

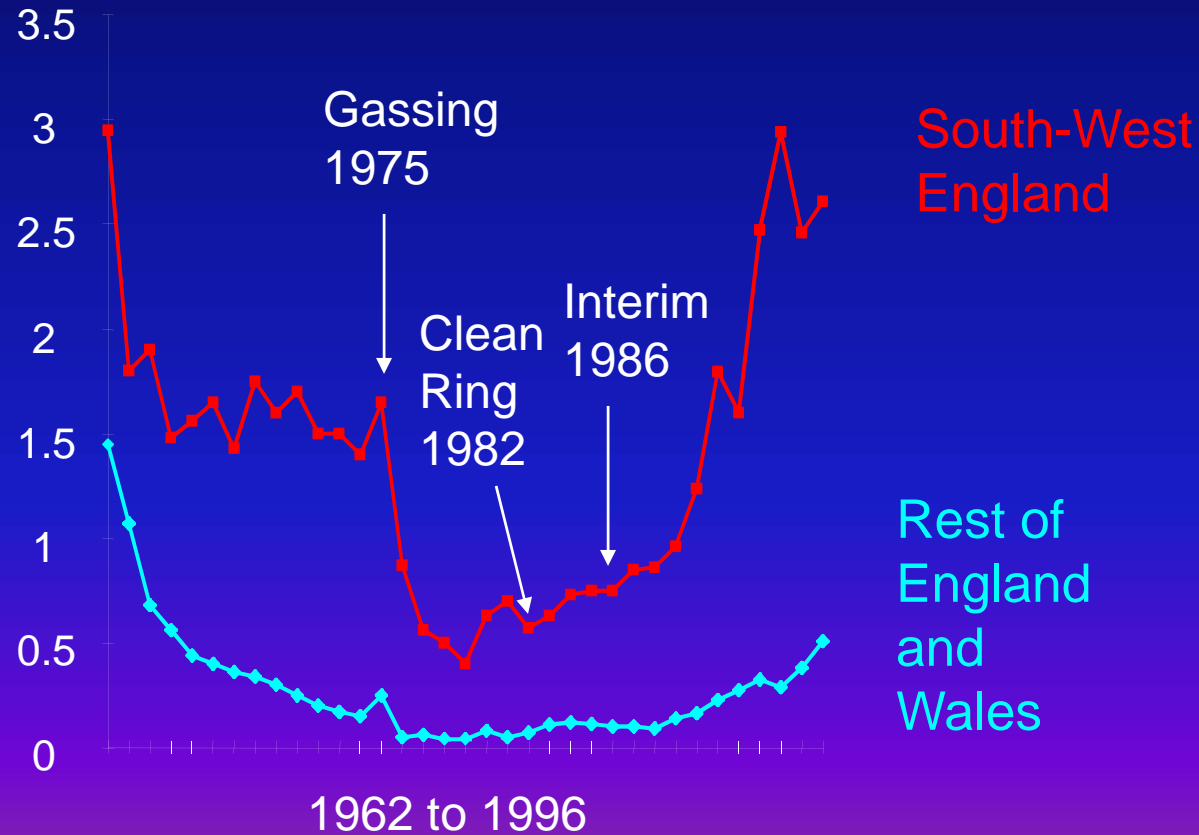
Bovine TB: Epidemiology and Ecology of a Multi-Host Disease

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**(and in spirit... Rosie Woodroffe,
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Percentage of total herds with reactor cattle (confirmed and unconfirmed)



In 1997, the government commissioned an Independent review chaired by Sir (now Lord) John Krebs.

Concluded that the evidence of a link between badgers and cattle TB is compelling but not conclusive

and that a field trial is required to test and quantify the impact of badger culling on disease in cattle

(with no culling outside trial areas)



Devastated by TB's bolt from the blue

I

The badger boom is an unexpected by-product of TB control. Badgers have been culled since 1981, but the number of TB-free badgers has risen to 1.7 million since 1995.



Farm dismay on heels of badger culling decision

Badger culling all but ended - Krebs report

B

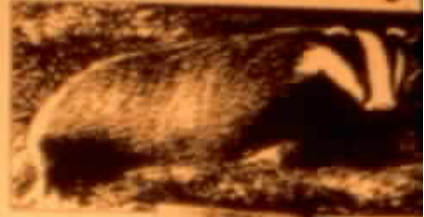
Badger boom wreaks havoc

The badger boom is an unexpected by-product of TB control. Badgers have been culled since 1981, but the number of TB-free badgers has risen to 1.7 million since 1995.



Badgers escape the death penalty

B



Farmers hit out at more delays in TB fight



Badger culling to be restricted

Culling halt stuns farmers

"Huge areas will be left without any control of badger TB"



KREBS REPORT SERVES TO DELAY REAL ANSWERS TO BADGER TB DESTRUCTION

The Krebs report serves to delay real answers to badger TB destruction. It is a major setback for farmers who have been waiting for a definitive plan to control the disease.

Farmers furious at TB risk in five-year experiment

Thousands of badgers to die

Is the badger an innocent scapegoat?

D



Latest badger cull is another Ministry gaff

Outrage MPs support massive cull of badgers

TB or not TB? Don't blame our badgers



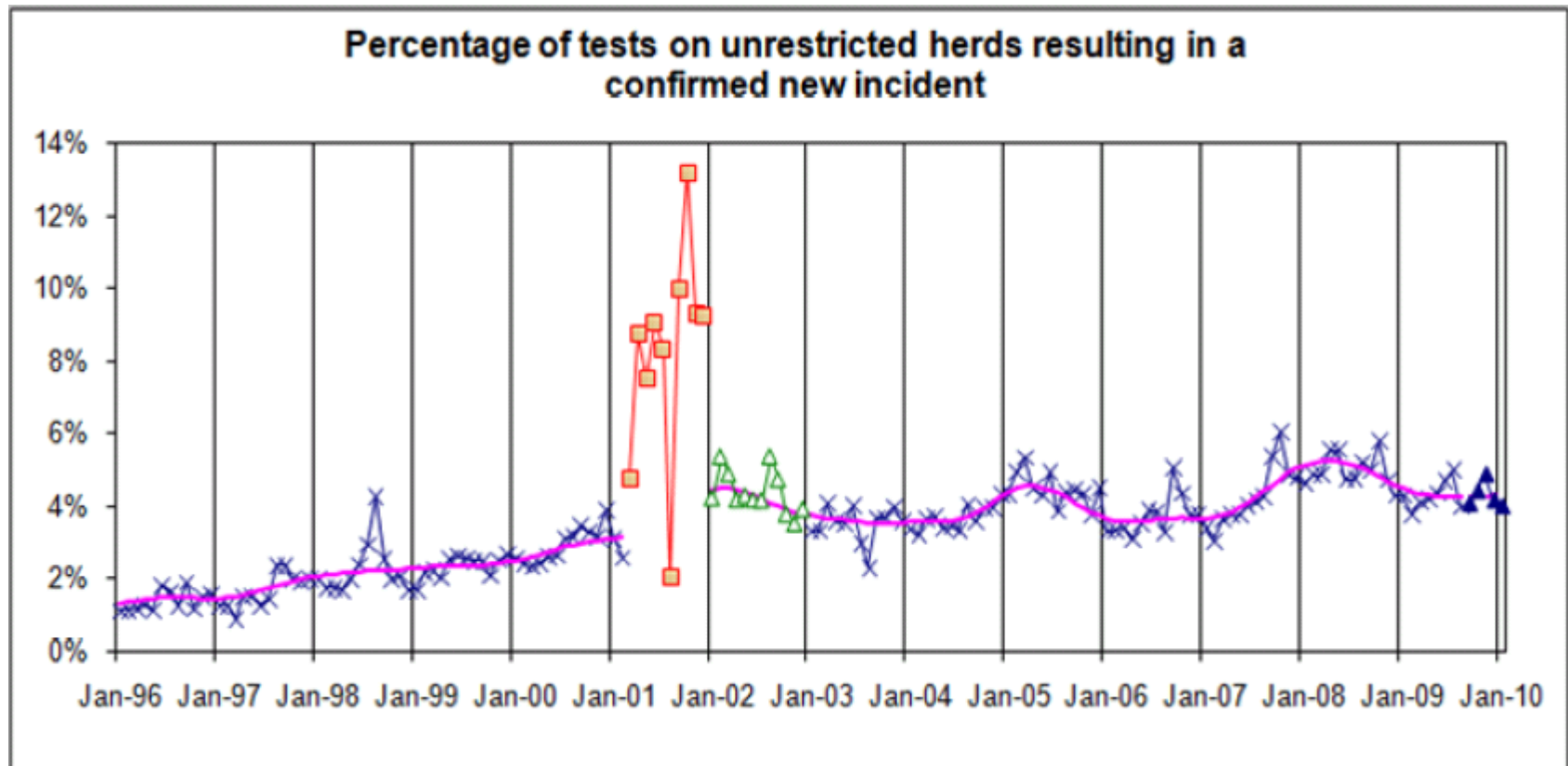
are groups from Krebs, Apollon's hot-spot test programme is ill-conceived

