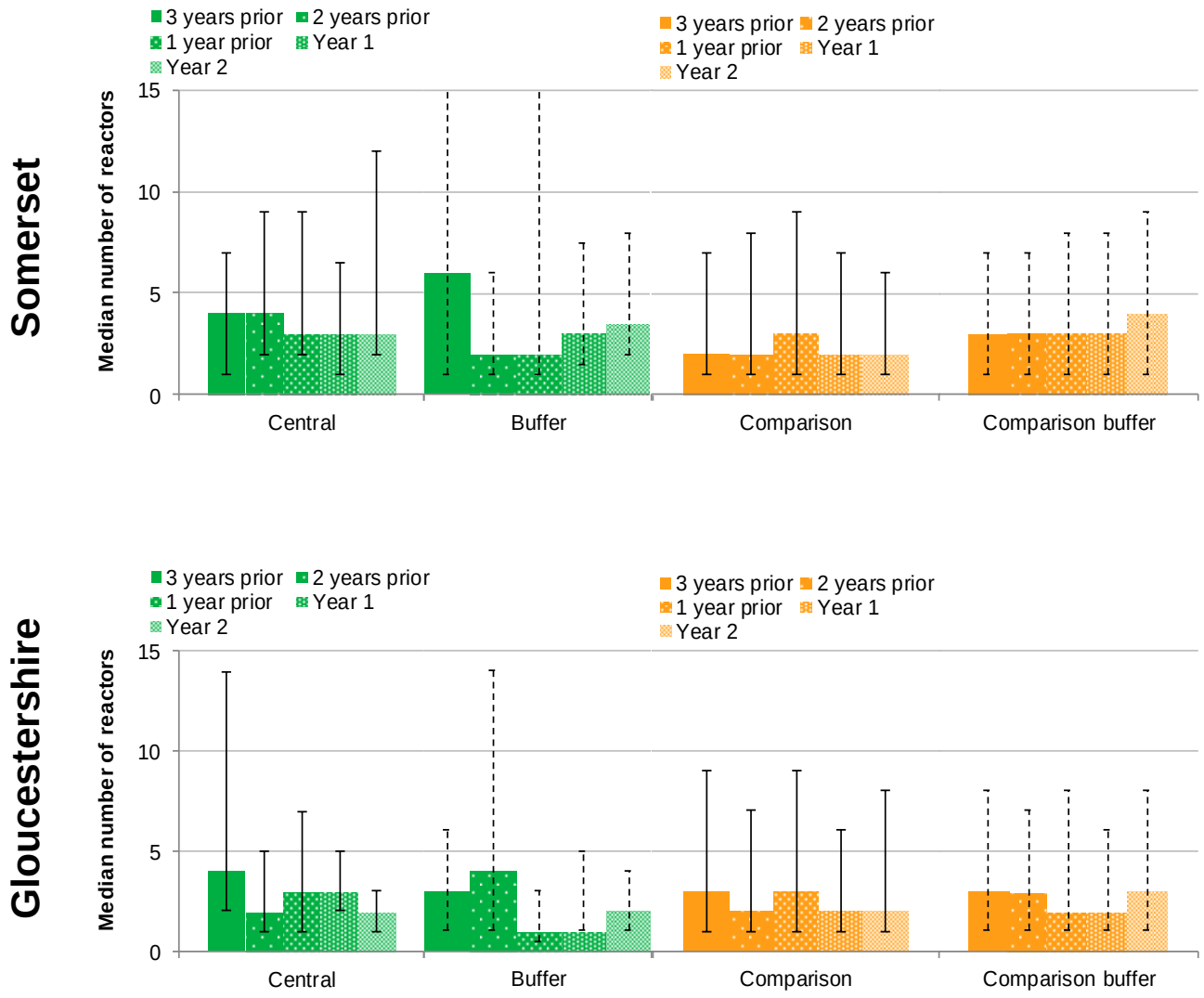
The prevalence of herds under restriction for OTF-W incidents only, per area and reporting period, is presented in Appendix Figure 1. There was a slight increase in prevalence in all Somerset areas except the central buffer area between the first and second years of culling. Despite this, prevalence appears to have reduced overall since 2010 across all Somerset and Gloucestershire areas, including declines in the three years prior to culling.



Appendix Figure 1 – Temporal changes in the number of herds under restrictions (OTF-W incidents only) at the end of the reporting period per 100 herds, in Somerset and Gloucestershire intervention areas and their respective buffer areas, and comparison areas and buffer areas. The horizontal axis represents the mid-point of the last month of the reporting period. Black dashed lines indicate the start of badger culling.

