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Predicting changes in reported notifiable disease rates for New Zealand using a SIR modelling approach

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The New Zealand health system has defined as 'notifiable' over 50 diseases. Of these campylobacteriosis is the most commonly reported comprising 41% of all notifications in 2011 (presently about 150 illness cases per 100,000 population per annum). Furthermore, the incidence of this mild illness, which is potentially waterborne, is under-reported by at least an order-of-magnitude. Increased downstream pathogen loads and/or disease incidence have been found to be associated with increased rainfall, particularly in agricultural landscapes. Therefore, given the predominance of agricultural land uses in New Zealand, transmission and exposure to its agent (thermotolerant Campylobacter bacteria) may be affected by changing rainfall and temperature patterns associated with climate change. Reporting rates for other potentially water-borne zoonoses are also noticeable (for example, the reported rate for cryptosporidiosis for 2011 was 14 per 100,000 population). The distribution of Cryptosporidium oocysts in the environment may be influenced by climate change because it has often been implicated in drinking-water contamination, and heavy rainfall events have been found to be associated with increased pathogen loads in rivers and disease incidence. Given this background, which may also be applicable to other countries with agriculturally-dominated landscapes, a New Zealand study was initiated to develop a decision-support system for the projected effects of climate change on a selected suite of environmentally-transmitted pathogens, including Campylobacter and Cryptosporodium oocysts. Herein we report on the manner in which a linear SIR (Susceptible-Ill-Recovered) model previously developed for campylobacteriosis can be extended to cryptosporidiosis, applied to changes in pathogen contact rate and hence reported illness, and coupled to climate change projections associated with different greenhouse gas emission scenarios. The resulting SIR model outputs provided projected changes in reported disease incidence as a function of temperature and rainfall. These models account for age-dependency (children versus adults), which is especially important because children can report substantially higher rates of zoonoses. The model is linear because the zoonotic pathogen 'reservoir' is overwhelmingly among animals, and so the usual interaction in which human-pathogen interactions affect the degree of environmental contamination does not apply in the short term (on the order of one year). Accordingly, the interaction can be approximated by a constant contact rate over a given year, even though the contact rates may vary between decades because of climate change and variability. This linearity property enables the derivation of analytical solutions to the model's governing equations, thereby providing for a more elegant examination of the model's properties and for making projections under climate change. The models have been calibrated to reported rates of these diseases. Simple exponential functions have been used to vary the pathogen contact rates for the reference years 2015, 2040 and 2090 under three climate change scenarios of low, medium and high emissions of greenhouse gases (B1, A1B, and A2). These formulations have been guided by the results of statistical models calibrated to historical disease reporting rates. The models have been used to calculate the ratio of reported illness rates to present rates projected for future years across New Zealand at the ~5 km scale. Detailed results will be presented for the reference year 2040.