Badger cull dismays animal campaigners

10,000 badgers face death in five-year TB cull experiment



That was then... this is now!

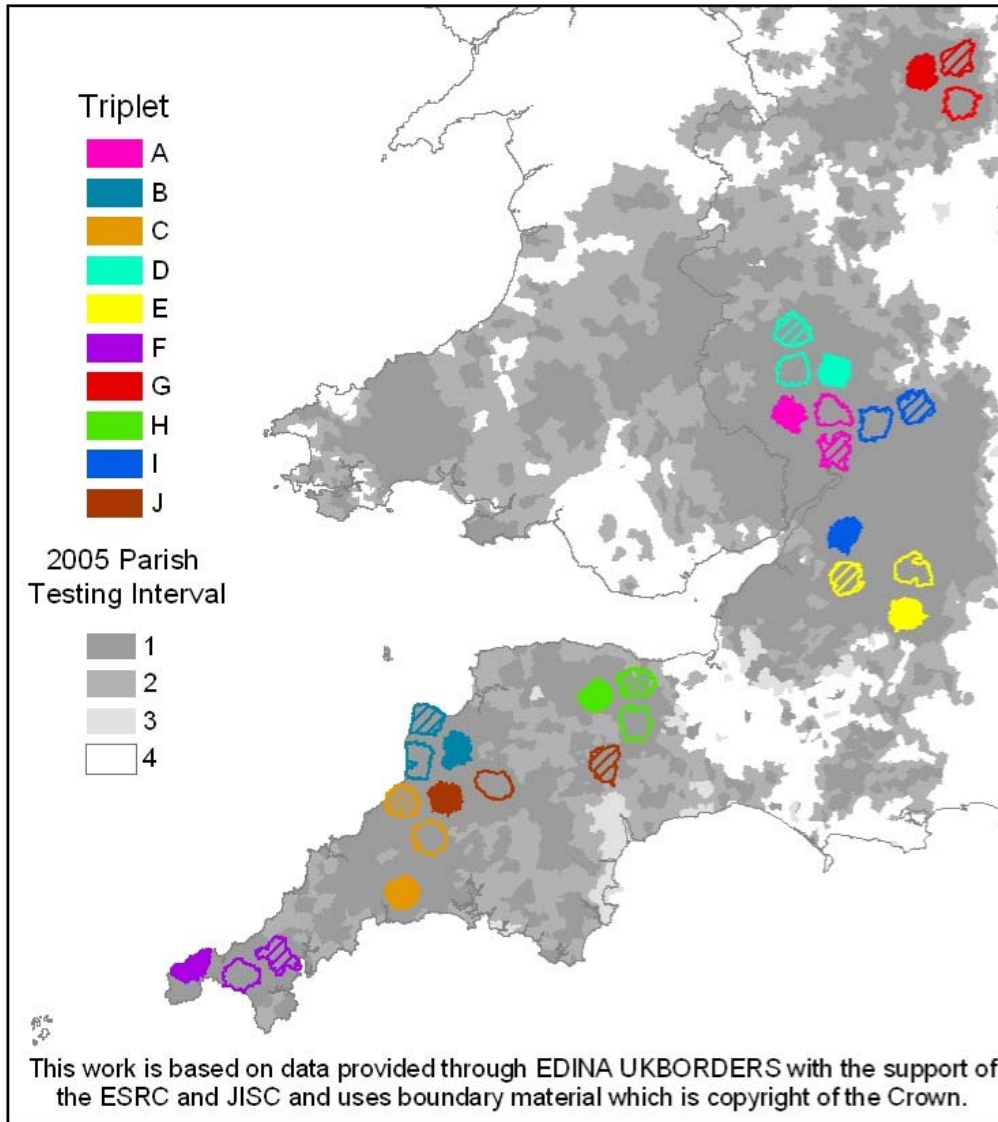


Data as of 21 April 2010 – as published by Defra.




<http://www.defra.gov.uk/evidence/statistics/foodfarm/landuselivestock/cattletb/documents/tbpn.pdf>

The Independent Scientific Group on Cattle TB





Randomised to 30 roughly 100km² areas where the incidence of confirmed TB breakdowns was greatest

-  No culling
-  Reactive culling
-  Proactive culling

No culling outside the field trial areas

Donnelly *et al.* *Nature* 2006.

RBCT Proactive Culls

Triplet	1	2	3	4	5	6	7
A	Jan '00	May '02	Nov '03	May '04	Oct '05		
B	Dec '98	Nov-Dec '99	Aug '00 - Jan '01*	Nov-Dec '02*	Jun '03	Jul-Aug '04	Oct '05
C	Oct '99	Jan '01	Aug-Nov '02*	Oct '03	Jun '04	Sep '05	
D	Dec '02	May '03	Sep '04	May '05			
E	May '00	Jan '01	Jun '02 - Jan '03*	Jun '03	Jul '04	Sep '05	
F	Jul '00	May '02	Dec '03	Sep '04	Jun '05		
G	Oct-Nov '00	Jul '02	Jul '03	Jun '04	Jun '05		
H	Dec '00	Jun-Jul '02	Sep '03	May '04	Jul-Aug '05		
I	Sept-Oct '02	Sep-Oct '03	Oct-Nov '04	Jul '05			
J	Oct '02	Jul-Aug '03	Oct-Nov '04	May '05			

Cattle Herds and Badger Prevalence

U (uninfected)

$$\frac{dU}{dt} = \frac{M}{p} - U \left(\beta \frac{I}{N} + k \right)$$

I (infected, and equivalently infectious, but undiagnosed)