Number of reactors

Very little difference was observed in the median number of reactors per area, prior to, or in the two years following the commencement of culling (Appendix Figure 2). There has been an apparent, small increase in the median number of reactors in the central buffer area in Somerset since commencement of the culls. However, this increase is likely to be an artefact of the small number of reactors within this area as opposed to being indicative of an increase. The interquartile ranges for the number of reactors were overlapping between central, comparison and buffer areas in both the Somerset and Gloucestershire areas.



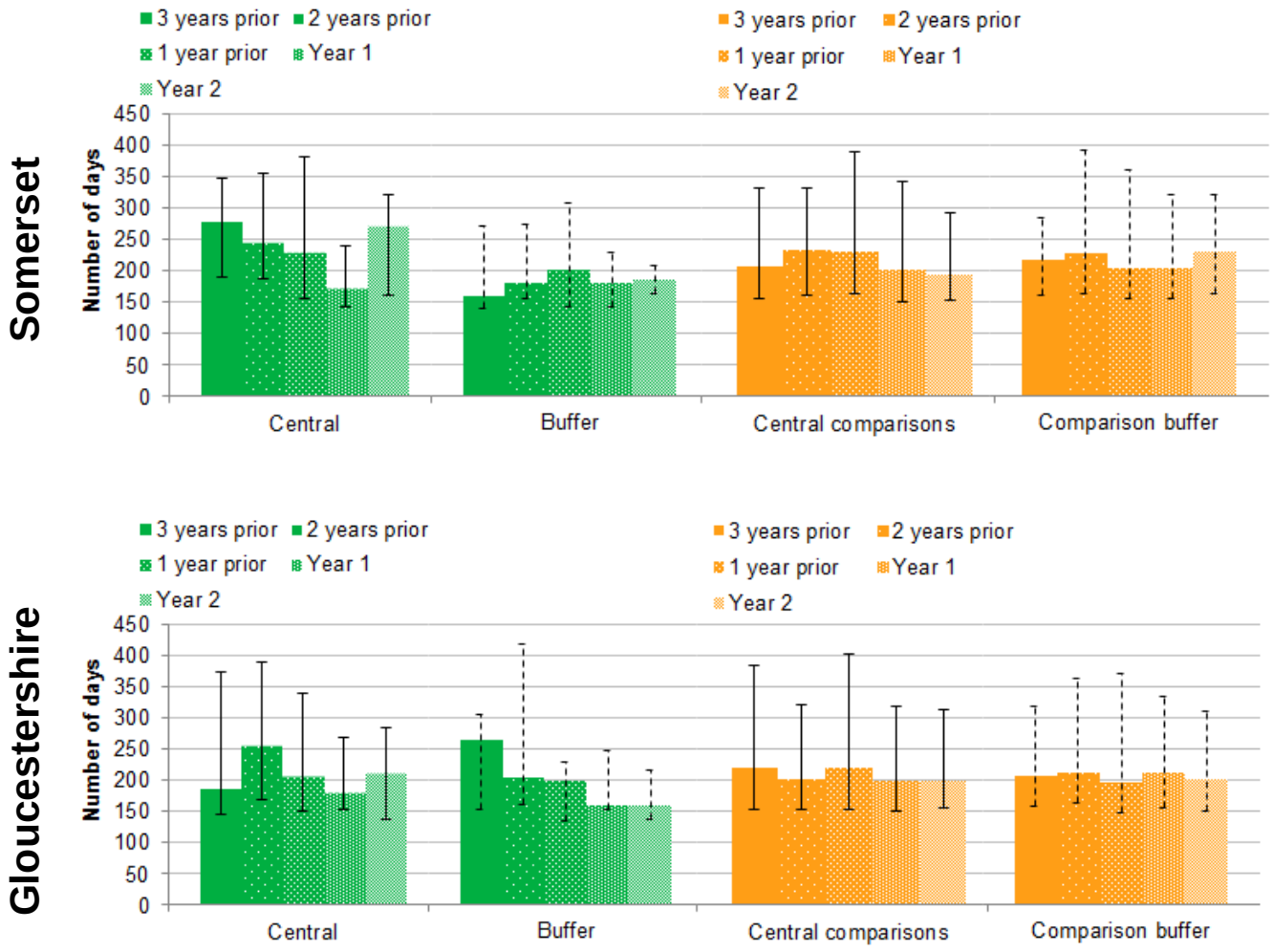
Appendix Figure 2 – The median number of reactors for OTF-W incidents that ended in the reporting period in Somerset and Gloucestershire; inter-quartile ranges are shown

Note: the upper quartile for the Somerset buffer region 3 years prior to culling (15.5) and 1 year prior to culling (16) are not shown to improve the clarity of the figure.

Duration of restrictions

The median durations of OTF-W incidents, with interquartile ranges, are shown in Appendix Figure 3. There was considerable overlap in the ranges of median duration of OTF-W incidents between areas.

