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Impacts of climate change on microbial food safety, as indicated by the growth of *Escherichia coli* O157:H7 in soils.

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1. Key points

- Outbreaks of foodborne illness resulting from consumption of vegetables contaminated by *Escherichia coli* O157-containing soils are increasing.
- The pathogen can enter the soil through contaminated irrigation water or manure. If conditions are favourable, it can rapidly multiply.
- We used laboratory experiments to develop a model that describes the effect of temperature on the growth of two outbreak-related *E. coli* strains in soil.
- The model was applied to a range of climate change scenarios to project future *E. coli* growth rates in Scottish soil.
- Our projections showed that the warmer temperatures expected for Scotland could cause the hourly growth rate of *E. coli* in soils to increase by up to 50%.
- The increased growth potential could lead to an increased risk of transmission of *E. coli* to fresh produce crops to levels exceeding the minimum dose required for symptomatic infection.

2. Introduction

Leafy green vegetables (LGVs) are identified as the fresh produce commodity group of highest concern from a microbiological safety perspective, because they are often grown in the open field and vulnerable to contamination from manure used as fertilizer and water used for irrigation (1). Moreover, they are grown and consumed raw and in large volumes. Pathogenic *Escherichia coli* strains are among the main pathogens causing foodborne disease through LGVs (2). Under favourable conditions *E. coli* can multiply in the soil, which greatly increases the risk of contamination of LGVs. Indeed, the largest outbreak of *E. coli* O157:H7 in the UK (2013) was attributed to soil-contaminated vegetables (2). A key consideration in risk assessment of food-borne bacteria is the number required for symptomatic disease, which for *E. coli* O157:H7 is particularly low (10-100)(3). In this study, laboratory experiments were used to determine a temperature response curve for the growth rate of two outbreak-related *E. coli* strains in soil, one of which (termed ZAP1589) was obtained from the UK outbreak. This was combined with probabilistic climate change data to project future growth rates in soil.

3. Research undertaken

Temperature response curves were fitted to the growth rate data for the *E. coli* O157:H7 strains Sakai and ZAP1589. The growth rates were determined from soil suspended (from Hartwood Farm Shotts, UK) in a buffered solution. The bacteria were always pre-cultured at 18°C prior to transfer into the soil extract at 14, 18, 20 or 25°C, for 24 hours. These were used as temperature-dependent risk models for pathogenic *E. coli* in soil. Probabilistic estimates of future spring (MAM) and summer (JJA) air temperatures for the Eastern administrative region of Scotland were obtained from the UK Met Office Climate Projections database (UKCP09). These were converted to soil temperatures using a relationship derived from a 15 year time series (1999-2014) of soil and air temperature data from Mylnefield weather station (56°27'25.04"N, 3°4'23.77"W). The soil temperature data were used to drive the *E. coli* risk models and produce projections of growth rates under a range of future time periods and CO_2 emissions (Fig. 1).

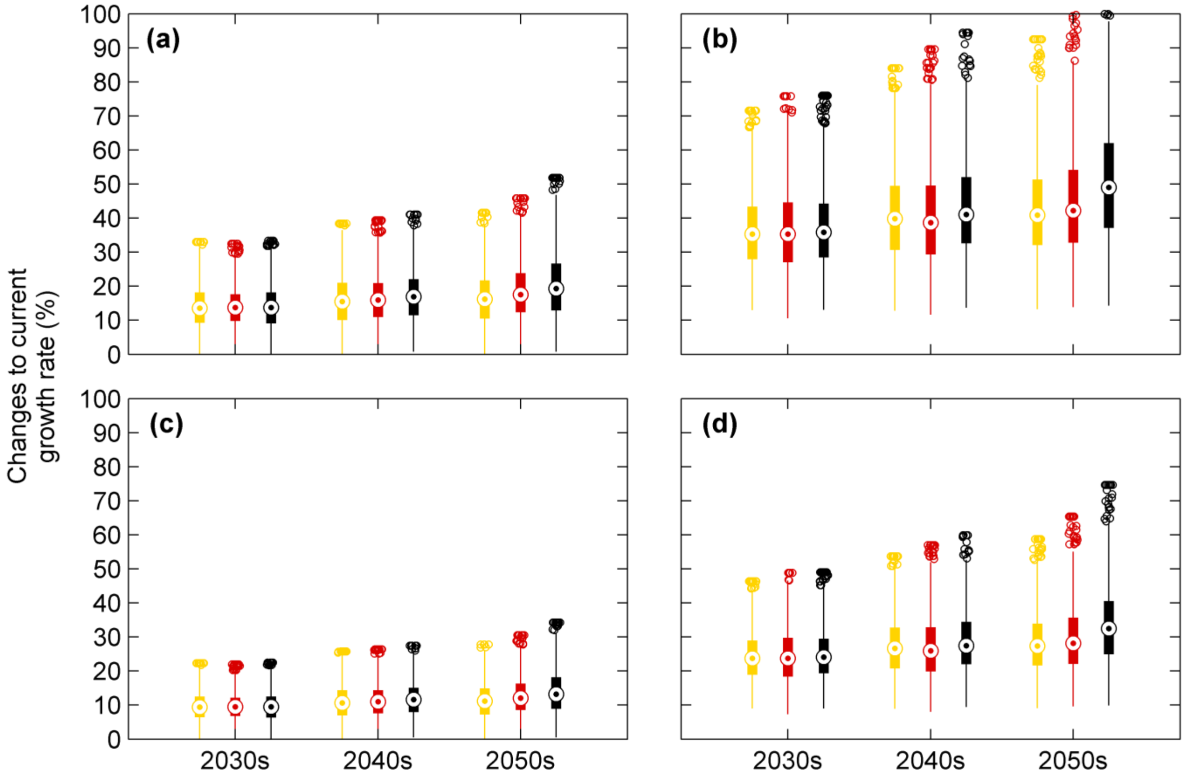

Fig. 1. Projected change in the maximum growth rate of two *E. coli* strains in Scotland under climate change. Boxplots show uncertainty due to internal climate variation for maximum growth rate (log cfu h^{-1}) of *E. coli* O157:H7 strain Sakai in (a) spring and (b) summer, and *E. coli* O157:H7 strain ZAP1589 in (c) spring and (d) summer. Colours of bars indicate the future CO_2 emissions scenario: yellow, red, and black are for low, medium, and high CO_2 emissions, respectively. Projected values are expressed relative to the 1961-1991 baseline climatology to show the proportional response. Boxes extend from first to third quartile, medians are marked in each box, and whiskers extend to the most extreme data points not considered outliers (circular markers).

4. Policy implications

- Food security (4): Increased growth potential for bacteria in soil will increase the risk of contamination of produce crops, exceeding the particularly low infectious dose.
- Common Agricultural Policy (5): Increased risk of contamination of food crops (for either animal feed or directly into the food chain) places an increased burden on retails and producers.
- Water (6): Water provides an important means for transmission of food-borne pathogens, and potential increased levels in soil will increase the risk of contamination onto produce crops from irrigation water (e.g. from bore holes), or during flooding events.
- Land use (7): Intensification of livestock farming and changes agricultural practices is likely to increase the likelihood of soil contamination of food-borne bacteria in arable system. This coupled with a

greater growth potential in soil will increase the chances of transmission of the bacteria to produce crops.

5. References

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6. Further information

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