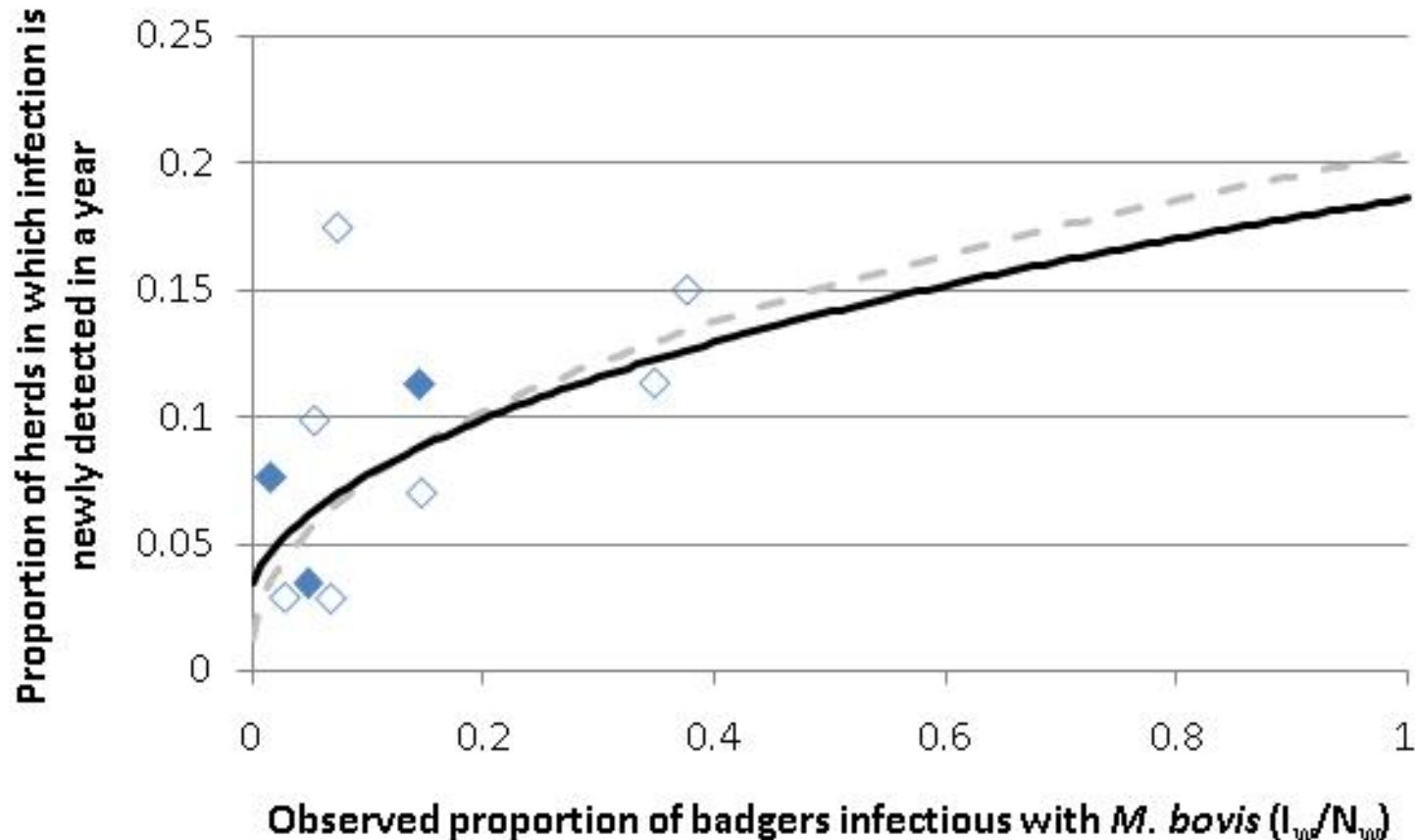
$$\frac{dI}{dt} = U \left(\beta \frac{I}{N} + k \right) - Ic$$

M (under movement controls and thus not infectious to other herds).

$$\frac{dM}{dt} = Ic - \frac{M}{p}$$

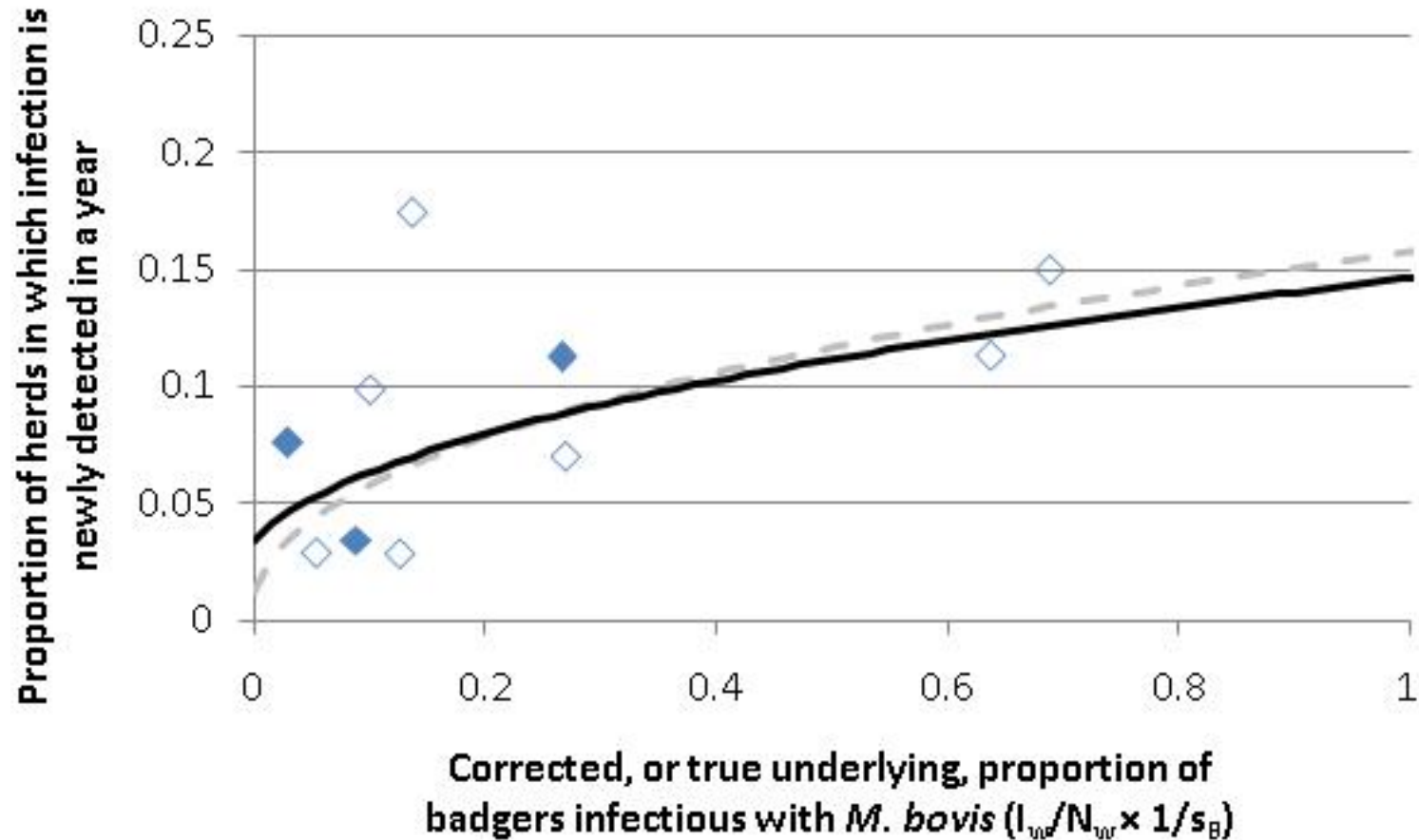
Donnelly & Hone. Is there an association between levels of bovine tuberculosis in cattle herds and badgers? *Statistical Communications in Infectious Diseases* 2 (1): article 3, 2010.