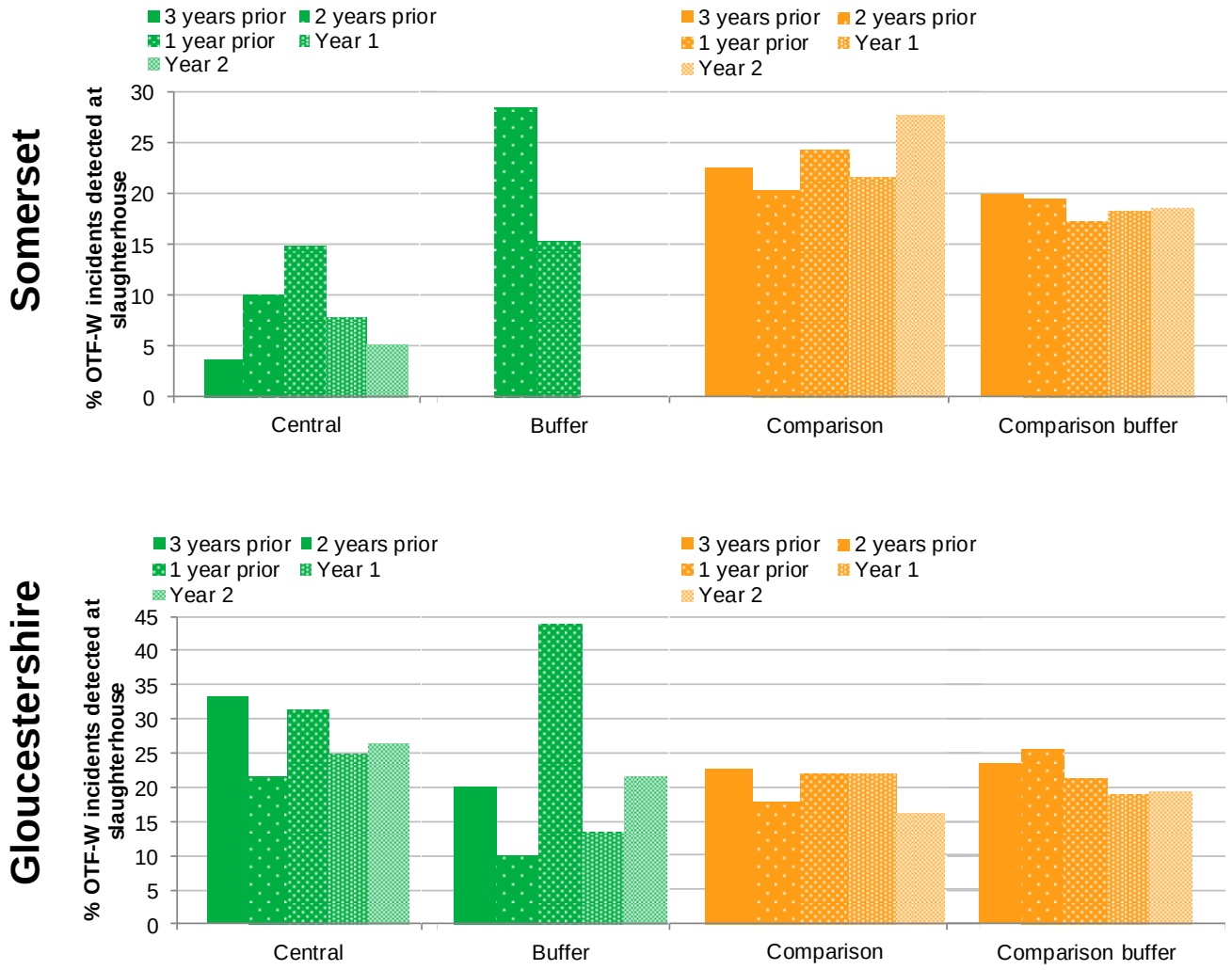
The proportion of herds with an OTF-W incident lasting for more than 550 days fluctuated across all areas and reporting periods due to the small number of incidents. There were no discernible trends in the proportion of OTF-W incidents which lasted more than 500 days (Appendix Table 6).



Appendix Figure 3 – Median duration of incidents in Somerset and Gloucestershire central and comparison areas, and respective buffer areas; inter-quartile ranges are shown.

Herd incident detection

The proportion of new OTF-W incidents first detected at slaughterhouse is shown in Appendix Figure 4. Across all areas and reporting periods the proportions of OTF-W incidents first detected at slaughterhouse (all OTF-W by definition) fluctuated between years, due to the small numbers observed. This is particularly apparent in both intervention buffer areas.

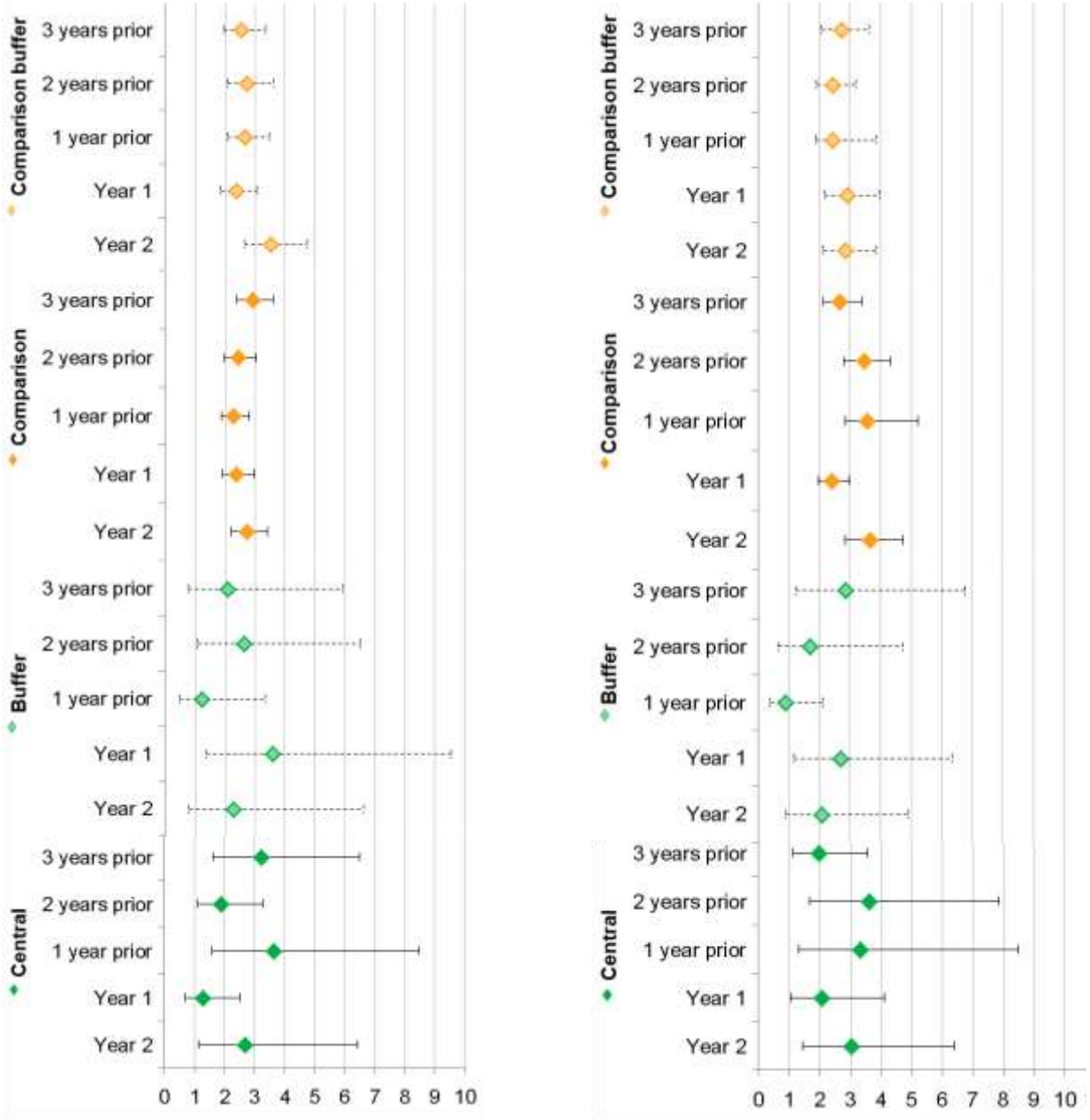


Appendix Figure 4 – Proportion of OTF-W incidents first detected at slaughterhouse in Somerset and Gloucestershire.

Recurrence

In Appendix Figure 5 recurrence is presented as the risk ratio of herds suffering any new bTB incident in the reporting period which also suffered a bTB incident in the preceding 36 months compared to herds suffering any new bTB incident in the reporting period without any bTB incidents in the preceding 36 months. A risk ratio greater than 1 indicates an increased risk among those with a history of bTB and a risk ratio less than 1 indicates a reduced risk. In both intervention areas, herds with a history of bTB were at a higher risk of having an incident in Year 2 (Somerset: RR = 2.7, 95% CI = 1.1 – 6.4; Gloucestershire: RR = 3.0, 95% CI = 1.5 – 6.4). Across all areas, the overall changes to the risk ratio over time were small, with considerable overlap observed in the 95% confidence intervals, so any changes should be interpreted cautiously.