Cattle Herds and Badger Prevalence



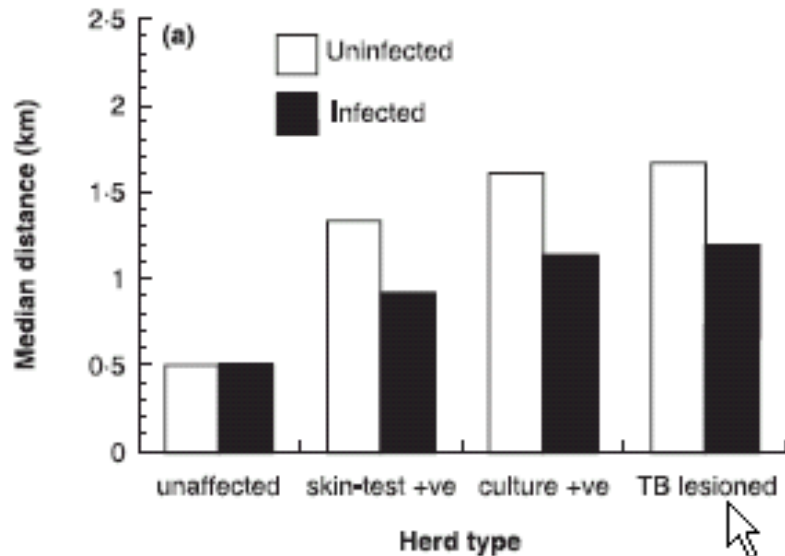
But... Crawshaw *et al.* (2008) estimated that the overall sensitivity of the standard protocol, to which RBCT badgers were subjected, was only 54.6% (95% CI: 44.9 – 69.8%), relative to the more detailed protocol. Donnelly & Hone. Is there an association between levels of bovine tuberculosis in cattle herds and badgers? *Statistical Communications in Infectious Diseases* 2 (1): article 3, 2010.

Cattle Herds and Badger Prevalence



Donnelly & Hone. Is there an association between levels of bovine tuberculosis in cattle herds and badgers? *Statistical Communications in Infectious Diseases* 2 (1): article 3, 2010.

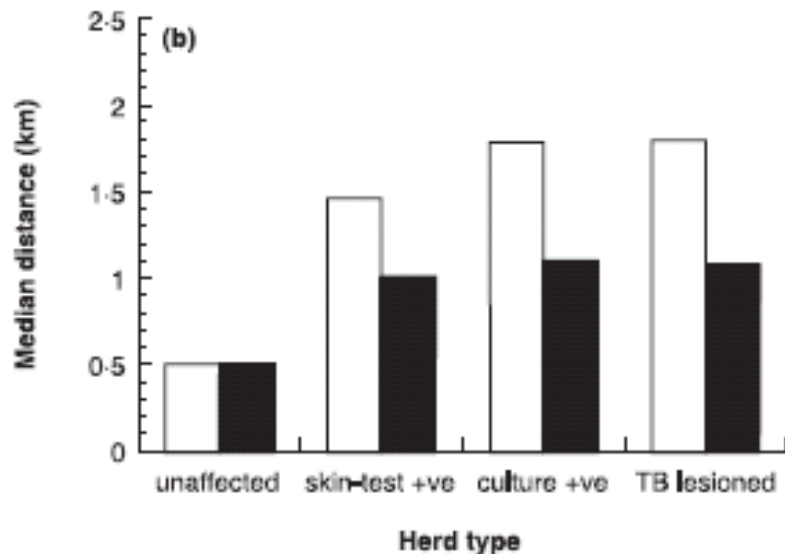
Spatial associations in badgers and cattle



The median distances from capture locations of infected (solid bars) and uninfected (open bars) badgers to the nearest cattle herds of various types.

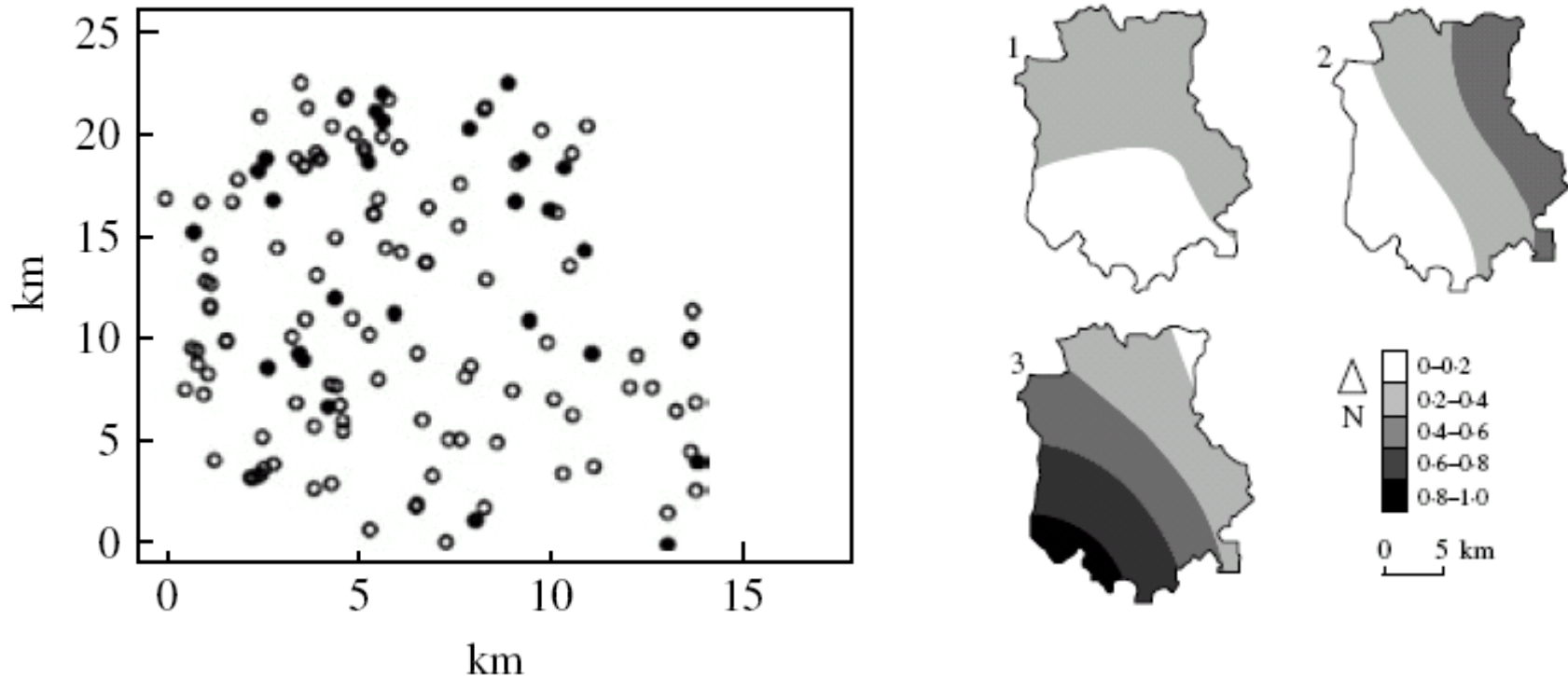
(a) shows the median distances from **adult badgers** to herds containing cattle that were either unaffected by TB, skin test-positive, culture-positive or TB-lesioned in the 12 months prior to the badger culls;

(b) has the same, but for **cubs**.