Somerset **Gloucestershire**



Appendix Figure 5 – Risk ratios and 95% confidence intervals for herds suffering any new bTB incident in the reporting period which also suffered a bTB incident in the preceding 36 months compared to herds suffering any new bTB incident in the reporting period without any bTB incidents in the preceding 36 months, in Somerset and Gloucestershire.

Appendix 2 – Raw data

*Appendix Table 1 – Total number of **new bTB incidents** at the end of the reporting period in Somerset and Gloucestershire intervention areas and buffers.*

Area	3 years prior	2 years prior	1 year prior	Year 1	Year 2
Somerset cull area	34	42	30	29	23
Somerset buffer	12	15	16	15	12
Gloucestershire cull area	41	31	18	29	24
Gloucestershire buffer	19	14	22	19	19

*Appendix Table 2 – Total number of **herds under restrictions** at the end of the reporting period in Somerset and Gloucestershire intervention areas and buffers due to any bTB incident, regardless of when it started.*

Area	3 years prior	2 years prior	1 year prior	Year 1	Year 2
Somerset cull area	27	31	16	13	14
Somerset buffer	9	10	7	6	6
Gloucestershire cull area	31	22	19	16	10
Gloucestershire buffer	15	10	10	11	8

Appendix Table 3 – OTF-W incidence per 100 herd years at risk at the end of the reporting period in Somerset and Gloucestershire intervention areas, comparison areas, and respective buffer areas (for all incidents and for OTF-W incidents only). Raw data for Figure 1.

Area	Total					OTF-W				
	3 years prior	2 years prior	1 year prior	Year 1	Year 2	3 years prior	2 years prior	1 year prior	Year 1	Year 2
Somerset										
Central	24.0	29.8	25.5	21.0	16.0	19.7	21.3	23.0	18.9	14.0
Buffer	14.3	18.2	20.2	18.3	14.0	10.7	17.0	16.4	17.1	11.7
Comparison area	18.9	16.4	18.6	17.5	17.1	15.0	13.3	15.3	14.5	14.4
Comparison buffer	18.0	17.1	18.3	20.7	19.3	13.6	13.5	15.3	17.3	15.6
Gloucestershire										
Central	20.0	15.4	8.7	13.8	11.7	14.6	11.4	7.7	9.5	9.2
Buffer	16.5	13.1	19.3	16.4	16.4	13.0	9.4	14.0	12.9	12.1
Comparison area	17.5	18.8	17.7	18.4	15.8	13.5	14.8	14.9	14.8	12.4
Comparison buffer	19.4	19.7	20.2	17.4	17.5	16.2	15.0	16.9	14.0	14.6

Appendix Table 4 – Number of herds under movement restrictions at the end of the reporting period due to a bTB incident, per 100 herds (for all incidents and for OTF-W incidents only) for Somerset and Gloucestershire intervention areas, comparison areas, and respective buffer areas. Raw data for Appendix Figure 1.

Area	Total					OTF-W				
	3 years prior	2 years prior	1 year prior	Year 1	Year 2	3 years prior	2 years prior	1 year prior	Year 1	Year 2
Somerset										
Central	17.5	20.1	10.4	8.4	9.1	16.9	16.2	9.1	7.1	8.4
Buffer	10.2	11.4	8.0	6.8	6.8	8.0	10.2	6.8	6.8	6.8
Comparison area	13.1	13.5	13.3	11.2	12.2	11.2	12.2	11.7	9.7	11.5
Comparison buffer	12.8	12.2	12.3	11.3	12.0	10.8	10.3	11.3	10.2	11.4
Gloucestershire										
Central	14.4	10.2	8.8	7.4	4.7	12.6	9.8	7.0	6.5	4.7
Buffer	12.4	8.3	8.3	9.1	6.6	10.7	6.6	6.6	6.6	6.6
Comparison area	12.7	13.7	12.5	11.0	10.2	11.2	12.3	11.4	10.0	9.5
Comparison buffer	14.7	14.7	14.4	13.0	11.4	12.3	12.6	12.9	11.9	10.7

Appendix Table 5 – Total number and median number (with interquartile range) of reactors per incident for all bTB incidents. Raw data for Appendix Figure 2.