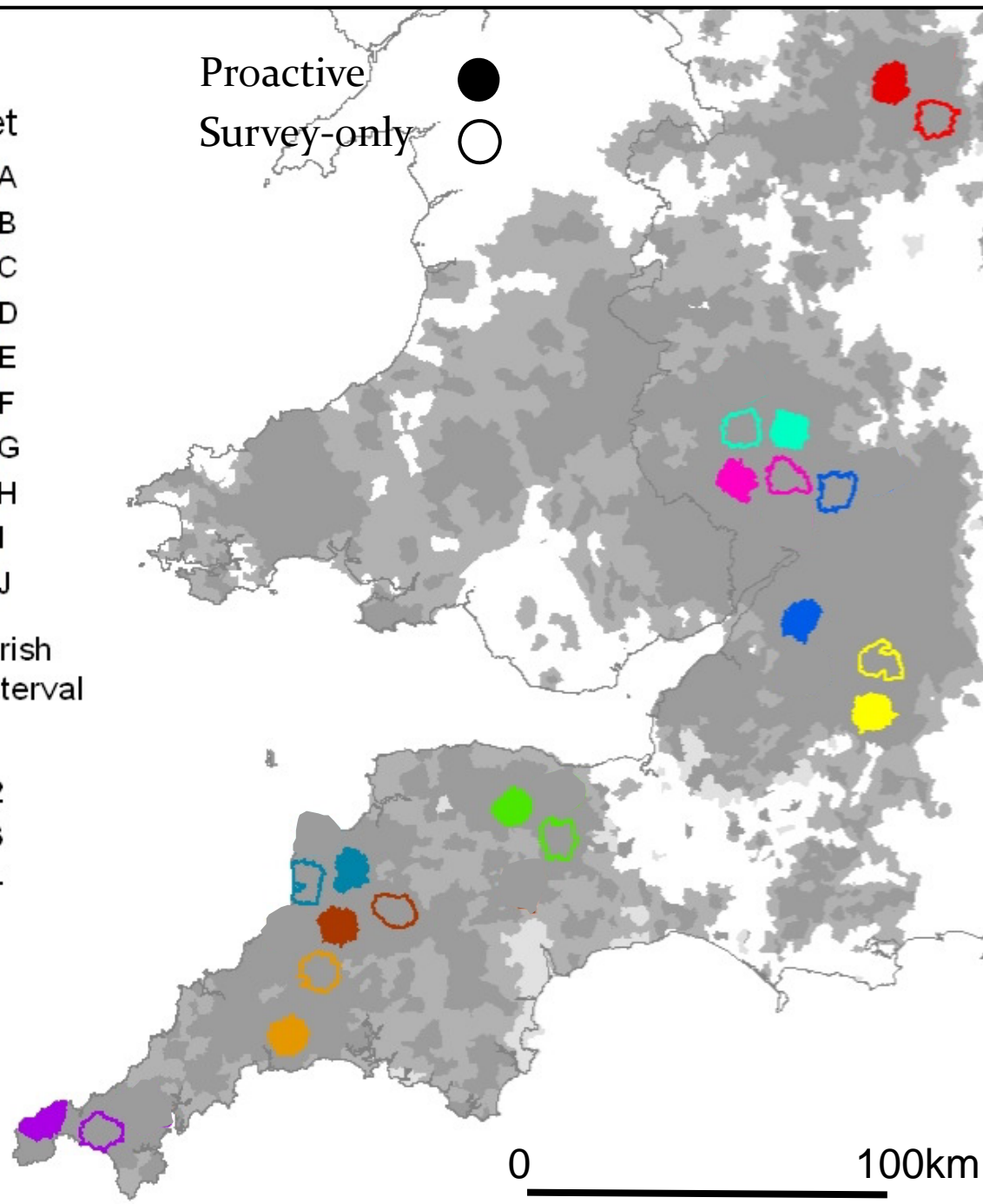
Spatial clustering of infection in Ireland

Kilkenny badgers



Kernel estimates of badger strain-specific probability surfaces in the Kilkenny area of the Irish Four Area study. 1: A1A1A, 2: A4A1H, 3: C1H1J strain-specific probability surfaces ($P < 0.001$ indicating spatial segregation).

Kelly *et al.* Estimating the extent of spatial association of *Mycobacterium bovis* infection in badgers in Ireland. *Epidemiol. Infect.* (2010), 138, 270–279.



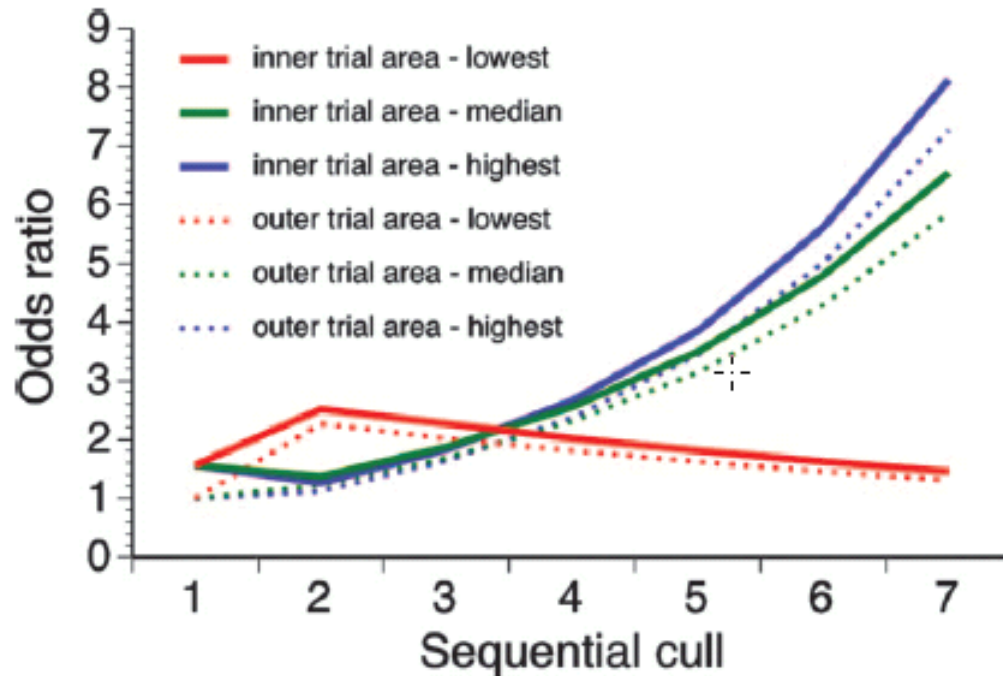
Results from inside proactive culling areas

TB incidence inside proactive culling areas was **23.2% lower** than that inside no-culling areas (95% CI: 12 to 33% lower)