ALL INCIDENTS												
	Central			Buffer			Comparison			Comparison buffer		
Reporting period	No. of reactors	Mean	Median (IQR)	No. of reactors	Mean	Median (IQR)	No. of reactors	Mean	Median (IQR)	No. of reactors	Mean	Median (IQR)
Somerset												
3 years prior	105	5.8	4 (1,7)	71	7.1	2 (1,14)	909	4.8	2 (1,5)	748	5.8	2 (1,5)
2 years prior	279	7.5	3 (1,6)	62	4.8	1 (1,6)	1589	6.0	2 (1,5)	1360	7.6	2 (1,6.5)
1 year prior	246	5.5	3 (2,7)	103	6.1	2 (1,3)	2348	7.2	2 (1,7)	1378	6.8	2 (1,5.5)
Year 1	208	5.8	3 (1,6)	81	4.8	3 (1,7)	2164	6.6	2 (1,5)	1563	7.5	2 (1,6)
Year 2	196	10.3	3 (1,12)	52	4.3	2.5 (1,6)	2612	9.8	2 (1,5)	1269	7.5	3 (1,8)
Gloucester												
3 years prior	252	7.6	2 (1,7)	88	5.9	2 (1,6)	1201	6.9	2 (1,7)	694	6.9	2 (1,7.5)
2 years prior	148	4.1	2 (1,4)	189	9.5	3 (1,10.5)	1485	5.5	2 (1,5)	1631	9.6	2 (1,5)
1 year prior	91	4.0	3 (1,7)	47	2.5	1 (0,2)	2308	7.5	2 (1,8)	1162	6.2	2 (1,5.5)
Year 1	161	5.8	2 (1,4)	65	3.0	1 (1,3)	1917	6.0	2 (1,5)	1253	7.1	2 (1,5)
Year 2	182	6.7	2 (1,3)	96	5.6	1 (1,4)	1689	6.8	2 (1,6)	1384	8	2 (1,6)

OTF-W INCIDENTS												
	Central			Buffer			Comparison			Comparison buffer		
Reporting period	No. of reactors	Mean	Median (IQR)	No. of reactors	Mean	Median (IQR)	No. of reactors	Mean	Median (IQR)	No. of reactors	Mean	Median (IQR)
Somerset												
3 years prior	98	6.5	4 (1,7)	69	8.6	6 (1,15.5)	822	5.6	2 (1,7)	706	7.4	3 (1,6)
2 years prior	271	9.0	4 (2,9)	60	5.5	2 (1,6)	1492	7.3	2 (1,8)	1320	8.6	3 (1,8)
1 year prior	233	6.3	3 (2,9)	99	7.6	2 (1,16)	2298	8.4	3 (1,9)	1321	8.1	3 (1,8)
Year 1	199	6.2	3 (1,6.5)	80	5.0	3 (1.5,7.5)	2094	7.6	2 (1,7)	1501	8.8	3 (1,8)
Year	195	11.5	3 (2,12)	51	5.1	3.5 (2,8)	2542	11.7	2 (1,6)	1232	8.8	4 (1,9)
Gloucester												
3 years prior	227	9.9	4 (2,14)	83	7.5	3 (1,6)	1142	8.1	3 (1,9)	631	7.6	3 (1,8)
2 years prior	137	5.1	2 (1,5)	183	10.8	4 (1,14)	1399	6.9	2 (1,7)	1586	11.7	3 (1,7)
1 year prior	85	4.3	3 (1,7)	45	2.8	1 (0.5,3)	2218	8.9	3 (1,9)	1115	7.5	2 (1,8)
Year 1	151	7.2	3 (2,5)	58	3.6	1 (1,5)	1863	6.9	2 (1,6)	1216	8.5	2 (1,6)
Year	174	8.3	2 (1,3)	92	7.1	2 (1,4)	1623	8.2	2 (1,8)	1356	9.1	3 (1,8)

Appendix Table 6 – Median duration of OTF-W incidents that ended in each of the reporting periods, and the proportion of OTF-W incidents that were >550 days. Raw data for Appendix Figure 3.

Reporting period	Central		Buffer		Comparison area		Comparison area buffer	
	Median duration (IQR)	% >550 days	Median duration (IQR)	% >550 days	Median duration (IQR)	% >550 days	Median duration (IQR)	% >550 days
Somerset								
3 years prior	278.5 (189.5,346.5)	11	159.5 (139,269)	10	209 (157,333)	12	216 (161,284)	11
2 years prior	247 (186,354)	13	179 (154,274)	9	235.5 (162,331.5)	11	228 (162,391)	13
1 year prior	230 (155,381)	5	202 (141,306)	0	230.5 (164,390)	13	203 (154,358.5)	10
Year 1	171.5 (143.5,240)	6	180 (142.5,227.5)	0	204 (150,344)	12	204 (154,319)	9
Year 2	271 (161,321)	12	185.5 (162,208)	10	194 (155,292)	8	230.5 (163,321)	9
Gloucestershire								
3 years prior	185 (146,372)	16	264 (152,304)	8	220 (154,385)	18	205.5 (158,318)	10
2 years prior	256 (169,388)	7	204 (161,416)	6	203 (153,323)	9	211 (162,362.5)	12
1 year prior	205.5 (151,338)	10	197 (134,229)	6	221 (153,405)	16	196 (148,371)	15
Year 1	179 (154,269)	5	160 (151,245.5)	13	200 (150,319)	12	212 (154,333)	12
Year 2	213 (138,285)	10	160 (137,214)	8	200 (157,313)	9	201 (150,309)	11

Appendix Table 7 – The annual proportion of new OTF-W incidents detected by SICCT test surveillance vs. slaughterhouse surveillance. Raw data for Appendix Figure 4.

Reporting period	Central			Buffer			Comparison area			Comparison area buffer		
	Total new OTF-W incidents	OTF-W incidents first detected at slaughterhouse (%)	OTF-W incidents disclosed through skin testing (%)	Total new OTF-W incidents	OTF-W incidents first detected at slaughterhouse (%)	OTF-W incidents disclosed through skin testing (%)	Total new OTF-W incidents	OTF-W incidents first detected at slaughterhouse (%)	OTF-W incidents disclosed through skin testing (%)	Total new OTF-W incidents	OTF-W incidents first detected at slaughterhouse (%)	OTF-W incidents disclosed through skin testing (%)
Somerset												
3 years prior	28	1 (3.6)	27 (96.4)	9	0 (0)	9 (100)	257	58 (22.6)	199 (77.4)	140	28 (20)	112 (80)
2 years prior	30	3 (10)	27 (90)	14	4 (28.6)	10 (71.4)	230	47 (20.4)	183 (79.6)	143	28 (19.6)	115 (80.4)
1 year prior	27	4 (14.8)	23 (85.2)	13	2 (15.4)	11 (84.6)	258	63 (24.4)	195 (75.6)	168	29 (17.3)	139 (82.7)
Year 1	26	2 (7.7)	24 (92.3)	14	0 (0)	14 (100)	244	53 (21.7)	191 (78.3)	175	32 (18.3)	143 (81.7)
Year 2	20	1 (5)	19 (95)	10	0 (0)	10 (100)	248	69 (27.8)	179 (72.2)	156	29 (18.6)	127 (81.4)
Gloucestershire												
3 years prior	30	10 (33.3)	20 (66.7)	15	3 (20)	12 (80)	203	46 (22.7)	157 (77.3)	141	33 (23.4)	108 (76.6)
2 years prior	23	5 (21.7)	18 (78.3)	10	1 (10)	9 (90)	230	41 (17.8)	189 (82.2)	144	37 (25.7)	107 (74.3)
1 year prior	16	5 (31.3)	11 (68.8)	16	7 (43.8)	9 (56.3)	233	51 (21.9)	182 (78.1)	151	32 (21.2)	119 (78.8)
Year 1	20	5 (25)	15 (75)	15	2 (13.3)	13 (86.7)	238	52 (21.8)	186 (78.2)	132	25 (18.9)	107 (81.1)
Year 2	19	5 (26.3)	14 (73.7)	14	3 (21.4)	11 (78.6)	192	31 (16.1)	161 (83.9)	139	27 (19.4)	112 (80.6)

*Appendix Table 8a – Number and proportion of herds in **Somerset areas** with any new bTB incident in the reporting period, in herds with and without a history of any bTB incident in the preceding 36 months. Raw data for Appendix Figure 5.*

Area	Reporting period	bTB incident in the preceding 36 months		No bTB incident in the preceding 36 months		Risk ratio[2]	95% CI for risk ratio	
		No. herds	No. herds with incident in reporting period[1] (%)	No. herds	No. herds with incident in reporting period[1] (%)			
Central	3 years prior	64	24 (37.5)	78	9 (11.5)	3.6	1.6	6.5
	2 years prior	59	23 (39)	78	16 (20.5)	1.9	1.1	3.3
	1 year prior	70	22 (31.4)	70	6 (8.6)	3.7	1.6	8.5
	Year 1	70	16 (22.9)	74	13 (17.6)	1.3	0.7	2.5
	Year 2	77	17 (22.1)	73	6 (8.2)	2.7	1.1	6.4
Buffer	3 years prior	21	5 (23.8)	62	7 (11.3)	2.1	0.7	5.9
	2 years prior	26	8 (30.8)	60	7 (11.7)	2.6	1.1	6.5
	1 year prior	26	5 (19.2)	58	9 (15.5)	1.2	0.5	3.3
	Year 1	30	10 (33.3)	54	5 (9.3)	3.6	1.4	9.6
	Year 2	33	7 (21.2)	54	5 (9.3)	2.3	0.8	6.6
Comparison area	3 years prior	594	187 (31.5)	1165	125 (10.7)	2.9	2.4	3.6
	2 years prior	567	150 (26.5)	1141	123 (10.8)	2.5	2.0	3.0
	1 year prior	588	161 (27.4)	1123	134 (11.9)	2.3	1.9	3.0
	Year 1	641	163 (25.4)	1089	116 (10.7)	2.4	1.9	3.0
	Year 2	646	175 (27.1)	1098	108 (9.8)	2.8	2.2	3.4
Comparison area buffer	3 years prior	360	94 (26.1)	749	77 (10.3)	2.5	1.9	3.3
	2 years prior	355	98 (27.6)	744	75 (10.1)	2.7	2.1	3.6
	1 year prior	380	110 (28.9)	729	79 (10.8)	2.7	2.1	3.5
	Year 1	394	114 (28.9)	723	88 (12.2)	2.4	1.9	3.1
	Year 2	405	120 (29.6)	706	59 (8.4)	3.5	2.7	4.7