Based on 55.8 triplet-years

Donnelly *et al.* *IJID* 2007

Impact of culling on Badger Prevalence

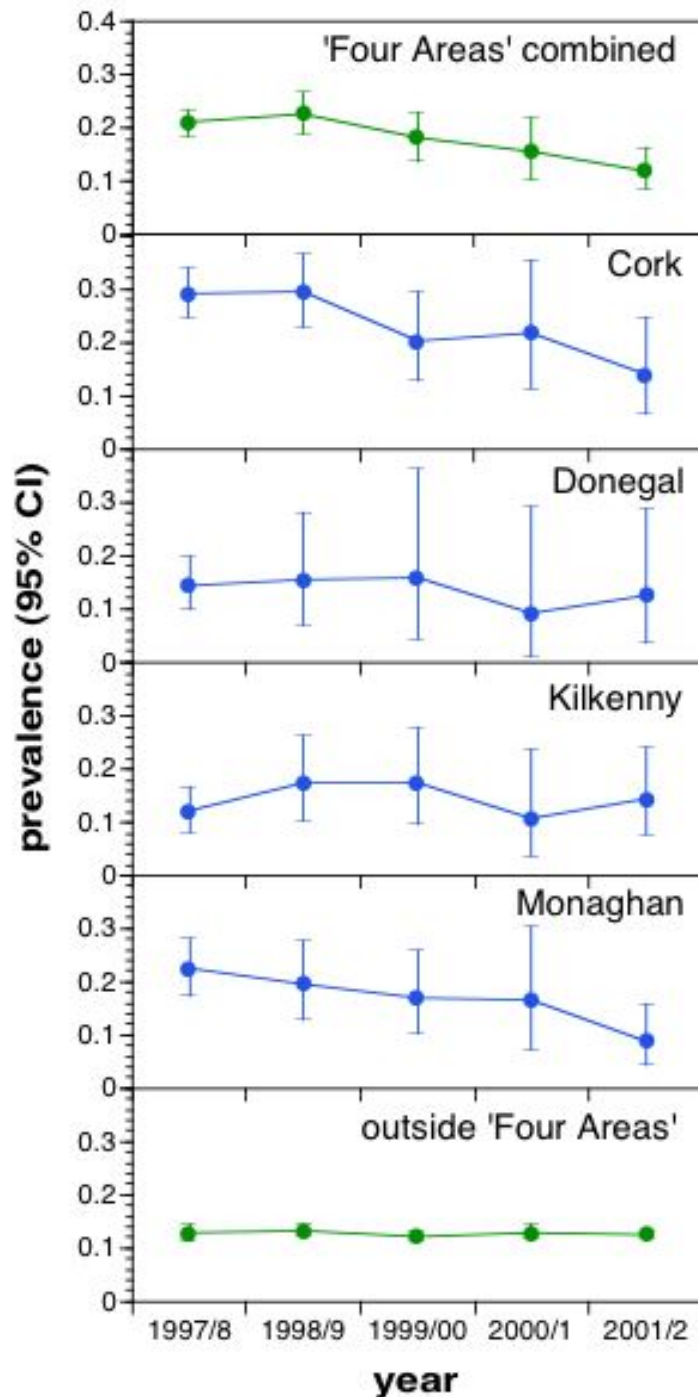


Boundary permeability

- lowest observed (0.55)
- median observed (0.94)
- highest observed (1.0)

A logistic regression model for badger *M. bovis* infection status had a significant interaction between repeated culls and the permeability of trial area boundaries, showing that successive culls led to increased prevalence only in less geographically isolated areas. We also detected a significant interaction between badger capture location and the variable describing initial vs. follow-up culls.

... and in the Republic of Ireland

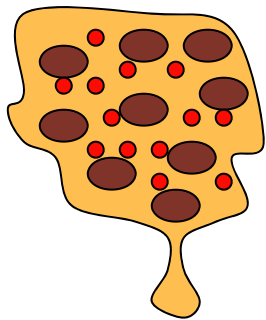
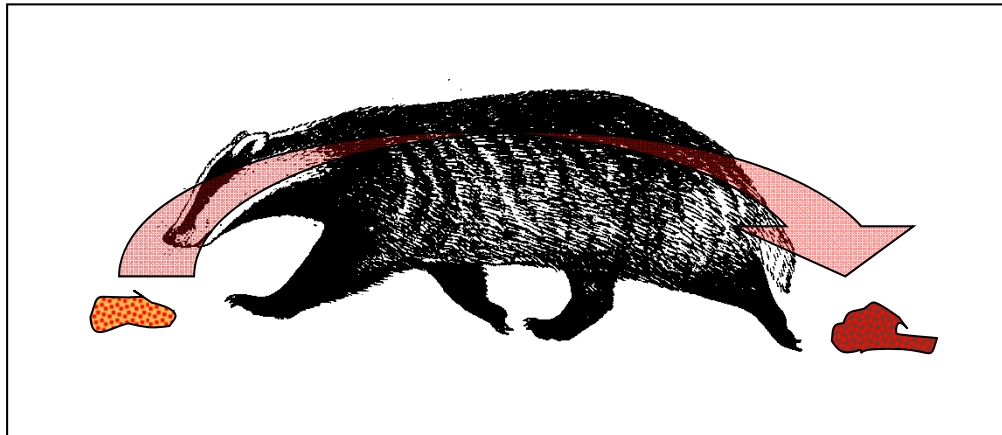


Prevalence rise observed on successive RBCT proactive culls was not detected among badgers culled in the Irish “Four Areas Trial”; indeed, overall prevalence appeared, if anything, to decline.

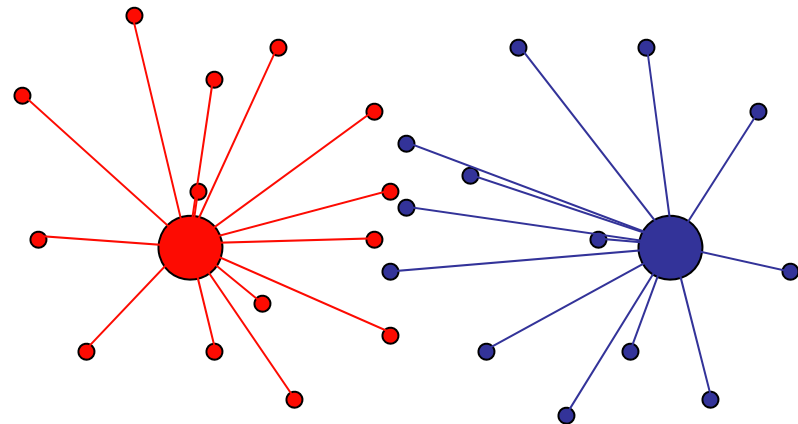
Because all of the “Four Areas” received their initial culls in the same 12-month period, it is not possible for the Irish prevalence data to be analysed with both inter-annual and cull sequence effects simultaneously.

Griffin *et al.* (2003) in *Selected Papers 2002-2003*. (Veterinary Epidemiology and TB Investigation Unit, University College Dublin),1-12.