[1] Herds under restriction for four or more months of the reporting period due to an incident that started before the reporting period were excluded from the analyses. It was considered that such herds had limited opportunity to become cases since there may have been no further testing in the period following the close of the incident. Setting a threshold of four months allowed for the detection of possible recurrence at the next test scheduled after lifting of restrictions in herds where restrictions were lifted within the first four months of the current year.

[2] Risk that herds under movement restrictions in the preceding 36 months had a new bTB incident in the reporting period compared with risk that herds that had no history of movement restrictions had a new bTB incident. The risk ratio is the proportion of herds with a history of bTB that had a new incident, divided by the proportion of herds with no history of bTB that had a new incident.

*Appendix Table 8b – Number and proportion of herds in **Gloucestershire areas** with any new bTB incident in the reporting period, in herds with and without a history of any bTB incident in the preceding 36 months. Raw data for Appendix Figure 5.*

Area	Reporting period	bTB incident in the preceding 36 months		No bTB incident in the preceding 36 months		Risk ratio[2]	95% CI for risk ratio	
		No. herds	No. herds with incident in reporting period[1] (%)	No. herds	No. herds with incident in reporting period[1] (%)			
Central	3 years prior	73	20 (27.4)	124	17 (13.7)	2.0	1.1	3.6
	2 years prior	78	19 (24.4)	119	8 (6.7)	3.6	1.7	7.9
	1 year prior	77	12 (15.6)	128	6 (4.7)	3.3	1.3	8.5
	Year 1	66	14 (21.2)	137	14 (10.2)	2.1	1.1	4.1
	Year 2	57	13 (22.8)	147	11 (7.5)	3.0	1.5	6.4
Buffer	3 years prior	39	11 (28.2)	71	7 (9.9)	2.9	1.2	6.8
	2 years prior	37	6 (16.2)	74	7 (9.5)	1.7	0.6	4.7
	1 year prior	35	6 (17.1)	79	15 (19)	0.9	0.4	2.1
	Year 1	45	12 (26.7)	71	7 (9.9)	2.7	1.2	6.4
	Year 2	43	10 (23.3)	72	8 (11.1)	2.1	0.9	4.9
Comparison area	3 years prior	528	142 (26.9)	1058	106 (10)	2.7	2.1	3.4
	2 years prior	522	178 (34.1)	1049	103 (9.8)	3.5	2.8	4.3
	1 year prior	532	168 (31.6)	1027	91 (8.9)	3.6	2.8	4.5
	Year 1	552	159 (28.8)	1036	124 (12)	2.4	1.9	3.0
	Year 2	616	164 (26.6)	992	72 (7.3)	3.7	2.8	4.7
Comparison area buffer	3 years prior	319	92 (28.8)	627	66 (10.5)	2.7	2.1	3.6
	2 years prior	299	97 (32.4)	620	82 (13.2)	2.5	1.9	3.2
	1 year prior	313	93 (29.7)	596	71 (11.9)	2.5	1.9	3.3
	Year 1	348	97 (27.9)	565	54 (9.6)	2.9	2.2	4.0
	Year 2	373	105 (28.2)	568	56 (9.9)	2.9	2.1	3.8

[1] Herds under restriction for four or more months of the reporting period due to an incident that started before the reporting period were excluded from the analyses. It was considered that such herds had limited opportunity to become cases since there may have been no further testing in the period following the close of the incident. Setting a threshold of four months allowed for the detection of possible recurrence at the next test scheduled after lifting of restrictions in herds where restrictions were lifted within the first four months of the current year.

[2] Risk that herds under movement restrictions in the preceding 36 months had a new bTB incident in the reporting period compared with risk that herds that had no history of movement restrictions had a new bTB incident. The risk ratio is the proportion of herds with a history of bTB that had a new incident, divided by the proportion of herds with no history of bTB that had a new incident.