Standard technique for mapping badger home ranges

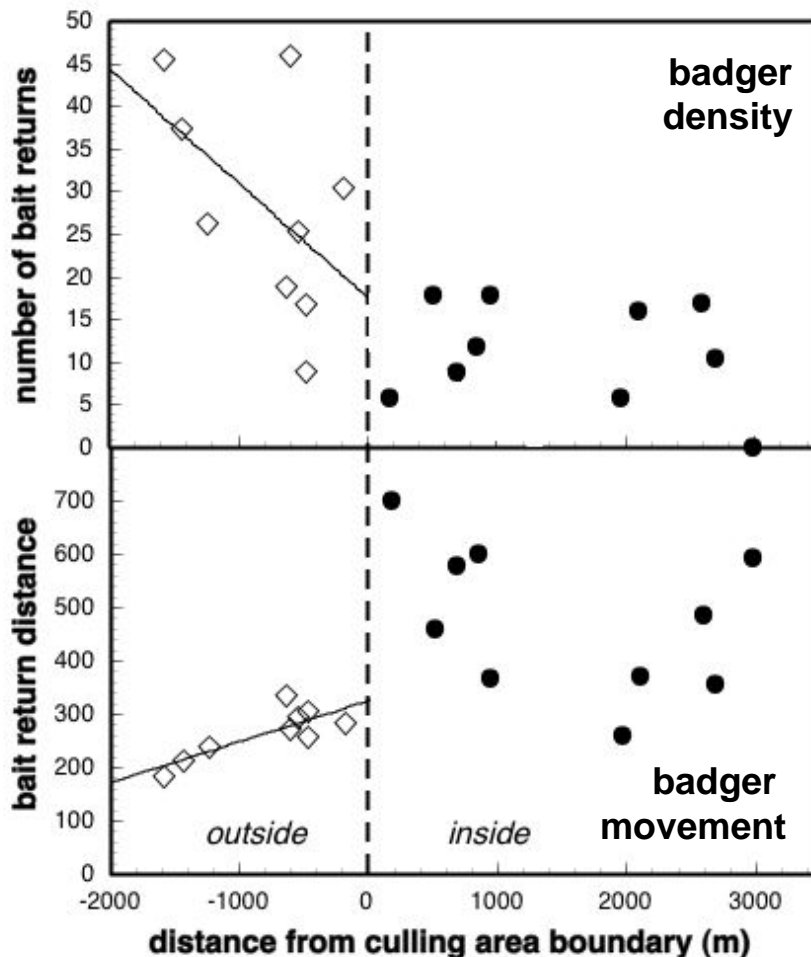


colour
marked bait

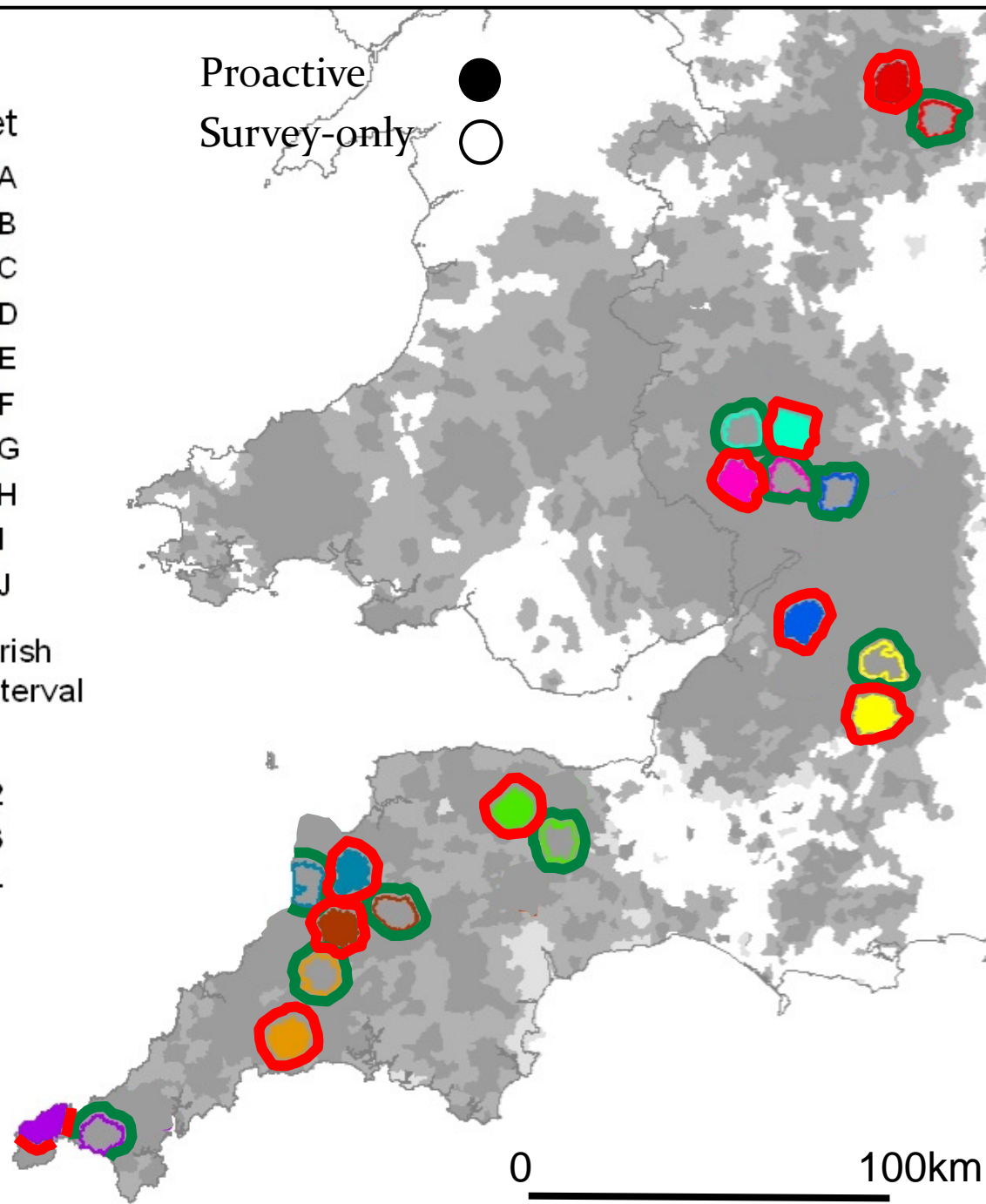


matching bait returns to sets

Badger densities were slightly reduced, and badger movements expanded, on land immediately outside proactive culling areas



If disruption of badger spatial organization caused the increased cattle TB incidence in localized (reactive) culling areas, ***the same effect might be observed on farms on land adjoining proactive culling areas.***



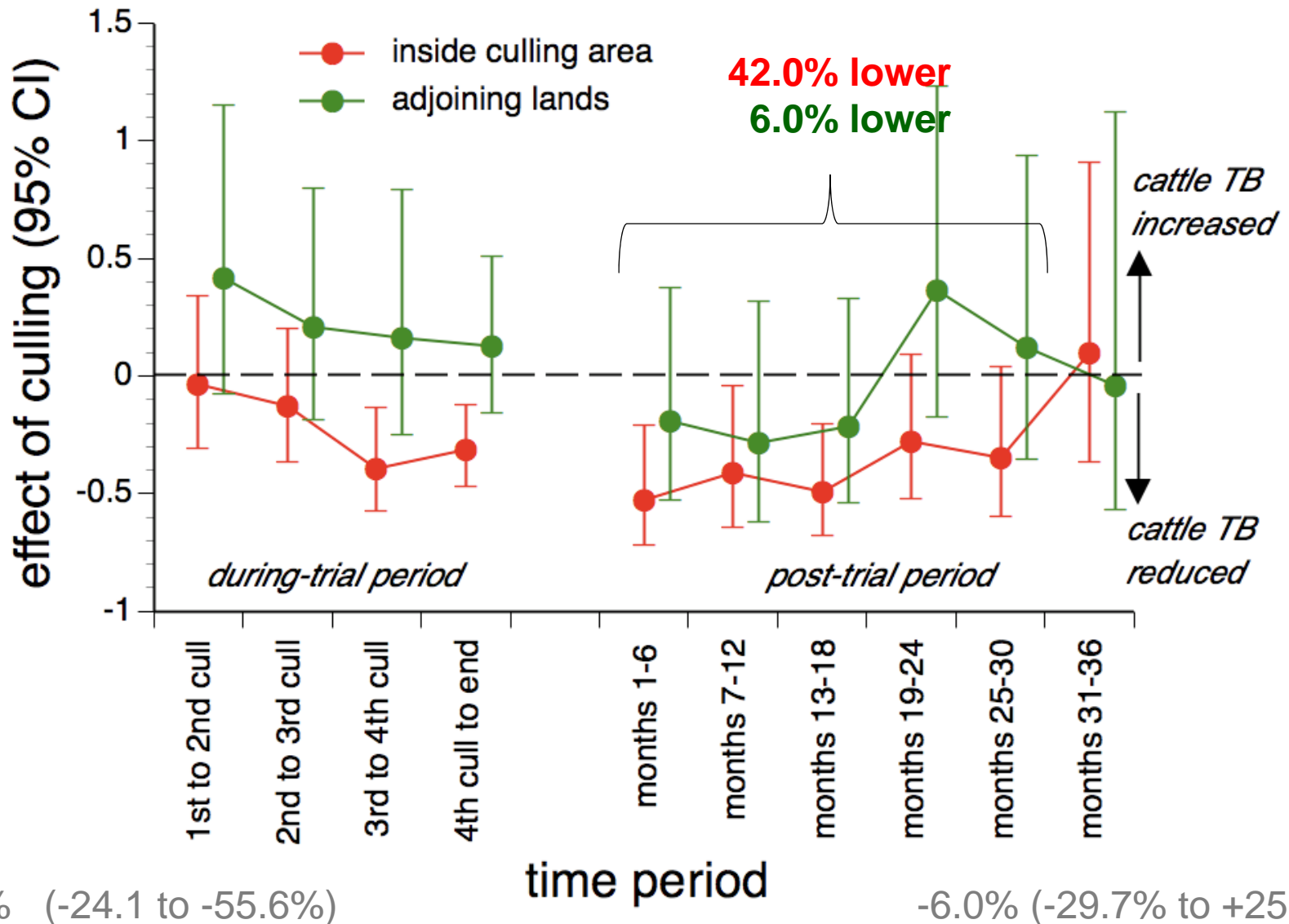
Results from just outside proactive culling areas

TB incidence up to 2km outside proactive culling areas was **24.5% higher** than that up to 2km outside no-culling areas (95% CI: 0.6 lower to 56% higher)

Based on 55.8 triplet-years

Donnelly *et al.* *IJID* 2007

After culling stopped



Key findings

In high cattle incidence areas, there is a clear association between cattle disease and badger prevalence – both between and within trial areas.

Repeated widespread badger culling reduces cattle TB inside culled areas

- by 23% during culling
- by 42% between 1 and 3½ yrs after the last cull
[no detectable effect thereafter]

Culling affects badger density and ranging up to 2km outside culled areas. It also increases *M. bovis* prevalence among remaining badgers.

Cattle herds up to 2km outside culled areas have TB risks

- 24.5% higher during culling
- 6% lower between 1 and 3½ yrs after the last cull

With heartfelt thanks to other ISG members:

John Bourne, University of Bristol

(former Director of the Institute for Animal Health)

Sir David Cox, Nuffield College Oxford

George Gettinby, Strathclyde University

John McInerney, University of Exeter

Ivan Morrison, University of Edinburgh

Rosie Woodroffe, Institute of Zoology London

and RAs: Gao Wei, Peter Gilks, Helen Jenkins,
Tom Johnston and Andrea Le Fevre

Thanks also to Defra and agencies:

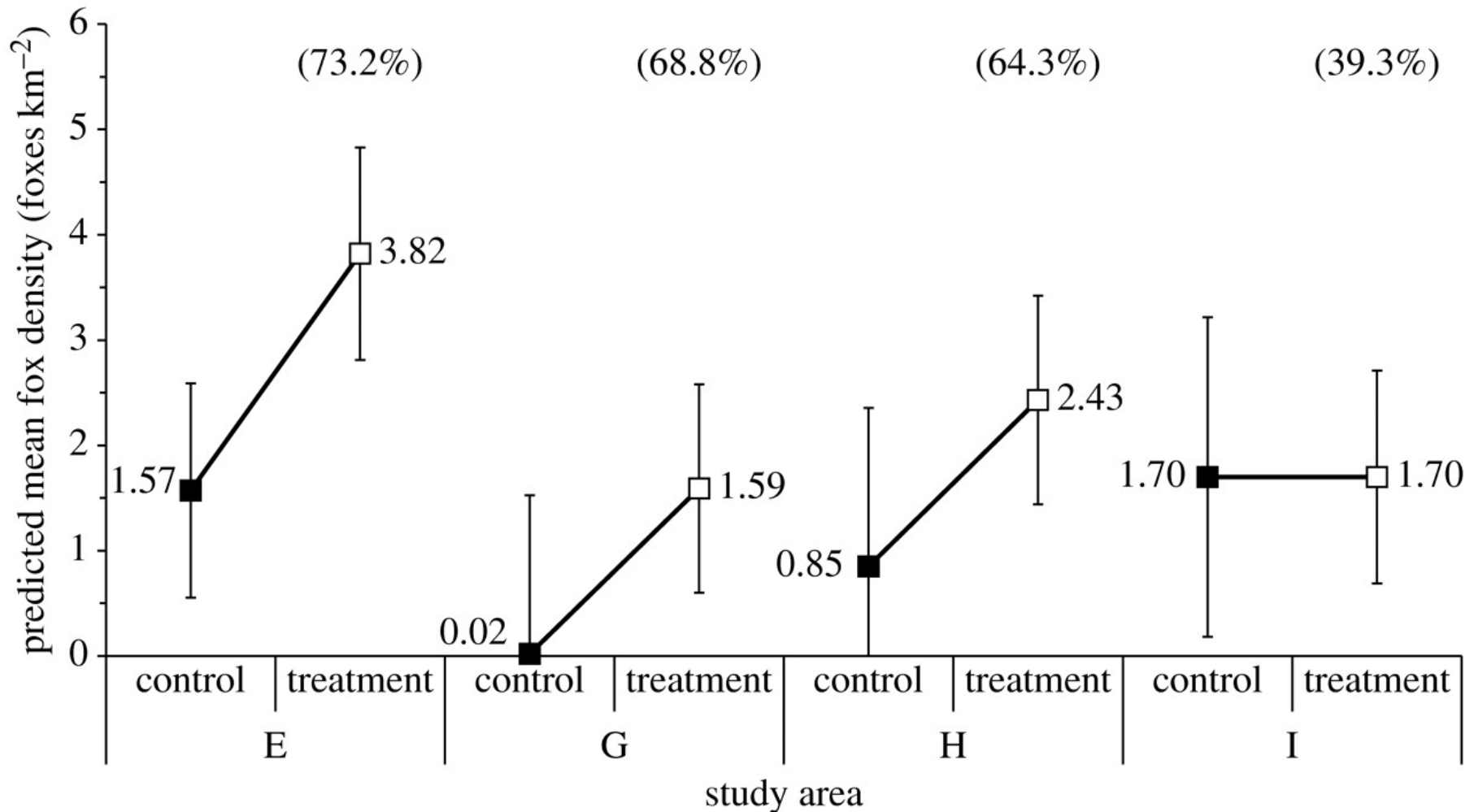
The Randomised Badger Culling Trial was implemented by the staff of Defra and its associated agencies.

Defra funds the ongoing collection and storage of routine surveillance data, which were utilized in this study.

Defra funded the secretarial and research assistant support for the ISG.

Defra also funds an ongoing project at Imperial College London to undertake further analysis of data from RBCT trial areas.

Predicted mean fox densities (and SEs) in response to experimental badger culling



Our publications mentioned in the talk

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